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POLICY EVALUATION WITH ADVANCED
ANALYTICS
NON-DOMESTIC PROPERTY TAX RELIEFS

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PhD 2018

POLICY EVALUATION WITH ADVANCED
ANALYTICS
NON-DOMESTIC PROPERTY TAX RELIEFS

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A thesis submitted in partial fulfilment of
the requirement of the Manchester
Metropolitan University for the degree of
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International Business

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ABSTRACT

The Small Business Rate Relief (SBRR) reduces the business rates payable by firms occupying lower cost premises. This thesis evaluates the success of the SBRR with regards to productivity and survival rates using longitudinal datasets from the Office for National Statistics. Simultaneously, the thesis adapts and adopts Duranton's *et al.* (2011) theoretical framework on non-domestic UK property taxation.

The framework argues that although in the short-term SBRR is likely to reduce deaths during a recession, it decreases total factor productivity (TFP) as well. However, in the medium term, SBRR may even be overcapitalised into rents, meaning that higher rents may fully offset the business rate reliefs. No long-term effects are identified. The framework argues that the degree of these effects should depend on the market supply constraints and spillovers such as concentration (Marshall-Arrow-Romer, 1890), competition (Porter, 1990) and diversity (Jacob, 1969).

In order to capture the complex clustering of effects within and across firms, the standard econometric approaches are supplemented with the recently developed non-parametric Random Effects Expectation Maximisation Decision Tree algorithm for productivity analysis and the Survival Tree algorithm for interval-censored survival estimation. As a result, the complex interaction and clustering of hierarchical effects are inferred from the data. This empirical approach is based on extensive micro data for all UK firms from which coarsened matching across a wide range of characteristics is employed to create a representative sample.

Contrary to policy expectations and widespread rhetorics, the findings show that property tax reductions are associated with consistently lower productivity and only a very marginal initial improvement in survival. The thesis also finds indications that market concentration towards major players is related to the extent of SBRR capitalisation into property prices, and that output diversity is associated with higher TFP.

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1 INTRODUCTION AND BACKGROUND

This thesis utilises non-parametric hierarchical analyses to investigate whether the homogeneous reductions in commercial property taxes for small firms has released putative pent-up animal spirits and led to gains in firm productivity or ability to survive demand shocks. These reductions, termed Small Business Rate Reliefs (SBRR), were first introduced in Scotland in 2003, England in 2005 and Wales in 2007. The most recent extension to reductions from April 2017 and 2018 will further reduce tax revenue across England by £9 billion over five years and remove 600,000 firms from liability (HM Treasury, 2017). This is just as the gradual return of Business Rate (BR) revenue to local control in England via devolution of powers or greater revenue retention.

In general, the UK government collects a higher proportion of its tax through property taxation than any other OECD country (Section 1.3 based on OECD, 2017). Tax on property is defined by the OECD “as recurrent and non-recurrent taxes on the use, ownership or transfer of property” (OECD, 2017:1). In the UK, different systems apply to commercial and residential properties. Residential property owners are likely to pay Stamp Duty Land Tax on the change of ownership of property, Income Tax on their rental income and Council Tax based on the value of residential premises they are occupying. Whilst, commercial property owners pay Stamp Duty Land Tax and in some instances Value Added Tax on the change of ownership of property, Corporation Tax on its rental profits and, finally, Business Rates (BRs) based on the value of commercial premises they are occupying.

Business rates, a tax on non-domestic property, is inherited in the UK taxation policy and dates back to 1572. In 1990, it was transformed by Margaret Thatcher’s government which introduced the uniform non-domestic property tax that existed until 2016. This meant that central government was made responsible for setting and distributing business rates for England¹. On the 5th October 2015, George Osborne announced opposing plans to allow councils to set and distribute all BRs collected. The Chancellor stated that it is the ‘biggest transfer of power to our local government in living memory’ (BBC, 2015:online). This is regarded as the “*end of the national tax on local growth*” (H.M. Treasury 2016:9).

¹ Other UK countries have set and collect their own business rates, but systems are relatively similar as described in Section 1.4.2.

The UK Government planned to devolve the setting and administration of BRs from the national to local governments in 2020². A principal element of this policy was to further local flexibility to reduce rates set nationally for specific projects or types of businesses and stimulate local growth. Nonetheless, in the March 2017 Budget, this flexibility was undermined by the same national Government. It significantly expanded and made permanent the current policy of National (English) reductions in the property tax for small businesses called Small Business Rate Relief³.

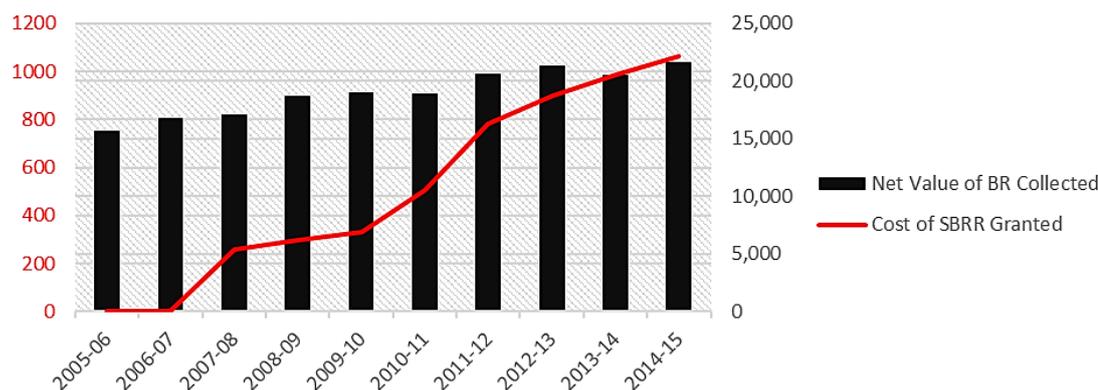


Figure 1:1 BRs collected by councils in England between 2005 and 2015 compared to cost of SBRR (available only after 2006). Notes: £ million (nominal). Source: Department for Communities and Local Government (DCLG) Official Statistics 2011 to 2015.

In fact, it was Scotland that was the first to introduce the property tax relief for small businesses as a temporary support lasting only a year with an aim “to target help at genuinely small businesses” (Scottish Government, 2004:1). However, the SBRR was also introduced in England in 2005, Wales in 2007 and Northern Ireland in 2010 and extended each year. Currently in England, this reduction in tax applies to properties with a rateable value below £18,000 (or £25,000 in London) per year, occupied by businesses. SBRR is entirely based on the rateable value, which weakly corresponds to the rent⁴, and it does not account for any other characteristics. The reductions now remove 600,000 businesses or around one-third of all businesses from local tax bases (H.M. Treasury, 2017). As the Figure 1:1 illustrates, SBRR was not proportionately increased to the tax collections. The bars indicate a marginal increase in tax collections, but the line shows a substantial rise in SBRR

² The timetable for the devolution of local finance has become unclear following the unexpected national elections in June 2017, which interrupted the legislative progress of the Local Government Finance Bill 2017.

³ In Scotland, it is called Small Business Bonus Scheme.

⁴ See Section 1.4.3 for more details.

spending. This raises concerns about future revenue, greater reliance on a small number of large firms and restrictions on local autonomy to achieve local objectives.

Furthermore, the exact objectives of the policy in the Small Business Rate Relief Orders were not identified. However, it seems that the justification of the SBRR might be based on the two most frequently used arguments. Firstly, it is likely that SBRR was justified on the belief that BRs form a higher proportion of small business' fixed costs than those for large businesses (e.g. repeated in H.M. Treasury 2016). Another often appearing perception is that small firms contribute more to innovation and productivity than their share of gross value added. These views are often expressed not just in the media with continuously published articles on both BRs and SBRR⁵ but also policy reports. For instance, JLL (2017:21) maintains that "small businesses complain they pay more in rates as a proportion of turnover than larger ones. The small business rates relief produces an artificial boundary and can lead to occupiers in the same building having a very different liability." However, the arguments do not account for capitalisation of the tax form, meaning that they do not acknowledge that SBRR is likely to be captured in rents and these higher costs, in themselves, might be difficult to justify as a sufficient reason for reliefs.

In fact, those two arguments are likely to be shaped by intense political pressures. The policy to expand and reduce the property tax follows a persistent campaign by the small business community. The then Prime Minister told the Federation of Small Businesses in 2014 that small business' number one complaint was BRs, which had risen relative to other costs over the economic recession (Adam and Miller, 2014 and Cabinet Office, 2014). In fact, the Federation of Small Businesses notes on their website⁶ that the BRs system "is out-dated, unfair and not related to the ability to pay, or changing economic circumstances." The organisation prides themselves on extensive lobbying to sustain and increase SBRR.

Little consistent evidence to back those claims influenced the governments to appoint several different reviews to evaluate SBRR: in Scotland in 2004, Wales in 2010/2012 and Northern Ireland in 2014. The most recent evaluation of SBRR was conducted by the Northern Ireland Centre for Economic Policy in 2014. This study investigated the recipients of SBRR by area and sector. It identified no correlation between deprivation of areas and SBRR, meaning that the relief did not specifically support the most deprived areas. The report's authors acknowledged that, because of capitalisation,

⁵ On 28/07/2018 google news had 95,100,000 results for the term 'business rates' and 11 articles were published in the past 3 days.

⁶ Their website can be accessed: <http://www.fsb.org.uk/standing-up-for-you/policy-issues/local-government-and-communities/business-rates> (Accessed 03.01.2018).

property owners were the primary beneficiary of the scheme. The 552 respondents to their survey suggest that the scheme was not able to drive increased employment or investment but helped with cash flow, survival and keeping the cost of overheads down. Further responses from their public consultation highlighted the need for better targeting with regards to turnover and employment. Political parties agreed that it was appropriate to introduce the temporary reliefs at that time but called for better targeting as well. The report recommended capping the relief at £17.3m during 2015/16 and over the following three years, to reduce the total amount awarded. The report asked for a better alternative to deliver better value for money. Contrary to the findings of this review, the Northern Ireland's government has recently extended the scheme until 31 March 2019⁷.

In contrast, it is worth noting that Scottish and Welsh evaluations were in favour of retaining the relief. The Welsh study (Peck *et al.*, 2014), as with the Northern Irish report (2014), included capitalisation into rents in their methodology, acknowledging that at least some of the relief might be taken by the increased rents. Two thirds (66%) of respondents with rented property reported that their landlords do not charge extra rent because of the SBRRS. 12% reported that landlords took most of the SBRR in extra rental charges. Given that relatively marginal reliefs in Wales were available just from 2007 (as detailed in Section 1.4.3.2), and the survey was conducted in 2010, the respondents were probably evaluating the short-term effects. This Peck's *et al.* (2014) study with many others are more extensively discussed in the Empirical Review Chapter (Section 3.3). In the long term, the evidence shows that the SBRR is likely to be offset by higher rents (Bond *et al.*, 1996, 2013; Mehdi, 2003).

To account for the capitalisation effect, a longitudinal study should be conducted because cross-sectional studies (e.g. Peck *et al.*, 2014) fail to include time. This need for a longitudinal study is also evident in the Barclays Review 2016, which was arranged by the Scottish government with the aim of reviewing BRs reforms. The review mainly focused on the BR system as a whole. They provided many suggestions how BR could be improved. One of their recommendations was that "the effectiveness of the Small Business Bonus Scheme should be evaluated" (online).

In response to the relative lack of reliable evidence, and extensive changes in policy, several HM Treasury reports (2015, 2016) also requested evidence regarding whether

⁷ Source: The Rates (Small Business Hereditament Relief) (Amendment) Regulations (Northern Ireland) 2018 Order, which can be accessed at <http://www.legislation.gov.uk/nisr/2018/61/regulation/1/made> (Accessed 28.07.2018).

SBRR is successful. For instance, in the HM Treasury release (2016:22), the following questions were published in their call for evidence:

If business rates remain a property tax, how do you suggest business rates could take into account the individual circumstances of businesses such as their size or ability to pay rates?

How does the proportion of total operating costs accounted for by business rates vary by the sector and size of business?

What is the impact of the business rates system on the competitiveness of UK businesses? Are there any particular impacts on SMEs?

How could the government better target support for SMEs given that the size of a company may not be reflected in the rateable value of property it uses?

In a similar vein, in academia, there were several direct and indirect calls for further investigation (Huggins and Williams, 2011; Bond *et al.*, 2013; Muldoon-Smith and Greenhalgh, 2015). Most directly, Bond *et al.* (2013:81) called for exploration of ‘how tax incentives affect the process of economic development and who actually benefits.’ They ask for assessment of whether SBRR has any measurable benefits. This direct request for empirical evaluation might be also because of the contradicting theoretical evidence⁸. For instance, Simon’s (1943) traditional view broadly implies that the occupiers should receive the relief but Mieszkowski’s (1972) new view infers that owners rather than occupiers are the actual recipients.

Calls from the government and academia, political rhetoric without a reliable evidence base and the concerns about the effects of this high-profile policy on the tax base and local autonomy had led this thesis to evaluate both the mechanism and the focus of the current tax policy and inform the debate about future local financing. More specifically, *this thesis aims to understand whether SBRR has any effects on small business performance*. To achieve this, the detailed microanalysis draws together and adds to diverse sets of literature. This thesis contributes to the literature on the role of taxation in both simulating small firms and reducing churn as well as the sparse BR literature. This thesis provides evidence that challenges the established policy narrative that taxation reductions for small firms aid small firm productivity and longevity. Simultaneously, the thesis summarises existing methodological approaches and introduces new recently developed approaches

⁸ See the Theory Review (in particular, Section 2.1.2) for a detailed discussion on these and other theories.

such as the RE-EM and survival trees to the field as well as applies several extensions to the more standard statistical methods. The broad findings show that property tax reductions are consistently associated with lower productivity and have marginal effect on survival especially in the longer terms. These findings bring into question the Treasury's homogeneous micromanagement of local property taxes.

The introduction chapter starts by defining a small firm (Section 1.1) and looking at statistics of UK business performance (Section 1.2) to identify the key factors related to business performance. Then, the reader is introduced to property based taxation (Section 1.3), British tax system (Section 1.4) and SBRR (Section 1.4.3). Also, to show complexities within the UK business support, key trends in government-backed support incentives are discussed in Section 1.5. Finally, the chapter is summarised and objectives of this thesis are presented (Section 1.5).

1.1 DEFINING A SMALL FIRM

SBRR is entirely based on the rateable value and it does not account for any other characteristics. However, it would probably be challenging for the government to define the exact criteria because of the differences in knowledge. Even the very definition of *the firm* depends largely on the economic school and the perspective. For example, standard neoclassical economists such as Coase (1937) and Williamson (1987) define a firm according to its output or profit. In management studies, a firm should include people who combine resources to gain competitive advantage (Teece, 2007). To behavioural economists such as Greve (2008), the firm is a social stage on which managers build their social status and prestige. Finally, the most cited⁹ growth article defines a firm as a 'collection of resources bound together in an administrative framework, the boundaries of which are determined by the 'area of administrative coordination' and 'authoritative communication' (Penrose, 1995:xi). The Penrose's definition highlights administrative framework. Anyadike-Danes *et al.* (2015) show that the majority of job-creating firms are small. Those firms may require other resources, more than managerial services (Pitelis, 2002). Thus, it might be misleading to base the definition only on the administrative framework.

However, the government may not be right in choosing only one criterion to differentiate between small and large firms. For simplicity, empirical studies often choose to quantify the firms according to their employment and turnover. These criteria might be

⁹ As according to the literature review done by Ferreira *et al.* (2015).

compared with the one chosen by the government. The government chooses to simplify its definition and does not include any of these measurements. UK policy scholars often cite two definitions, either the definition of SMEs derived from the Companies Act (2006) or from the EU (Commission Recommendation, 2003). These are entirely based on the employment and turnover. The first two columns in the Table 1:1 indicates that, according to the EU definition, a micro firm does not have more than ten employees and turnover higher than two million, a small firm not more than fifty employees and turnover higher than ten million and a medium firm not more than 250 employees and turnover greater than fifty million. Whilst, the UK government for the purpose of SBRR indirectly defines small businesses entirely based on the rateable value of the property during the revaluation (see Section 1.4.1). The third column in the Table 1:1 compares these definitions. In the SBRR context, a micro property would receive 100% available relief at that year, a small firm would get between 1% and 99% relief at that year, and a medium firm would receive no relief.

For the purpose of this study, these two definitions are combined to define a firm as according to the Table 1:1. A micro firm would not have more than ten employees and turnover higher than two million but receive 100% SBRR after 2009 (or 50% before 2010). A small firm would not have more than fifty employees and turnover higher than ten million but receive between 1 and 99% SBRR after 2009 (or 50% before 2010). Whilst, a medium firm not more than 250 employees or turnover greater than fifty million and no SBRR.

	Employees		Turnover (m)		Balance Sheet (m)		Rateable Value
	EU	The UK	EU	The UK	EU	The UK	The UK
Micro	≤10		≤ €2		≤ €2		100% (50%)
Small	≤50	≤50	≤ €10	≤ £6.5	≤ €10	≤ £3.26	1-99% (1-49%)
Medium	≤250	≤250	≤ €50	≤ £25.9	≤ €43	≤ £12.9	0%

Table 1:1 Definition of a small firm. The table is based on Companies Act (2006) and EU Commission Recommendation (2003) and the UK government's orders on non-domestic property taxation.

1.2 UK BUSINESS PERFORMANCE

The broad aim of this thesis is to understand whether SBRR has any effects on small business performance. The small firm was also defined as having not more than 50 employees, turnover not exceeding €10 million and receiving some SBRR. To further develop the aim, this subsection reviews three fundamental business performance indicators, which are the unemployment rate, productivity and churn. According to the

discussion presented in this section, this thesis chooses to assess business performance by estimating productivity and survival.^b

The focus should not be on the employment because the UK had a lower unemployment rate than other advanced economies. To compare UK unemployment to the other OECD countries, OECD (2017) statistics on harmonised unemployment rates were used. The OECD defines the unemployed as people of working age who are without work, are available for work, and have taken specific steps to find work. The first reliefs were introduced in 2003, that is why 2000 was chosen as a starting year in the Figure 1:2. This graph shows that between 2000 and 2016, the UK unemployment rate was lower than the OECD average and significantly lower than other advanced economies in G7¹⁰, EU and EU eurozone averages. This indicates that employment levels might be less of an issue in the UK economy.

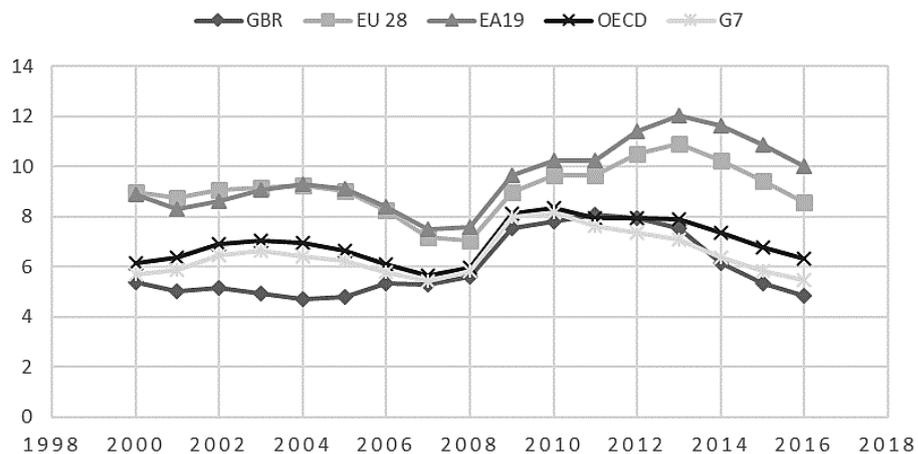


Figure 1:2 Harmonised unemployment rates. Total, % of labour force, 2000 – 2016. Source: OECD Labour market statistics (2017).

As a result, instead of looking at employment as it was done by previous scholars assessing BRs (e.g. Bond *et al.*, 1996, 2013), the focus of this thesis is on productivity. Productivity is known to be a key measure of supply-side economic performance and labour efficiency. Higher productivity is often linked to lower average costs, improved competitiveness and trade performance, higher profits and wages and economic growth. There are two widely used measurements of productivity, labour productivity and total factor productivity (TFP). The former relates to how efficiently labour input is combined with other factors of production and used in the production process, whilst the latter

¹⁰ Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

reflects the overall efficiency with which labour and capital inputs are used together in the production process.

The figures related to UK labour productivity are more concerning than those related to employment. Figure 1:3 (p. 15) highlights the major trends reported by the OECD (2017). Britain performed worse than other advanced economies with regards to labour productivity. All countries were growing steadily except during the recession. The UK historically underperformed G7 and EU Euro area countries but outperformed OECD and all EU countries. This underperformance was further enhanced by the recession as the UK recovered slower than other countries. The OECD reports that some countries such as Luxemburg or Ireland experienced 75% higher labour productivity than the UK in 2015. Less extreme but similar trends are evident when UK is compared to the Euro area and G7 countries¹¹. It is also worth noting that in 2016¹², the UK labour productivity turned lower than the 28 EU countries' average. This suggests that the UK should focus its resources towards enhancing productivity.

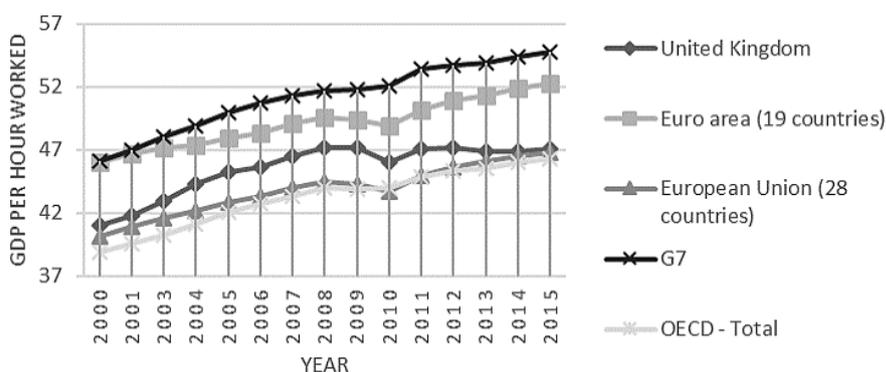


Figure 1:3 GDP per hour worked between 2000 and 2015. US dollar constant prices, 2010. Source: OECD data (2017).

The data from the Office for National Statistics (ONS) provides more recent evidence on the UK productivity. Figure 1:4 (p. 16) shows the main trends within service and manufacturing sectors. Manufacturing output per hour has been more unstable than service output. This reflects a degree of divergence in manufacturing between gross value added (GVA) and hours, especially in 2009 and 2011 to 2012, while in services, GVA and hours follow similar trends. More specifically, non-financial services are the main positive contributor to productivity growth over this period (2007-2017), partly offset by negative contributions from non-manufacturing production and finance.

¹¹ Canada, France, Germany, Italy, Japan, the United Kingdom and the United States.

¹² This is not reported in the Figure because of missing data for OECD and G7 countries for 2016.

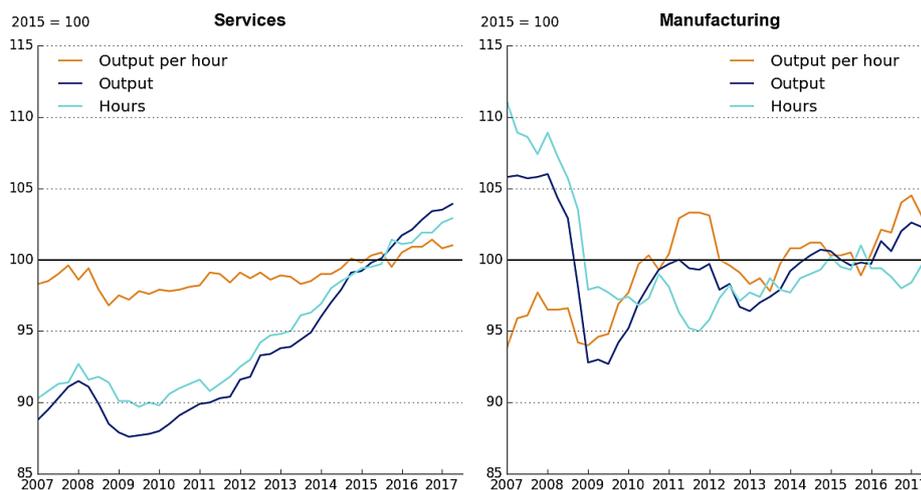


Figure 1:4 Comparing output per hour (orange), output (blue) and hours (light blue) across service and manufacturing sectors between 2007 and 2017. It indicates that the output per hour is up in services but down in manufacturing. Source: ONS (2017).

The thesis argues that labour productivity is not sufficient to account for the overall business performance because a different picture of productivity emerges when the capital efficiency is also accounted for with such indicators as TFP. Official statistics rarely report on the TFP, but Harris and Moffat (2017) provided an up to date descriptive analysis of TFP in the UK. Their methodology is described in Methodology Review with other empirical articles using generalised method of moments (GMM) approach in Section 5.1.4.5.3 (Methodology Review Chapter).

Harris and Moffat showed that all productivity indicators experienced significant post-recession declines. TFP declined slightly slower than labour productivity or GVA after the recession (Figure 1:5, p. 17). Furthermore, the differences between TFP and labour productivity can be identified by comparing the manufacturing and service sectors. Harris and Moffat's results are different from those provided by ONS. In fact, they show that the growth in TFP in the manufacturing sector was sustained during the post-recession period. This suggests that the decline in labour productivity, as reported in Figure 1:4, p. 16, in manufacturing may be explained by changes in factor proportions, but not by an absolute decline in TFP (reported in the Figure 1:6, p. 17). However, they demonstrate that the service sector accounts for the total decrease in TFP. Further insights come to light when Harris and Moffat (2017) group firms by their size of the output. As illustrated in Figure 1:7 (p. 17), the post-2008 decline in TFP is mainly caused by the smallest plants and is absent for plants producing over £714,000 sales per year (in 2000 prices).

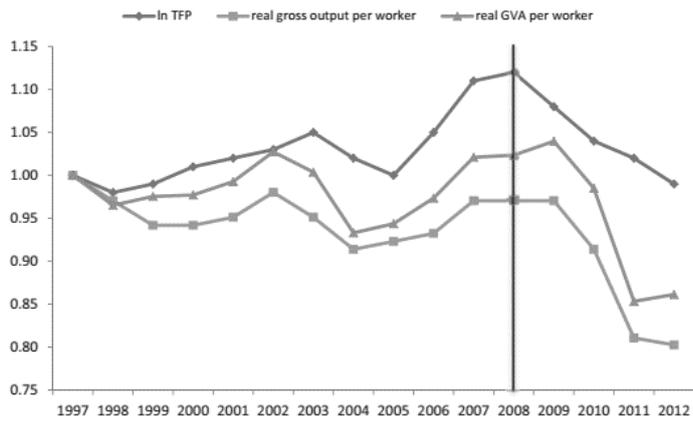


Figure 1:5 Weighted mean TFP and labour productivity for all marketable output sectors (1997 $\frac{1}{4}$ 1) for Great Britain. Source: Harris and Moffat (2017:537).

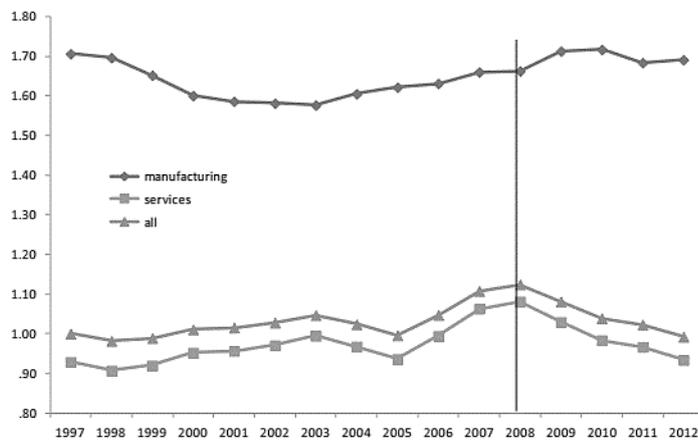


Figure 1:6 Weighted mean TFP for manufacturing and services (1997 $\frac{1}{4}$ 1 for all plants) for Great Britain. Source: Harris and Moffat (2017:538).

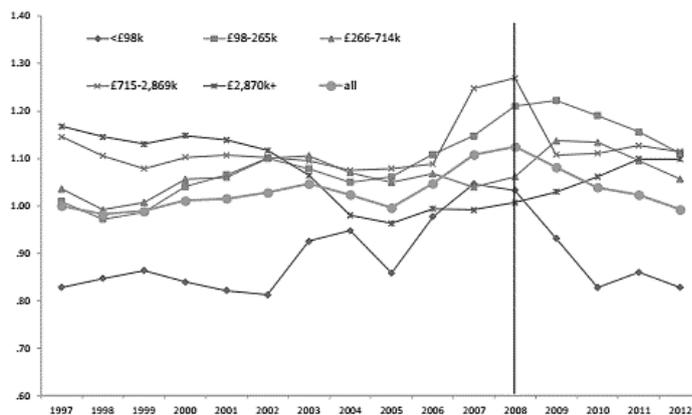


Figure 1:7 Weighted mean TFP for plants of different size based on real gross output (1997 $\frac{1}{4}$ 1 for all plants) for Great Britain. Source: Harris and Moffat (2017:539).

These statistics direct the discussion to two contradicting arguments. Firstly, it is unclear whether the TFP could be improved by supporting those businesses that caused a decline in TFP in line with standard arguments presented in the introduction of this chapter. On the other hand, the government might only sustain those supported underperforming businesses and their inefficient practices by providing them with reliefs like SBRR. These arguments are further unpacked in the Theory Review (Section 2.2).

Building on the previous argument that the relief might help to sustain underperforming firms that drive the decline in TFP, statistics on churn are also included. In general, the births¹³ and deaths¹⁴ of firms play an essential role in economic growth and productivity. The OECD provides some statistics for churn, but these are not complete for all countries and limited to 2007 onwards data for the UK. The Figure 1:8 and Figure 1:9 (p. 19) illustrates that both UK births and deaths have exceeded the OECD or EU average figures historically and especially substantially since 2012. This suggests that SBRR might enhance those new births of small firms that are incapable of sustaining activity in the long term.

ONS also provides annual statistics of birth and death rates. In 2008-2011, business births have surpassed deaths. In recent years, businesses are born at a rate which is 4.9 percentage points higher than the death rate. The increase in the rate of business births is consistent with the strengthening of the labour market from an employment rate of 70.1% in September 2011 to 74.1% at the end of 2015. The data indicates that the rate of business births rose to 14.3% in 2015 (highest level since 2000). The churn does not seem to deviate much across regions and sectors with some minor exemptions like London being more active than Northern Ireland. The differences between regions and sectors are also discussed in Appendix 10.1.2 (p. 264).

¹³ Enterprise births are defined (in Commission Regulation (EC) No 2700/98 of 17 December 1998 concerning the definitions of characteristics for structural business statistics) as follows: "A count of the number of births of enterprises registered to the population concerned in the business register corrected for errors. A birth amounts to the creation of a combination of production factors with the restriction that no other enterprises are involved in the event. Births do not include entries into the population due to: mergers, break-ups, split-off or restructuring of a set of enterprises. It does not include entries into a sub-population resulting only from a change of activity."

¹⁴ The Commission Regulation No 2700/98 defines enterprise deaths as follows: "A count of the number of deaths of enterprises registered to the population concerned in the business register corrected for errors. A death amounts to the dissolution of a combination of production factors with the restriction that no other enterprises are involved in the event. Deaths do not include exits from the population due to mergers, take-overs, break-ups and restructuring of a set of enterprises. It does not include exits from a sub-population resulting only from a change of activity."

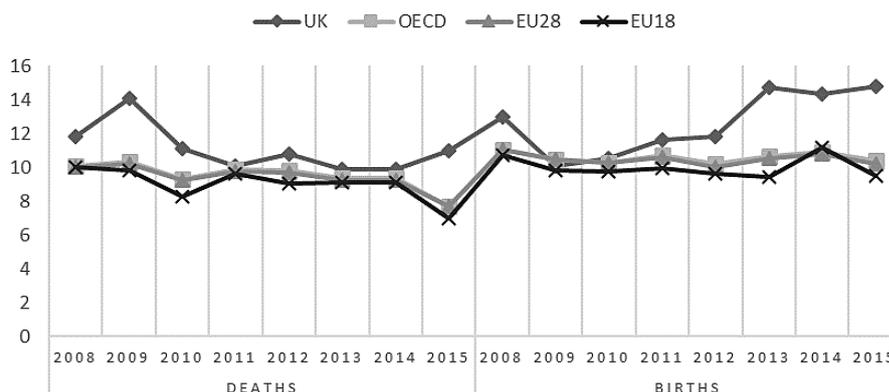


Figure 1:8 Death and birth rates in OECD countries. Birth (death) rate meaning the number of enterprise births (deaths) in the reference period (t) divided by the number of enterprises active in t ; t is between 2008 and 2015. Source: OECD data (2017).

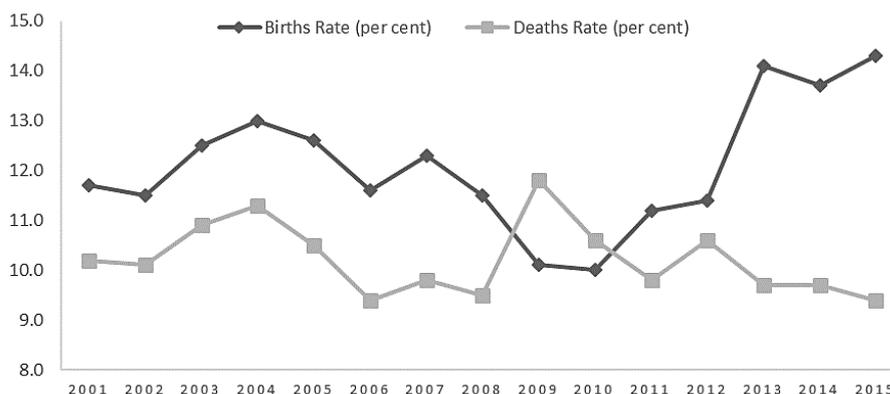


Figure 1:9 Birth and death rates of UK businesses between 2001 and 2015. Source: ONS (2010; 2015).

To sum up, this subsection reviewed two outputs that will be investigated throughout this thesis. The first one is productivity. Britain seems to perform worse than other advanced economies concerning labour productivity. It also recovered its labour productivity growth since the recession slower than other advanced economies. Further analysis of TFP, highlights the differences between TFP and labour productivity. Manufacturing output per hour has been more unstable than service sectors, but TFP shows that the overall decrease in TFP may be explained by a decrease of TFP in the service sector. TFP in the manufacturing sector has been increasingly growing throughout the period, which could probably be explained by different proportions of labour, capital and output. When it comes to the churn, births have started exceeding deaths since 2011. The ratio of births and deaths are more diverse through sectors than regions. These insights will be supplemented by the Theory Review Chapter to inform the Framework.

1.3 INTERNATIONAL PERSPECTIVE ON PROPERTY TAXATION

The central aim of this thesis is to understand whether SBRR has any effects on small business performance with regards to productivity and survival. This subsection shows why the focus of this thesis should be on the property taxation and how the UK compares to other countries. It also discusses non-domestic property taxation in other countries and explains why the theories formed for other countries may not be directly applicable for the UK system implying that the UK needs its own theories and evidence. This subsection is mainly based on the Kenyon's *et al.* (2012).

Historically, UK collects more substantial proportion of its revenue from property than any other country in the OECD (Figure 1:10). Other countries choose different mixes of taxation. The chapter starts with several figures (Figure 1:11 - Figure 1:15, p. 21) discussing how the receipt deviate within OECD countries. It is evident, that Hungary's tax system is more based on a tax on goods and services, while Denmark collects proportionately more in income tax than other countries. Norway has a larger proportion of collection from corporate profits than others. Finally, the greatest proportion of the percentage of GDP from property tax is in the UK. However, since 2011 Britain has been having close to the OECD average percentage of GDP from tax on goods and services and slightly lower before. Income is being taxed at a higher rate than the OECD average and corporate profits around the same as the OECD average. It seems apparent that the only major difference between the UK and other OECD countries is in terms of its property taxation.

There are some advantages and disadvantages to each form of taxation. The often-applied narrative in favour of property taxation is lower rates of tax avoidance and easy administration (e.g. the Green Book of HM Treasury, 2013). The property tax tends to be a reliable option to estimate the tax but arguably profits might be a better indication of ability to pay. Whilst, with regard to tax avoidance, property is much easier to tax and cannot be moved to other countries like other taxes such as corporation tax, which multinational enterprises often shift to the countries with lower taxation rates. Large companies are known to devote substantial resources to corporate income tax avoidance. They have more opportunities for tax avoidance because of their complexity, multi-territoriality, and general scale and scope. With these regards, it seems that the property-based taxation is performing well. According to HMRC (2017), the UK tax gap fell from 2015 to 2016 to its lowest-ever level of 6 %. However, just 5% (£1.7bn) of this 6 % is assigned to avoidance. In their estimate, they did not include these controversial transfer pricing structures.

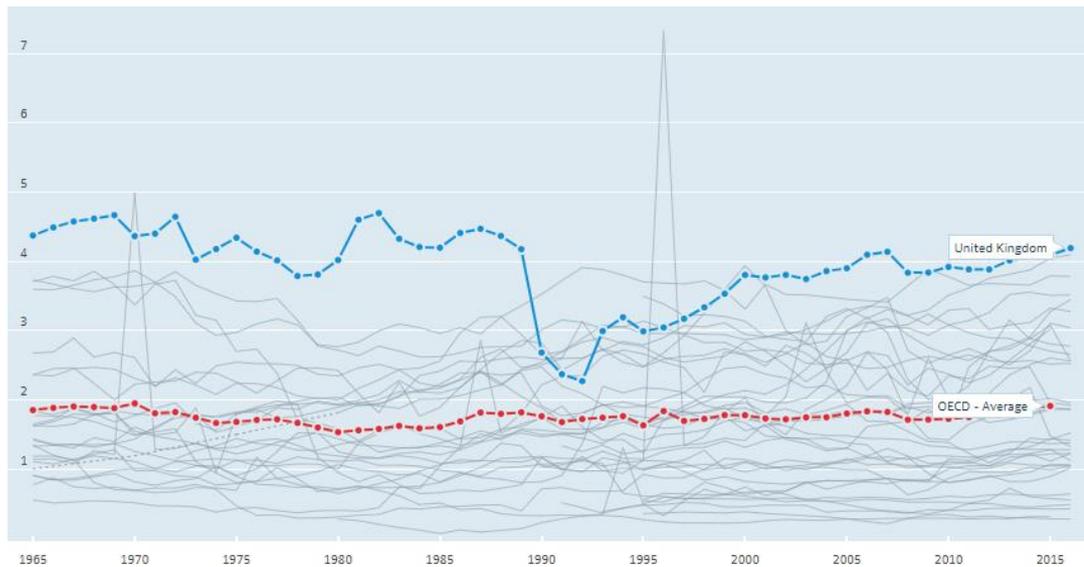


Figure 1:10 Tax on property in OECD countries with UK (blue) and OECD average (red) highlighted. Total, % of GDP, 1965 – 2015. Source: OECD (2017).

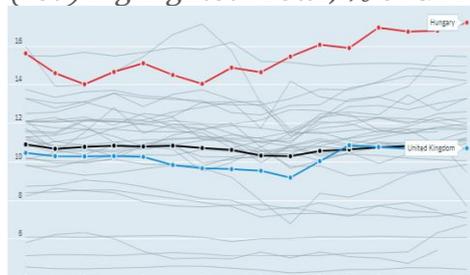


Figure 1:11 Tax on goods and services in OECD countries with UK (light blue), OECD average (black) and Hungary (red) highlighted; Total, % of GDP, 2000 – 2015. Source: OECD (2017).

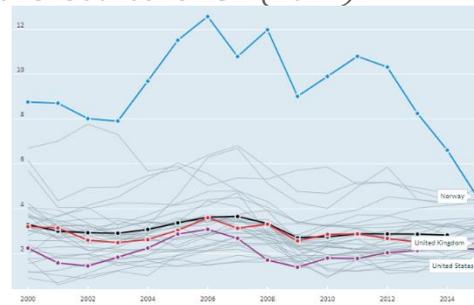


Figure 1:13 Tax on corporate profits in OECD countries with UK (red), OECD average (black), Norway (blue) and US (purple) highlighted; Total, % of GDP, 2000 – 2015. Source: OECD (2017).

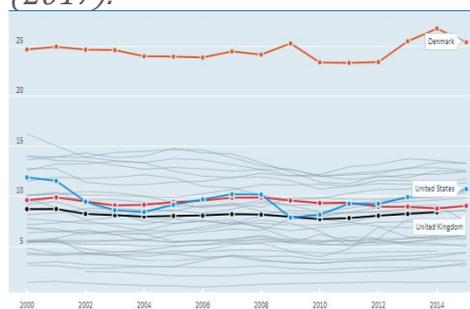


Figure 1:12 Tax on income in OECD countries with UK (dark red), OECD average (black), US (blue) and Denmark (lighter red) highlighted.; Total, % of GDP, 2000 – 2015; Total, % of GDP, 2000 – 2015. Source: OECD (2017).

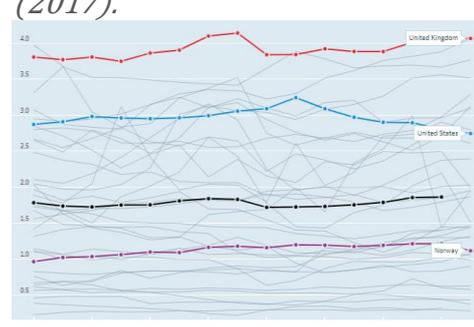


Figure 1:14 Tax on property in OECD countries with UK (red), OECD average (black), US (blue) and Norway (purple) highlighted; Total, % of GDP, 2000 – 2015. Source: OECD (2017).

1.3.1 Non-domestic property taxation

The existing theories formed for other countries (e.g. traditional, new and benefit views as introduced in the Theory Review, Section 2.1.2) may not be directly applicable to the UK system because countries use different definitions and systems and they cause different issues. However, almost every country in the world raises substantial funds from the property taxation. Although there are many different perspectives on commercial property, the International Property Tax Institute (IPTI), which provides up to date information on various commercial taxes, highlights three critical questions that are very similar to all countries (p. 14):

- *What should be taxed?*
- *How much tax should they pay?*
- *Who should pay the tax?*

Different countries have different definitions of non-domestic property. It may consist of land, buildings, fixtures, fittings, plant and even machinery. In the UK, BRs combine two taxes: a tax on the value of the commercial property and a tax on land values. Authors such as Vickrey (1996) named these as a bad and good tax, respectively. The bad tax refers to the debate against levying a tax on buildings used for business purposes. A fundamental concept of the taxation, according to Diamond and Mirrles (1971), is that intermediate inputs to production such as buildings should not be taxed. The main effect of non-domestic taxation could be that economic activity is artificially moved away from property-intensive production activities. Land, as Adam and Miller (2014) argue, is not the result of a manufacturing process: its supply is necessarily fixed and taxing it would make it less valuable to its owners without discouraging any desirable activity.

The amount of tax that should be collected is often controversial. The fundamental thought is that a country should raise sufficient revenue to pay for the costs of public service, but these costs are difficult to define. That is why rates vary significantly. For instance, UK has ~50% business rates, while Hong Kong asks property owners to pay only ~5% (IPTI data, 2017) and local councils in Norway removed these taxes (Borge and Rattsø, 2014).

Furthermore, even the basis of valuation is a debatable issue. While it is relatively easy to look at corporate gains and tax them with a corporate tax, it is more complicated with property taxation. The clear majority of countries define their basis of valuation as a market value, which could be either capital or rental value. These and other differences are presented in Table 1:2 (p. 23). For instance, in the UK the tax is based on the rental value, but in the US, it is on capital value. Also, there are inconsistencies in the bodies that set the

tax. In the UK from 1990, the tax base is assessed centrally, while in the US, it is set by jurisdiction. Revaluations would add rigour to the taxation but are often costly. Some places like Hong Kong or British Columbia have annual revaluations, while the UK supposed to have them each five years. Ireland ‘solves’ this problem by using self-assessment. However, it is uncertain whether the Irish solution would be suitable for the UK economy because of its more substantial receipts from property taxation.

	The UK	The US
Tax base	Rental values	Capital values
Tax base is set by	Local authorities	Central government
Assessment	Periodically and national	By jurisdiction, unusual for wholesale reassessment of the tax base in any particular administrative area
Formal (legal) incidence	Occupier	Owner
Local authorities amount	<500 (OECD, 1997)	>39,000 (OECD, 1997)
Overlapping jurisdictions	Not possible	Possible

Table 1:2 Non-domestic property taxation in the UK vs US. Based on Kenyon’s et al. (2012).

This thesis attempts to increase our understanding of the third question: *Who should pay the tax?* Firstly, there are some differences between parties that pay the bill. For instance, legal incidence in the UK falls on the building occupier, while in the US it falls on the building owner. One of the issues in this thesis is whether a small business should receive preferential treatment given an array of incentives that are already available¹⁵ and pay no or lower non-domestic property tax. IPTI highlights this debate and question whether everyone should be paying the equal tax.

1.4 FUNDAMENTALS OF UK TAX SYSTEM

The previous section showed that the UK relies on the property taxation more than any other country. This section demonstrates how the major tax receipts are distributed. It is important to discuss the tax system as a whole as it funds the relief (at least in Wales) and may influence business performance. Figure 1:15 provides insight into the distribution of the tax receipts in the UK. Income tax and national insurance accounted for around 15% GDP in 2015-16. The second tax with the most substantial contribution is value added tax (VAT) with 6.2% of GDP. Property taxes (business rates and council tax) account for 3% of GDP. The fourth largest tax is corporation tax accounting for 2.4% of GDP.

¹⁵ See Section 1.5 (p. 36) for more detail.

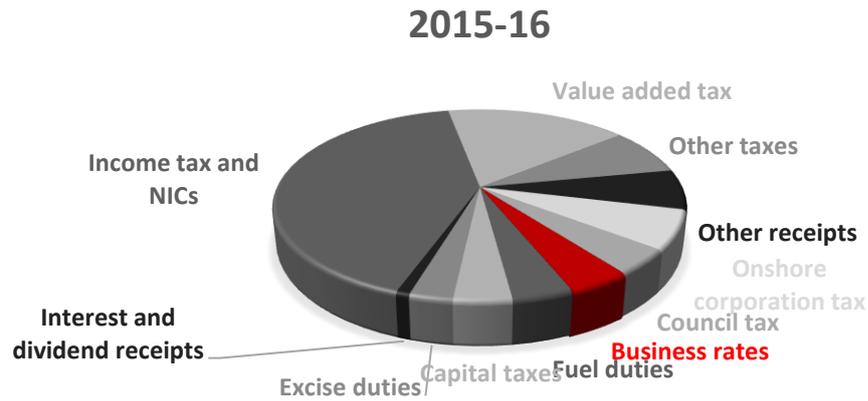


Figure 1:15 Major receipts as a percent of GDP in 2015-16. Business rates highlighted in red. Source: Office for Budget Responsibility (2017).

It is worth noting that Her Majesty's Revenue and Customs (HMRC) is the central government agency responsible for tax collection. However, local councils collect a tax called business rates from businesses and council tax from households.

The Value Added Tax Act 1994 is the primary act regulating VAT. However, other acts such as the Finance Act setting the annual VAT rates are also applicable. Before passing the revenue on to HMRC, firms may deduct any VAT they paid on inputs into their products. Thus, it is a tax on the value added at each stage of the production process but not merely on all expenditure. There are three rates of VAT: standard rate (20%), reduced rate (5%) and zero rates (0%). Also, some goods and services are exempt from VAT or outside the VAT system. Since April 2002, small firms (defined as those with sales of no more than £230,000 including VAT, in 2016–17) have had the option of using a simplified flat-rate scheme.

Income tax dates back to the Napoleonic wars when it was first introduced and later in 1942 re-introduced permanently. Substantial changes came with the 1979-2007 governments that reduced the personal income tax basic rate from 44% to 20%. This was done by the Thatcher's government, who favoured reduced government spending. They shifted taxation more to taxes on consumption rather than earnings. The Income Tax Act 2007 is the primary act regulating this tax. The rate of income tax depends on their allowance and how much of their earned income is above the allowance in the tax year.

In the UK, corporation tax was introduced in 1965. The Corporation Tax Act 2010 is the primary act regulating corporation tax. Limited companies and foreign companies with a UK branch or office must pay corporation tax on taxable profits. Taxable profits include chargeable gains from selling assets, investments and trading profits. A UK limited

company pays corporation tax on all its profits from the UK and abroad. Since 1st April 2015, the corporation tax rate is 20%, but government plans to cut corporation tax to 17% by 2020. However, according to the Office for Budget Responsibility (2017), collections from corporation tax is still forecasted to grow.

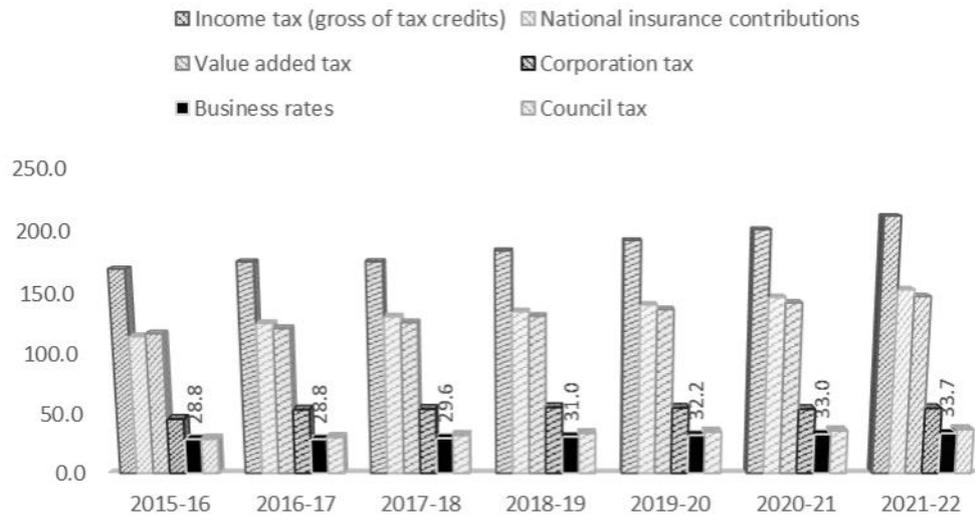


Figure 1:16 Comparison of actual (2015-16) and forecasted tax receipts (between 2016-17 and 2021-22). Source: Office for Budget Responsibility (2017).

Finally, the Local Government Finance Act 2012 and the Local Government Finance Act 1988 is the primary act regulating BRs, also called non-domestic rates, a property tax introduced in England and Wales in 1990. BRs are a tax on the occupation of non-domestic property. Non-domestic property is defined by the Local Government Finance Act “if it is wholly or mainly used in the course of a business for the provision to individuals whose sole or main residence is elsewhere of accommodation for short periods together with domestic or other services or other benefits or facilities” (p. 40). The receipt from BRs have been increased by 7% since 2010 and are planned to further rise as according to the Figure 1:16. BRs are charged on most non-domestic properties. Local councils send a BRs bill in February or March each year to either the occupier of the property or the party who has the right to occupy the premises should it be vacant. An example of the bill from one of the councils with a detail explanation is presented in Appendix 10.1.1.

1.4.1 Estimation of the Business Rates

The website Gov.uk ¹⁶provides a guide on how BRs are estimated. One should multiply a rateable value by a multiplier. These components are described in the following paragraphs.

¹⁶ <https://www.gov.uk/introduction-to-business-rates> (Accessed 10/06/18).

The rateable value (RV) is assessed by the Valuation Office Agency (VOA), which is an agency of HM Revenue and Customs. The VOA regularly reassesses and updates the RVs of all business properties, usually every five years. This is called a revaluation. Until 31 March 2017, the RVs are based on a valuation date of 1 April 2008 but from 1 April 2017, the RVs will be based on the valuation date of 1 April 2015. RV is a value ascribed to a domestic or commercial building based on its size, location, and other factors used to determine the rates payable by its owner.

The British and Scottish governments set two multipliers: the Small Business Non-Domestic Rate Multiplier for small businesses and the Non-Domestic Rate Multiplier for other businesses. The Welsh government sets just one multiplier. For 2017/18 the multiplier is £0.479, and the small business rate multiplier is £0.466 in the UK. Local councils can set a special levy (business rate supplement or BRS) on top of the national rates. In the Greater London area, it is 2% meaning that BRs in London are 2% higher than the rest of the UK. A more extensive discussion on the differences between countries is presented in Section 1.4.3.

1.4.2 Major Business Rates Reforms

Figure 1:17 (p. 27) outlines the development of BRs and proposed reforms (in pink). The property-based tax formation dates back to 1572 with the Elizabethan Poor Law Act. The Justice of the Peace for each parish was allowed to collect a tax from those who owned land in the parish to distribute it to those in need. Later, land tax was imposed in Scotland from 1667 and in England, Ireland and Wales from 1692. This was followed by extensive reforms and changes but the rates were always decentralised meaning that local councils set and collect the receipts. In 1990, Margaret Thatcher's government centralised the national business rate in 1990. In 2003, the Scottish government introduced substantial reliefs to the small businesses. England, Wales and Northern Ireland followed them and introduced similar reforms in 2005, 2007 and 2010, respectively. More recently, the government policies became less centralised. On the 5th October 2015, George Osborne announced plans, allowing councils to retain all BRs collected. The Chancellor stated that it is the 'biggest transfer of power to our local government in living memory' (BBC, 2015:online). This signals the start of the reverse reforms introduced in 1990. The power of setting and keeping the BR receipts is back to national governments.

A principal element of this policy was to further local flexibility to reduce rates set nationally for specific projects or types of businesses and stimulate local growth. Nonetheless, in the March 2017 Budget, this flexibility was undermined by the same national Government. The Government significantly expanded and made permanent the

current policy of National (English) reductions in the property tax for small businesses called Small Business Rate Relief¹⁷. The following paragraphs will show the extent to which the reliefs were increased between 2003 and 2017.

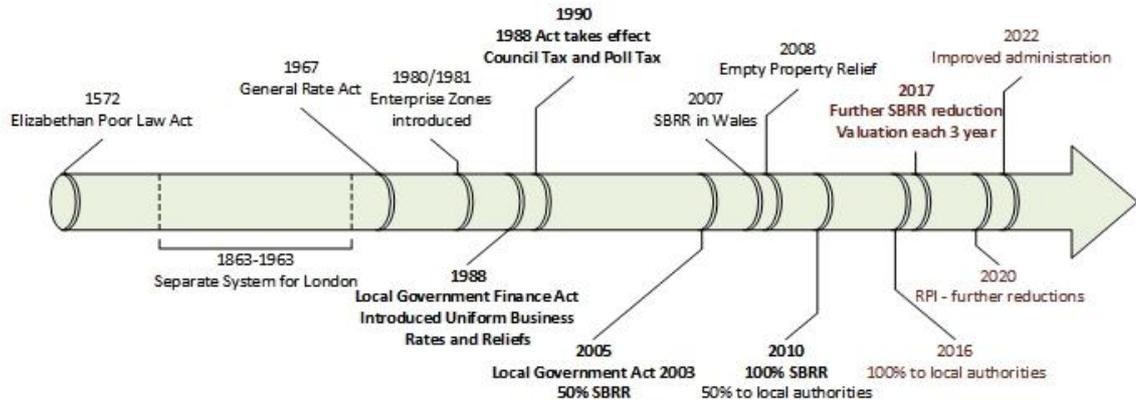


Figure 1:17 The development of BRs. The timeline shows the key reforms (black) and proposed further reductions (red). Based on HM Treasury, 2016 and 2015.

1.4.3 Small Business Rate Relief (SBRR)

1.4.3.1 Scotland

Table 1:3 (p. 28) provides an overview of Scottish small business non-domestic property reliefs. The first to introduce Small Business Rate Relief was Scotland in April 2003 with the Non-Domestic Rate (Scotland) Order 2003 and supplemented with the Non-Domestic Rates (Levying) (Scotland) Regulations 2003 Act which ended in March 2008. During this period, there were relatively marginal changes. RV was increased by £500 - £1,000. For instance, properties with RV up to £3,500 were granted 40% reliefs between 2003 April - 2005 March and 50% between April 2005 and March 2008.

From 1 April 2008, the Small Business Rate Relief Scheme was replaced by the Small Business Bonus Scheme. Businesses had to apply for the Small Business Bonus Scheme but did not need to reapply as long as their circumstances stayed the same. Relief can be awarded for a maximum period of five years without a review being undertaken.

The Scottish government announced a substantial increase in the Non-Domestic Rates (Levying) (Scotland) Regulations 2008. Properties with RV of up to £8,000 were granted 80% relief. Other properties were granted either 40% ($8,000 < RV \leq 10,000$) or 20% ($10,000 < RV \leq 15,000$). This was further increased in 2009 when some properties

¹⁷ In Scotland, it is called Small Business Bonus Scheme.

were granted 100% SBRR ($RV \leq 8,000$). The SBRR for other categories were increased by either 10% ($8,000 < RV \leq 10,000$) or 5% ($10,000 < RV \leq 15,000$).

Finally, in 2010, the SBRR reached its peak. Properties with RV of up to £10,000 were granted 100% reliefs. Twice lower (50%) relief was given to properties with RV between £10,000 and £12,000. Moreover, 25% reliefs were available for properties with RV of £12,000-£15,000. There was a further increase from £25,000 (2010) to £35,000 (2014) in available cumulative value when several properties have RV of up to £18,000. Thus, the reliefs were substantially increased over years.

		SCOTLAND					
RV \ Year	Year	Until 2003 April	2003 April-2005 March	2005 April - 2008 March	2008 April-2009 March	2009 April-2010 March	2010 April-2017 March (planned)
	$0 < RV \leq 3,000$		50%	50%			
	$3,000 < RV \leq 3,500$		40%				
	$3,500 < RV \leq 4,000$			40%			
	$4,000 < RV \leq 4,500$		30%		80%	100%	
	$4,500 < RV \leq 5,000$			30%			100%
	$5,000 < RV \leq 5,750$		20%				
	$5,750 < RV \leq 6,000$			20%			
	$6,000 < RV \leq 7,000$		10%				
	$7,000 < RV \leq 8,000$			10%			
	$8,000 < RV \leq 10,000$				40%	50%	
	$10,000 < RV \leq 12,000$		lower multiplier		20%	25%	50%
	$12,000 < RV \leq 15,000$						25% (for each property)
	$15,000 < RV \leq 18,000$			lower multiplier			
	$18,000 < RV \leq 25,000$	No SBRR			lower multiplier	lower multiplier	
	$25,000 < RV \leq 28,000$						
	$28,000 < RV \leq 29,000$						
	$29,000 < RV \leq 35,000$						
	$RV > 35,000$						lower multiplier

Table 1:3 Changes of the SBRR in Scotland. Based on various Non-Domestic Rate (Scotland) Orders.

1.4.3.2 England

Similarly, once introduced, the reliefs were continuously increased by the English government. In England, SBRR was announced in 2004 with the Non-Domestic Rating (Small Business Rate Relief) (England) Order as a temporary relief. Later, it was updated in 2008, further revised in April 2010 and then updated in October 2010. There were no objectives identified in these policy papers. Also, annual extensions of the relief were published each year. All of them are publicly available in electronic format at legislation.gov.uk.

Table 1:4 illustrates the main changes of SBRR in England (and Wales after 2010) between 2005 and 2017. Until 2005, there were no reliefs. In between January 2005 and March 2010, properties with RV of £5,000 or less were able to claim 50% reduction. Firms that had the second property with RV of £2,199 (increased to £2,599 in 2010) were still able to claim SBRR. Properties with RV of between £5,001 and £10,000 were subject to a tapering discount ranging from 0% to 49.99%, on the basis of 1% relief for every £100 of RV. Properties with RV between £10,000 and £12,000 were entitled to a lower multiplier.

ENGLAND (including London) & WALES (after 2010)

Year RV (£)	before 2005	2005 January – 2010 March	2010 April – 2017	2017 and after (planned)
RV≤5,000	NO SBRR	50%	100%	100%
5,000<RV≤6,000		0% - 49.99%		
6,000<RV≤10,000			0% - 99.99%	
10,000<RV≤12,000		lower		
12,000<RV≤15,000		multiplier	lower multiplier (not Wales)	0% - 99.99%
15,000<RV≤18,000				lower multiplier (not Wales)
18,000<RV≤£51,000				
51,000<RV				

Table 1:4 Changes of the SBRR within England and Wales (after 2010). Based on various Non-Domestic Rate Orders.

In 2008, the Non-Domestic Rating (Small Business Rate Relief) (England) Order was amended by doubling SBRR. From 2010 April, properties with RV up to 6,000 were entitled to 100% reliefs. Properties with RV of between £6,001 and £12,000 were subject to a tapering discount ranging from 0% to 100%, on the basis of 1% relief for every £60 of RV. However, properties with higher RVs were still able to use a lower multiplier up until the RV of 18,000. Additionally, businesses situated in Greater London had increased RV thresholds to accommodate greater commercial property prices. London businesses with RVs of up to either 21,499 (2005-2010 March) or 25,499 (after 2010 March) were eligible to use a small business multiplier.

Later, the government increases reliefs of up to 100%, which existed from 2010 onwards, for a property with RV of up to £12,000. It is a significant increase in reliefs in comparison with 50% applied in 2005 (RV<£5,000) and no SBRR until 2005. Furthermore,

businesses with RV between £12,000 and £15,000 receive tapered relief from 2017. Also, the threshold for the standard BRs multiplier will increase to RV of £51,000.

1.4.3.3 Wales

The development of SBRR in Wales is outlined in Table 1:5. The Welsh government announced the scheme with the Non-Domestic Rating (Small Business Relief) (Wales) Order 2006, which was first applied in 2007. Properties with RV of £2,000 or less were able to claim 50% relief. Other properties with RV between £2,000 and £5,000 were granted 25% relief. However, post offices were granted either 100% ($RV \leq £9,000$) or 50% ($£9,000 < RV \leq £12,000$).

In 2008, the Non-Domestic Rating (Small Business Relief) (Wales) Order 2008 changed the upper limit for 25% relief to £6,500. In 2010, two other orders were issued by the Welsh government that made Welsh SBRR identical to the English SBRR system. Therefore, from 2010 (April) until 31 March 2017 business premises with RV up to £6,000 will attract 100% relief. Ratepayers with RVs of between £6,000 and £12,000 will receive relief on a tapered basis from 100% to 0%.

The primary difference to the UK past 2010 SBRR is that the Welsh Assembly Government finances the scheme. Therefore, it does not operate a small business multiplier. In fact, the Assembly had the power to set the multiplier since its establishment in 1999. Furthermore, there is no requirement, unlike in England, for eligible businesses not to occupy any other premises with RV over £2,600. Furthermore, Wales has not applied a transitional rate relief scheme to increases or decreases following the 2010 revaluation. The permanent Small Business Rates Relief scheme was introduced from 1 April 2018. It provides 100% relief for sites with a rateable value of £6,000 or less and then tapered relief for sites with a rateable value of between £6,000 and £12,000.

		WALES (before 2010)		
		Year	until 2007 April	2007 April – 2008 March
RV				
RV ≤ 2,000	No SBRR		50%	50%
RV ≤ 5,000			25%	25%
RV ≤ 6,500				
RV > 5,000				

Table 1:5 Changes of the SBRR within Wales (before 2010). Based on various Non-Domestic Rate (Wales) Orders.

1.4.3.4 Comparison of the Three Countries

BRs are for the most part a devolved policy matter, though the system works in very similar ways in England, Scotland and Wales. Valuation is the responsibility of the Scottish Assessors in Scotland and the Valuation Office Agency for England and Wales. Scotland provided the most substantial reliefs, while Wales was seen to have the lowest reliefs up until 2010. After 2010, Welsh SBRR became identical to English SBRR. Although even after 2010 Scottish SBRR was substantially higher, Scottish SBRR may be lower than English SBRR after reforms. Also, Scotland and England operate separate multipliers for large and small businesses which should cover SBRR, while the Welsh government aims to cover the relief by their own financing.

1.4.3.5 Other BR reliefs

Besides the SBRR, businesses may be entitled to rural rate relief, charitable rate relief, exempted buildings and empty buildings relief, hardship relief, transitional relief and relief for pubs. Also, they can relocate to enterprise zones (EZ) with preferential taxation. These will not be covered in this thesis but are presented in Appendix 10.1.3 (p. 266). The reliefs are not covered in the thesis because they are much less frequently applied so less expensive, often targeted to very specific businesses (e.g. pubs in Appendix 10.1.3.7) or applied just for a few months (e.g. transitional relief in Appendix 10.1.3.3).

1.5 TRENDS IN SUPPORT FOR BUSINESSES

The chapter concludes with the debate on UK policies aimed at supporting businesses. Section 1.4.2 suggested that BRs policies shifted from decentralised to centralised and now it seems directed again towards decentralisation. This section shows that the decentralisation and enhanced support was not isolated to BRs but also affected many other policies. It also discusses the cost of the decentralisation to suggest that BR reforms together with enhanced SBRR may not be the *“end of the national tax on local growth”* (H.M. Treasury 2016:9) but rather the start of the expensive and inefficient system.

‘Improving the economic performance of every country and region of the UK is an essential element’ (Treasury, 2001:v). Statements like this were standard because the government emphasised that its policies should be more concentrated on regional development. In line to the BR policy discussed in Section 1.4.2, regional policies with top-down approaches attracting development to uncompetitive areas with policy instruments such as infrastructure (Acs and Szerb, 2007) were shifting to bottom-up approaches focusing on measures such as advice and training (Halkier and Danson, 1997) and fostering

entrepreneurship (Acs and Szerb, 2007). This concentration in deprived neighbourhoods may have increased the growth of the SMEs situated there. Simultaneously, it may have enhanced such issues as recruitment and skills shortage. For example, Stuetzer *et al.* (2015) revealed that British regions with large industries, such as textile mile in Manchester, in the 19th century, had lower entrepreneurship rates and weaker entrepreneurship culture today. This may explain a possible mismatch between legislative goals and outcomes.

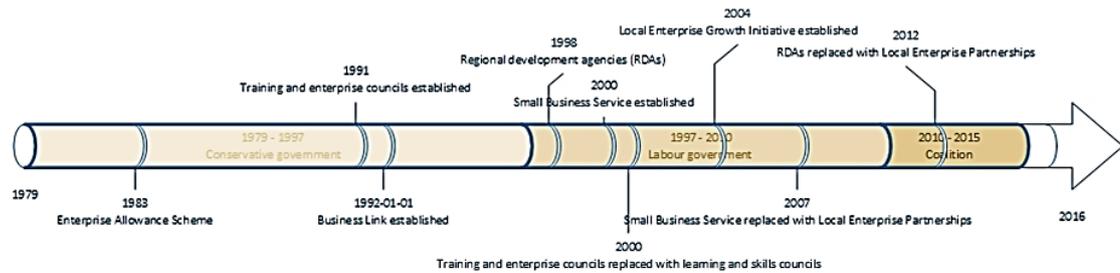


Figure 1:18 Enterprise policy timeline showing the key changes in the UK. Compiled from various UK Government Orders.

Figure 1:18 outlines fundamental trends in small business policy development. Labour government came to power in 1997 and shifted policies to both start-ups and existing SMEs with emphasis on regions. However, the number of initiatives rapidly increased to 3,000 (DTI, 2007). The Labour government then aimed to simplify the programme. In 1999 regional development agencies (RDAs) were launched to improve the performance of the regions and reduce inequalities between them (McVittie and Swales, 2007; Pearce and Ayres, 2009).

Eight RDAs were created on 25 November 1998 following the Regional Development Agencies Act 1998. The ninth, in London, was established in 2000. The statutory objectives of the RDAs were:

1. *to further economic development and regeneration;*
2. *to promote business efficiency and competitiveness;*
3. *to promote employment;*
4. *to enhance the development and application of skills relevant to employment, and*
5. *to contribute to sustainable development.*

The core activities of RDAs were financed through single pooling money from all the contributing Government Departments. PricewaterhouseCoopers LLP (PwC) was appointed by the Department for Business, Enterprise and Regulatory Reform. One of their

aims was to assess RDAs' achievements against previously outlined objectives. They use the Impact Evaluation Framework (IEF) and data supplied by eight RDAs. They start by explaining that between 1999/2000 and 2006/07, the RDAs have collectively spent around £15.1 billion. They find that 'across all interventions the annual impact on GVA resulting from jobs which have already been created or safeguarded is broadly equal to the cost, but if allowance is made for the expected persistence of these benefits, then every £1 of RDA spend will add £4.50 to regional GVA.' (BERR, 2009:viii). However, it is arguable that the expenditure of £24,377 for each job created provides a value for money for the taxpayer. Other criticisms of RDAs were: little improvement in start-up environment (Huggins and Williams, 2009), lack of clarity how specific initiatives fit with the overall policy objectives (Huggins *et al.*, 2015).

£1.4 billion was spent (according to the 2010 Spending Review) in order to transform RDAs. RDAs were narrowed to the twenty four Local Enterprise Partnerships (LEPs) announced in the October 2010 White Paper Local Growth: Realising Every Place's Potential. Several reports such as the Business, Innovation and Skills Select Committee (2010) claimed that the LEPs may be able to offer a higher focus on local economics needs and improve co-operation between local businesses and local government. LEPs had responsibility for Enterprise Zones and took various responsibilities of RDAs.

LEPs were expected to meet their day-to-day administration costs (BIS, 2010). However, in 2011 £5 million start-up fund was made available to LEPs. From 2012, the amount of funding was introduced and increased significantly. Furthermore, in 2010, £1 billion regional growth fund was introduced, and a further £2.7 billion was allocated to 2011/12-2015/16. LEPs were able to bid for funding from the first four rounds of the Regional Growth Fund but banned from bidding in rounds 5 and 6, which were only open to private enterprises.

There were various reactions to the LEPs. Lord Haseltine's report (2012) made many recommendations for economic growth and wealth creation. These included a recommendation for a higher devolution of funding from central government to LEPs. In the beginning, LEPs had limited funding, so criticism was directed at the effectiveness of LEPs, their vision (Pike *et al.*, 2013) and whether they would be capable of delivering the value for taxpayer's money (British Academy, 2012). National Audit Office's (NAO) (2013:41) report stated that Local Enterprise Partnerships are "not yet capable of delivering value for money." Later NAO's (2016) report further adds the lack of objectives, pressure to spend their funds at that year, lack of resources and established track record of delivery to the list of their drawbacks.

However, the widely accepted ‘fiscal decentralisation’ theorem further discussed in Theory Chapter (with works of Tiebout, 1956; Oates, 1972; Brennan and Buchanan, 1980) takes a different view. Local authorities should have an informational advantage. Therefore, local councils should be better at tailoring the provision of public goods and services to the need of their customers. The fiscal decentralisation should bring benefits for allocative and production efficiency and, eventually, economic growth. These benefits come with higher costs. The spending of other departments that have the nominal responsibility for SMEs increased from £2.5 billion (direct) in 2001/2 (HM Treasury, 2000) to £4.9 billion (direct) in 2014/15 (Cabinet Office, 2015). However, according to Richard (2008:10), these costs were about £12 billion from which £4 billion to tax incentives. This, as Bennett (2012) suggested, is because decentralised government costs more. He estimated that decentralised governance cost 10-12 times more than centralised.

Thus, it seems evident that SBRR fits within the government’s devolution strategy because it should make cheap properties even cheaper and encourages business owners to move into more deprived neighbourhoods. However, as the Theory Review Chapter shows, it is not necessarily the case. If SBRR were to be capitalised into rents, the landlords would receive the relief and government spending would produce negative returns by enhancing market inefficiency. Further discussion of these theories is delivered in the Theory Review Chapter.

1.6 SUMMARY AND OBJECTIVES

The concerns relating to the effects of this high-profile policy on the tax base and local autonomy, coupled with the axioms of tax theory and broader applied evidence influenced in forming the primary aim of this thesis. The aim is to understand whether SBRR has any effects on business performance, in particular with regards to their productivity and survival.

Employment, productivity and survival rates were reviewed through official statistics. Britain seems to outperform other nations with regards to maintaining the unemployment rate but performs slightly worse than other advanced economies concerning productivity. Manufacturing output per hour has been more unstable than service sectors and as total factor productivity (TFP) indicators show, the overall decrease in TFP may be explained by a decline in the service sector. When it comes to churn, births have started exceeding deaths since 2011. The ratio of births and deaths were more diverse through sectors than regions.

The devolution of SBRR and its enhancement might raise concerns about future revenue, greater reliance on a small number of large firms and restrictions on local autonomy to achieve local objectives. This is especially important because the UK collects more tax through property taxation than other OECD countries. However, it is difficult to compare the collection rates because countries have different tax systems. In a similar vein, foreign theories might not be adaptable to the UK environment. Instead of property tax, countries like Norway may base their system on corporate profits. Higher corporate tax rates may encourage companies to shift their profits elsewhere. On the other hand, the major disadvantage of property taxation is unknown incidence and lack of clear criteria (e.g. profits). The disadvantages of property taxation may be directly applied to SBRR.

SBRR fits within the government's devolution strategy and other policies administrated since 2000. It focuses on the cheaper properties and, subsequently, may encourage businesses to move into more deprived neighbourhoods. However, this is not confirmed by the evidence. The report on Northern Ireland (2014) showed no relation between deprivation and SBRR. Furthermore, if the incidence falls on owners, the government may be only supporting property owners instead of businesses, adding more expenditure to already extensive devolution bill. Given these insights, the following objectives are formed:

- To create a theoretical framework which suggests whether SBRR may influence productivity and survival. The framework should be based on the existing theories of tax incidence and the UK business environment.
- To find appropriate data and analytical technique which could be used to either support or disprove the framework. Simultaneously, to explore other fields for techniques that were not used previously in policy evaluation.
- To acquire the knowledge through the theoretical framework and empirical evidence of the extent to which SBRR may influence productivity and survival.

More specifically, this Introduction and Background Chapter defined the problem that is investigated within this thesis and provided the background. The more extensive discussion of theoretical issues that were touched upon Introduction Chapter are presented in the Theory Review Chapter, which is split into the central concepts of capitalisation and governmental intervention. Then, the Empirical Review Chapter looks how those theories were employed by other researchers. This literature is used to form a theoretical framework based on the existing theories of tax incidence and the UK business environment. This framework is presented in the Chapter Four. To find an appropriate

methodology for testing this framework, various approaches are reviewed in the Methodology Review Chapter. According to this, the Research Design Chapter starts by reviewing available datasets, so that a suitable dataset could be found. Once it is identified, the management of the data is discussed to provide assurance. The Research Design Chapter concludes by presenting the methodology, which is both suitable for data and is informed by the Methodology Review. The productivity is estimated using the Generalised Method of Moments (GMM) and Regression Trees with Random Effect (REEM), and survival rates are estimated mainly with Cox Proportional Hazards (CPH) and REEM. The results from these models are presented and discussed in detail.

The primary contribution of this thesis is the evaluation of the SBRR using rich sensitive data, which find no evidence that the often-expressed narrative underlying the policy of reductions introduced at the beginning of this chapter is accurate. The thesis highlights that the substantial reductions in tax revenue totalling up to £9 billion over five years only in England¹⁸ result in only marginal initial benefits in survival and no benefits to productivity. Simultaneously, the thesis gathers the literature, updates and adopts Duranton's framework and applies not only improved¹⁹ standard econometric techniques but also the machine learning approaches that were not used previously in policy evaluation.

¹⁸ The most recent extension to reductions from April 2017 and 2018 will further reduce tax revenue across England by £9 billion over five years and remove 600,000 firms from liability (HM Treasury, 2017).

¹⁹ Improved by CEM matching and more precise deflators.

2 THEORY REVIEW

This chapter aims to discuss the theoretical foundations of the thesis. The overall aim of this thesis is to understand whether Small Business Rates Relief (SBRR) has any effects on firms, in particular with regards to their productivity and survival. Total factor productivity (TFP) is the portion of output not explained by the inputs used in production. Whilst, survival analysis in this setting is a method for analysing the expected duration of time until closure. The chapter is divided into two major sections. As illustrated in Figure 2:1, the chapter starts with Section 2.1 focusing on capitalisation. It is an essential element of property tax reliefs because the UK government may be supporting property owners instead of businesses. Once theories on capitalisation are discussed, the focus turns towards the reasons why the government might still use this instrument to support firms (Section 2.2).

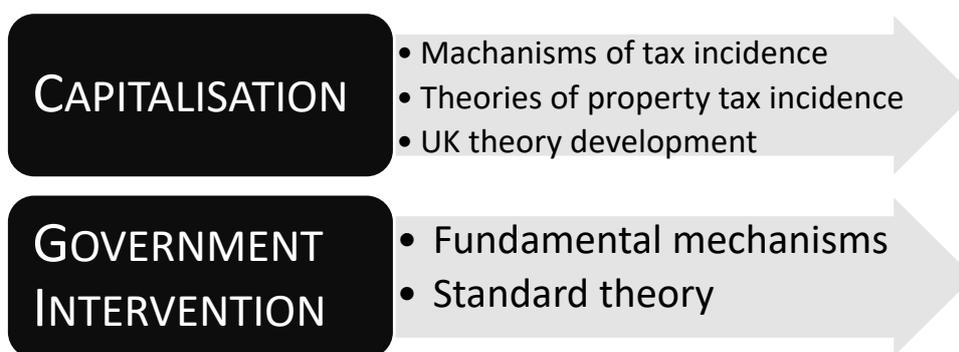


Figure 2:1 Content of the Theory Review Chapter.

First and foremost, business rates (BRs) system might not comply with traditional taxation cannons. In 1776, Smith highlighted four cannons of taxation: *certainty*, *convenience*, *efficiency* and *equity*. However, the business environment has changed significantly, and it is arguable that any of these cannons could apply directly to the BRs system. The first two criteria seem to, at least partly, comply with property taxation because BRs are relatively easy to administrate and could be a convenient way to tax companies. This is approached in the Introduction and Background Chapter (Sections 1.3 and 1.4).

The equity part is the most challenging of all these cannons in the context of BRs. That is why the starting point in this thesis is the standard tax incidence debate - whether an occupier or property owner is a recipient of the relief. The equity part may be further split to the fairness and ownership of the tax. There are two fundamental approaches to investigate tax incidence, which will be detailed in Section 2.1. This is important when

focussing on the SBRR because the government, could just increase profits to property owners instead of targeting help at small businesses to enhance economic activity. In fact, the government may also reduce the economic efficiency. *The excess burden* is the reduction in economic efficiency that is attributable to the tax system. It is also known as the deadweight loss (or loss of taxation) which is the financial loss that society suffers resulting from such government activities as taxation or reliefs. The concept is more formally introduced in Section 2.2.1.3.1

The potential deadweight cost may be high, which is why distinguishing between two concepts, *formal* and *economic* incidence, is essential. Policymaking tends to ignore any divergence between the statutory and economic incidence of taxation (Oates and Fischel, 2016), yet this divergence is central to the effectiveness of SBRR and the support for the policy. BR is levied on property occupiers and this makes it particularly salient to businesses and puts policymakers on the defensive. Yet the relative inelasticity in the supply of business properties to the flexibility of demand would see the economic incidence transfer to property owners, i.e. capitalised into the rental price. Then, in response to a reduction in taxation property owners would be increasing rents in line with the decrease in tax. The degree and time it takes for SBRR and other changes to capitalise provide space in which the tax, and policy, could influence production and survival decisions. More specifically, the formal tax incidence refers to the entity on which the law says that the tax obligation falls. This is the occupier in the SBRR context. The economic incidence refers to the person on whom the actual tax obligation falls. The Section 10.1 and this thesis in general focus on the economic incidence, which highly depends on the capitalisation.

Tax capitalisation refers to how asset value is changed when cash flow is changed by an increase or decrease in the tax liability for that asset. One of the costs that must be subtracted from a future income stream is the tax assessed on that asset. These concepts are important because if the tax were completely capitalised into rents, SBRR would be inefficient.

2.1 CAPITALISATION

This section looks into various theories related to capitalisation and the extent that capitalisation impacts any effects experienced by the firms receiving the relief. Two main versions of modern neoclassical incidence theory have been established - the capital (or traditional) view and the benefit (or new) view. The former, introduced by Harberger (1962), is based on the general equilibrium model showing that capital owners bear the

burden of property tax. Kotlikoff and Summers (2017) and Chetty *et al.* (2009) provide substantial coverage on tax incidence. These authors mainly speak about the taxation of goods, but their insights could be equally applicable to the property tax. More recently, Wildasin (2017) reviews recent theoretical models on property taxation. In this chapter, his review is extended and models are applied to the SBRR context.

In general, modern incidence theory is an illustration of how capitalisation could occur. It is worth noting that it is formed on a slightly unreasonable formulation of how firms operate. For instance, marginal costs and rising average costs are often used instead of constant average costs in modelling. However, this basic supply and demand inspired insights suggests how property owners perceive SBRR.

Thus, the mechanisms of the fundamental models are presented first (Section 2.1.1), as illustrated in Figure 2:2. Once these are explained, a discussion on incidence theory development is offered (Section 2.1.2). This is supplemented with a review of UK literature (Sections 2.1.3-2.1.5). Finally, the chapter concludes with the insights from this discussion (Section 2.1.6) that will be included into the framework.

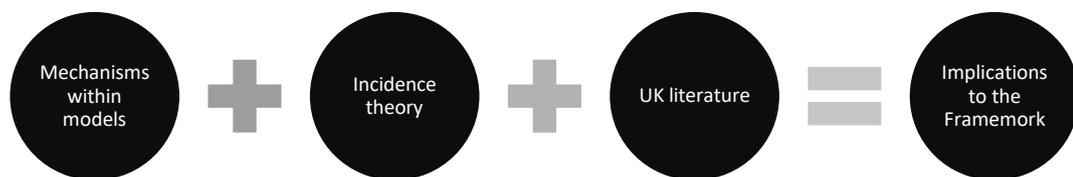


Figure 2:2 Overview of the capitalisation debate discussed in Section 2.1.

2.1.1 Mechanisms of the Fundamental Models in Tax Incidence

Several fundamental models are presented to show how and why SBRR may influence the demand and supply of goods. The section starts with the partial equilibrium model that shows that demand and substitution elasticities should have an impact on whether and to what extent businesses receive the relief. This understanding helps explain how tax capitalisation into rents or property prices occurs.

2.1.1.1 Partial Equilibrium

In the partial equilibrium model, the division of the tax between occupiers and owners depends on the elasticity of demand and supply. The theory says that if there are many properties to choose from and supply is elastic (or demand is inelastic), occupiers

would receive the whole SBRR. On the other hand, if there are no alternatives and the demand is inelastic then property owners would have all relief for themselves.

Kotlikoff and Summers (2017) invite us to look at a partial equilibrium analysis which considers what happens to prices in the market with a tax change. The approach requires assumptions which may be unlikely to hold in applied settings. Some of these are that taxed commercial property should not be linked to other properties, so there should be no substitute/complement properties. Also, income effect is not considered, so BRs should not take a significant proportion of firm's income, which may not be the case for the micro firms. Finally, the collected taxes are assumed to disappear from the economy, so they do not affect demand.

Let's assume that there is no relief and price is P and supply is equal to demand, $D(P) = S(P)$. Once relief is introduced and received by occupiers, the new equilibrium would be satisfied by $D(P - SBRR) = S(P)$. If landlords collect the tax, it becomes $D(P) = S(P + SBRR)$. The resulting equilibrium is similar in both cases. This shows that neither quantity nor tax collected depend on the party that is taxed.

Suppose occupiers receive the relief ($SBRR$) per property they occupy. This means that occupiers pay, $p - SBRR$, when landlords obtain the price, P . The property owner's function would still depend on the relief $P(SBRR)$ because the property owner receives part of the tax relief when $SBRR > 0$. Therefore, the occupier price could be given by differentiating:

$$\frac{dP}{dt} = \frac{\frac{dD(P)}{dP}}{\frac{dS(P)}{dP} - \frac{dD(P)}{dP}} = \frac{Elasticity_S}{Elasticity_S - Elasticity_D}$$

2.1.1.1.1 Four Scenarios with Polar Demand and Supply

The previous section showed that in the partial equilibrium, the division of the tax between occupiers and owners depends on the elasticity of demand and supply. Figure 2:3 (p. 41) presents four scenarios with perfectly (in)elastic demand and supply. These extreme scenarios are going to be discussed, so that the succeeding section, which looks at more complicated mechanisms, can be more easily explained.

In the top left of Figure 2:3 (p. 41), the world is represented with perfectly inelastic demand. In this scenario, consumption does not increase despite a decrease in price. SBRR shifts the supply curve and the price decrease, but quantity stays unchanged. Given that demand is not affected, occupiers pay the entire tax. For instance, if business properties are assumed to be in fixed supply for a few years because of the long time for building

permissions to be granted and buildings to be built. Then, once SBRR is introduced to an occupier, the landlord may just increase the rent.

On the contrary to inelastic demand, when demand is perfectly elastic (the top right graph), owners pay the entire tax. The latter may be expected in a world where businesses are similar and can move without costs as well as locations are identical. Two spatial equilibrium models (Rosen, 1974, 1982) and the open monocentric city model (Brueckner, 1987) assume such unrealistically perfectly elastic property demand. Other studies, such as Hilber and Mayer (2009) and Lutz (2015), have shown that demand is not perfectly elastic. Overall, the more inelastic the demand is, the larger proportion of the tax relief is received by occupiers.

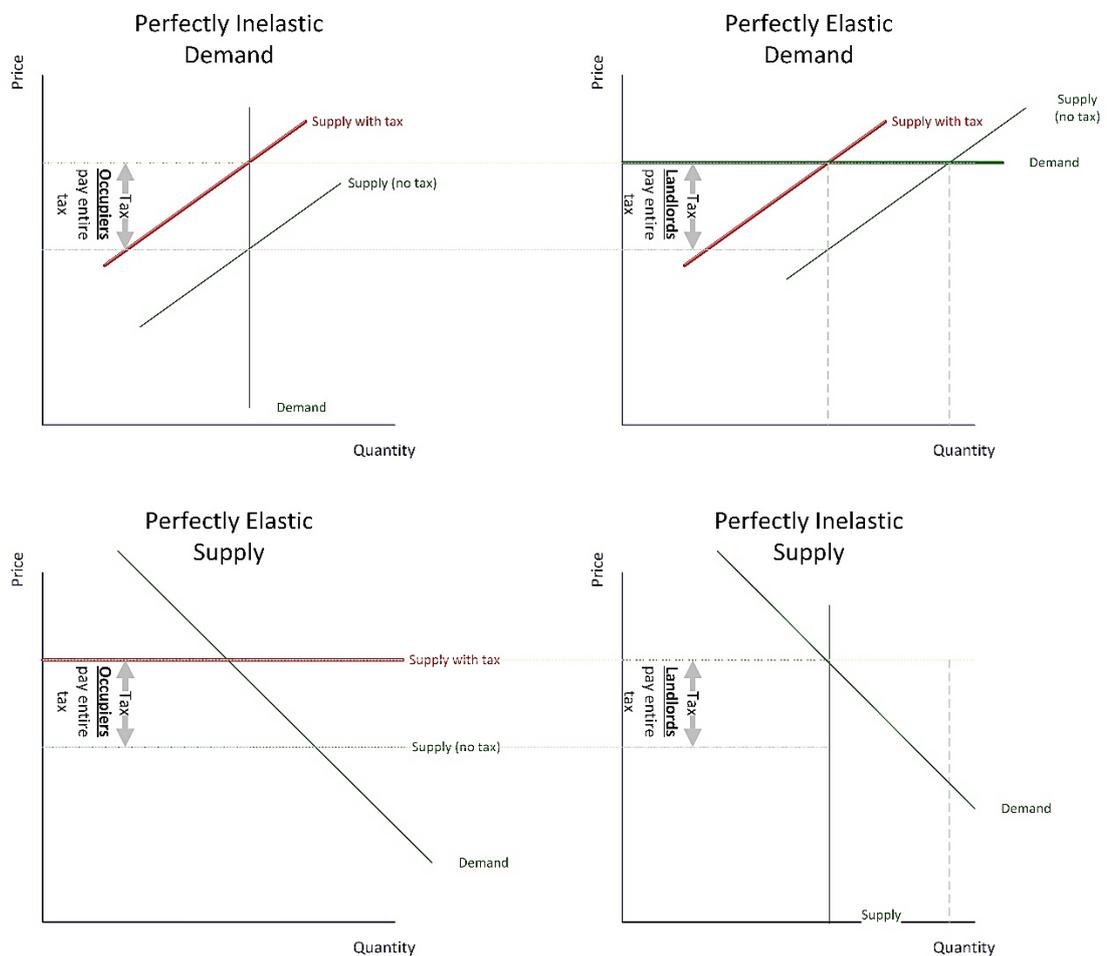


Figure 2:3 Demand and supply elasticity after SBRR introduction. Based on Parkin (2016) and Glenn (2013).

In a scenario with downward sloping demand curves, assumptions on the slope of the supply curve are crucial for the response of businesses to demand shocks. Figure 2:3 (lower graphs) illustrates that perfectly (in)elastic supply have the opposite trends. When the supply of properties is fixed and occupiers are willing to pay just the same amount of

money, the landlord effectively receives SBRR. However, when supply is perfectly elastic, occupants benefit from the relief.

It is worth noting that the demand and supply conditions in Figure 2:3 (p. 41) are extremes. The combination of effects could follow from a relief in tax. A reduced price is payable by occupiers and an increased price is receivable by landlords. This is likely to be influenced by the time scale of the analysis because the respective elasticities are likely to vary between the short-run and the long-run supply and they also are likely to depend on the degree of factor substitution. Mechanisms behind these results are provided in the following section.

If land were to be considered as unimproved, land situated in a jurisdiction with exogenously fixed boundaries would be perfectly inelastically supplied. Thus, the land tax should be neutral with no shifting and no efficiency loss (Vickrey, 1970). However, Bentick (1979) and Mills (1981) have studied the neutrality of land value taxation. They conclude that neutrality breaks down in a dynamic economy. Wildasin (2013:1157) explains this with a simple model. He asks to consider a case where a parcel of land can be developed in a way that will yield a constant return (R) per year in perpetuity. These returns are discounted at a rate r and the market value of the property is taxed at rate t , then market value V should satisfy:

$$V = \frac{R - vT}{r} = \frac{R}{r + t}$$

He compares the cases with no tax ($t = 0$) and tax ($t > 0$). It is evident that the taxation on land is identical to that of an increase in the discount rate. This case becomes even more complex when discount rates and tax are allowed to vary over the time but these did not change the conclusion. Bentick (1979) and Mills (1981) argue that land value taxation promotes the excessively rapid development of land because the market value of a parcel differs over time according to its use. If the tax on land were independent of the use of land, the tax would be neutral. However, this is not the case for the rateable value in BRs context because land may be used not only by businesses. When buildings or capital is included into the equation the situation becomes even more complex.

2.1.1.1.2 Substitution and Output Effects

The tax incidence depends on whether the output effect outweighs the induced substitution effect. It is difficult to find the right demand and substitution elasticities that

should have an impact on the substitution and output that may be applied in the framework of this thesis.

For the firm, the output effect demonstrates how the use of inputs changes when the firm takes a new profit-maximising output level. Whilst, the substitution effect indicates how the use of inputs is changed when the firm was to produce the same amount of output. If substitution is very extreme, the substitution effect dominates the output effect. Labour gets more expensive and capital cheaper. As a result, the firms are likely to select a different mix of inputs for the same amount of output. This is illustrated in Figure 2:4 showing the capital ($K1a$) and labour ($L1a$) shift to $K1b$ and $L1b$, respectively. Thus, the occupiers receive the relief. If the output effect dominates the substitution effect or no substitution is possible, the output effect would predominate. If the factor price decreases (all other variables being unchanged) because of SBRR, then marginal costs decrease and, simultaneously, output increases. This should cause the demand for both factors to increase and the output curve would shift to Output 2b. This new marginal cost curve is likely to require firms to change their volume of output to maximise their profits. Both - substitution and output - effects are likely to imply a downward-sloping input demand curve when a firm maximises profit without a fixed budget constraint. However, assuming that the land is fixed as well as total output and the price cannot change as shown in the previous equitation, the gross rental value of land will increase to keep the unit cost of production constant. In this case, none of the relief is shifted to businesses but all is capitalised, so the property owners profit from the relief.

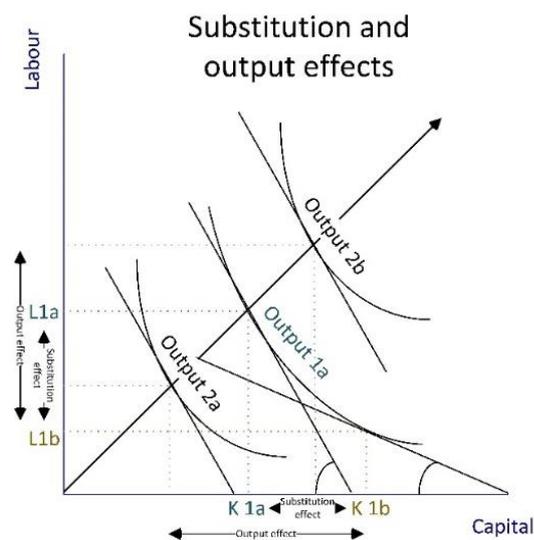


Figure 2:4 Substitution and output effects. Based on Parkin (2016) and Glenn (2013).

These substitution and output effects are shown in multiple studies and extensions (for an extensive review, see Wildasin, 2013:1149). For instance, LeRow (1976) looks at a monocentric city model with explicit spatial structure. Other studies (Sonstelie, 1979; Lin, 1986) have studied the effects of differential taxation on capital between the housing and non-housing production. Mieszkowski (1972) introduces more than one immobile factor in the model. Richard *et al.* (1977) and Sullivan (1985) provide computable general equilibrium models, which may help to simulate the effects of taxation. It is worth noting that this literature assumes $El \rightarrow \infty$ for traded goods, so exporting of the property tax relief, in the form of lower output prices, is not allowed.

This subsection emphasised that it is difficult to find the right demand and substitution elasticities that are likely to have an impact on the substitution and output. To control for these, the framework proposed in this thesis (Chapter 4) mimics both negative or positive shocks in demand with different scenarios depending on the relief. To at least partly control for these cases, the framework also includes various indexes to control for varying competition, which are presented in Section 4.6 (p. 89).

2.1.2 Development of the Incidence theory – Old, New and Benefit Views

The first part of this chapter was devoted to the mechanisms on capitalisation. This part provides more insight on how these models were applied to form theories. The development of the incidence theory is based mainly on the US property taxation that, as discussed in the Introduction and Background Chapter (Section 1.3), is different to the UK tax environment. Thus, the development of the incidence theory provides us just with an indication to whom UK tax incidence might fall. These developments are also compared to the UK scholars such as Fraser (Section 2.1.3), Duranton (Section 2.1.4) and Hilber (Section 2.1.5).

The previously discussed partial equilibrium model (Section 2.1.1.1) needs to be extended to include the whole view of the market. While general equilibrium refers to the whole economy, where demand is equal to the supply of every single good and service in every market, partial equilibrium takes into consideration only a part of the market. The general equilibrium is used for a traditional view in incidence theory. It claims that a tax on property is levied in part on land and in part on the structures that create the value of a parcel property. The traditional view is often associated with Simon (1943) but it dates back to Edgeworth (1897). Generally, scholars such as Musgrave *et al.* (1974) support this view by emphasising that some rental markets are likely to be imperfectly competitive. Since the land is fixed in supply, owners pay the tax in proportion to land's share in the value of the property. Structures are assumed to be mobile in the long run. The net return

to capital is taken as given. Therefore, given the perfect mobility of capital, the gross cost of capital decreases with SBRR and the occupier supposedly receives part of the relief.

This thesis supports Aaron (1974), who argues that this view is incomplete. Firstly, he stresses that housing and other consumption expenditures may have income elasticities not too far from unity. Then, he says that infrequent assessment may introduce regressive taxation. For instance, in Britain, the assessment should be undertaken every five years but the most recent valuation was delayed from 2015 to 2018. In some areas like Manchester, property values may have increased disproportionately as compared to those in Liverpool, for example. Thirdly, other factors are not incorporated into the model, which are available in the general equilibrium framework. GE mechanisms are used in the new view of tax incidence. Aaron also introduces several other observations that are not directly related to this study. For instance, he argues that tax increase may cause a capital outflow and, thus, this adverse effect may follow once SBRR relief is introduced.

Aaron (1974) highlights the fundamental difference between traditional and new views. The incidence of property tax is now on owners rather than occupiers. GE analysis takes account the fact that markets operate together. Thus, a relief for some properties would change demand and prices for other properties. For instance, firms occupying premises with higher rateable value would have greater incentives to move to premises with lower rateable value assuming no capitalisation. Also, a relief on the indirect costs of some manufacturers or service providers would potentially reduce the demand for other providers. This argument is further extended in Section 2.2.1.3. The general equilibrium analysis is more complicated because it considers a two-factor, two-sector model which is developed by Harberger (1962) but applied directly to the property market by Mieszkowski (1972).

Mieszkowski (1972) is the first to apply Harberger's model to property taxation. This model carries all previously discussed GE assumptions. He decomposed property taxation (PT) into two components, average property tax rate over the entire country (AT) and the deviation of the local rate from the national average (DT). Simple mathematical expression would be $PT = AT + DT$. The model fits the US case because the US has multiple jurisdictions that set their own non-domestic property tax rate. However, UK BRs have been uniform since 1990, so it is not directly applicable there. Mieszkowski's (1972) analysis of property tax incidence deals with a model of an economy containing only one sector and three factors, in which labour is immobile. He argues that the uniform rate would impact capital income, which is progressive under the new view, whilst the later tax

increase would raise town's cost of housing, so would be regressive under the traditional view.

Mieszkowski's (1972) paper offers an interpretation that applies under certain conditions. For instance, when supply is inelastic (a typical assumption in the GE framework), the burden of a local property tax falls ultimately on national capital (as well as having some local effects). The tax is progressive because capital income is distributed progressively with respect to total revenue. The opposing ideas are presented by Courant (1977), who shows that non-uniform taxation cannot produce the same total revenue as a uniform one.

Another, often discussed scenario, is the benefit view described by Hamilton (1976), Chaudry-Shah (1988) and Ross and Yinger (1999). It is based on Tiebout (1956), who apply Musgrave (1939) and Samuelson's (1954) ideas to their new framework. Hamilton, inspired by Tiebout, argues that the taxpayer would not live in a territory that taxes businesses higher than the value of services provided to them. The implications of this theory to British SBRR would be that house prices would increase by the capitalised value of any positive stream of fiscal surpluses, when local service exceeds taxes. This model suggests that rational consumers measure (to some extent at least) the cost of their tax and the benefits from local public services.

The benefit view has more validity in the US context, where many jurisdictions with varying BRs and service quality exist. The ideas from this theory are unlikely to be applicable in this theses because the UK is one of the most centralised countries in the world. The UK tax system until recently cannot be considered anywhere close to benefit view because the central government is responsible for the collection, valuation and distribution of the relief. Furthermore, all these studies have followed Tiebout, so they assume high mobility between local jurisdictions, replace lump-sum taxes with property tax and introduce an assumption of zoning ordinances, which may be inefficient. The burden would be shifted from the below average property owners to the above average value owners. In this case, zoning or other regulation should be introduced to limit this. Hamilton concludes that tax incidence is unknown until there is a framework to understand political forces influencing land-use policy (for more extensive discussion see Hamilton, 1976; Mieszkowski and Zodrow, 1989). This is also further discussed with Hilber's (2017) discussion on the unintended consequences of SBRR (Section 2.1.5.1.2).

2.1.3 Fraser's British Theory

In the previous section, the main theories mainly originating from the US were introduced. In 1984, Fraser provides a descriptive analysis of UK property tax incidence. Fraser (1985) delivers a valid theoretical analysis of fiscal impacts that is both complete, is applied directly to the UK business property and serves well as an introduction to the issue from the UK perspective. However, it is worth noting that his theory was established before the uniform BRs were introduced. Thus, this theory, in hand with all three previously introduced views, assumes a decentralised system, where jurisdictions can set their own rates, which is not the case for current UK BRs.

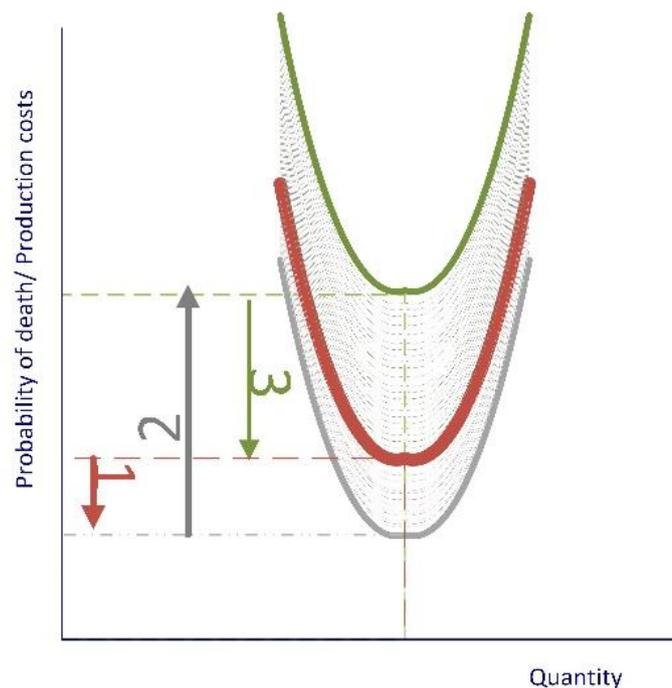


Figure 2:5 Author's interpretation of Fraser's survival (productivity) cycle: 1. Receiving SBRR lowers the probability of closure (production costs). 2. After a few years, because of increased competition death probability (production costs) is increased. 3. In the long run, survival rate (production costs) is stabilised.

As Figure 2:5 (p. 47) illustrates, Fraser argues that in the short run, SBRR (1 in Figure 2:5, p. 47) would be received by the occupiers because of the lag in rent review, which may have the effect of shifting the tax relief. In this case, lower death rates and higher productivity should be expected. In the medium run (2 in Figure 2:5, p. 47), the owners would receive SBRR through increased rents and capital gains, which should increase the mortality rates. While in the long run (3 in Figure 2:5, p. 47), the supply of new properties should be increased by the relief, in line with the decrease in demand so that property values would return to their previous values, and the SBRR would be received by occupiers

meaning some improvements in productivity and survival rates. However, it is worth noting that the theory was based on the situation before the 1990s. Thus, there was no uniform taxation. Although this theory provided a clear explanation of BRs, it did not include the exact mechanisms.

2.1.4 Duranton's *et al.* Theory

In 2011, Duranton with colleagues published their paper 'Assessing the Effects of Local Taxation Using Macroeconomic Data' in the *Economic Journal*. This, according to this review, is the most recent and theoretically challenging study on the UK BRs. Their model is based on Britain (unlike previous studies) and provides more rigour than Fraser by developing a detailed theoretical framework. This novel theoretical framework is used as a starting point in the theoretical framework for this thesis (Chapter 4).

Broadly, their reasoning is similar to that of Fraser's, but they quantify the mechanisms to which BRs should behave. Previously discussed Fraser's framework looked only at capitalisation, but Duranton *et al.* (2011) study the impact of local taxation on the location and growth of firms. They start the article by acknowledging the primary issues that, according to them, were failed to be resolved by the existing literature: many heterogeneous locations, heterogeneous firms and tax system being endogenous to firm decisions.

Duranton *et al.* (2011) in hand with Bond's *et al.* (1996) theoretical framework (discussed with all empirical studies in Section 3.2) suggest that BRs should be capitalised into property values. This standard conclusion from the neoclassical frameworks helps them to reason that rental prices for commercial properties should not be affected. The only possible effect, assuming standard neoclassical assumptions, is on the construction/improvement of new buildings. However, once the authors incorporate moving costs and the proportion of total expenditure to BRs, they conclude that the taxation would not have a sizable effect on employment. However, they add two more realistic assumptions. They further theorise that the overall rental costs of properties are affected by property taxes, and property valuations occur in case of building improvements. They magnify the effects of an increase in property tax. The rest of this section will describe the details of this theoretical model, while estimation techniques used with empirical data is discussed with all empirical studies in Section 3.2.

They start by assuming that businesses use labour and building space to produce a final good. These two products are assumed to be perfect complements. Occupiers pay the tax. Given that the model is based on the data before 1990, they assume that the tax varies

between jurisdictions, times and historical value of the building. A jurisdiction is capable of setting its BRs. The unit rental cost of buildings in jurisdiction a comprises two elements: the building rent, b_a and the local tax, referred to in the UK as BRs, r_a . They further assume that the price for final good is exogenous, common in all councils and equals to $1+p$, establishments could live up to 2 periods and new starters may join at any time. During the first period demand for their good is normalised to utility. Therefore, profit is given by:

$$\pi_{at}^1(i) = p - b_{at} - r_{at}$$

Then, Duranton *et al.* (2011) assume that the firm experiences both a shock in demand for final goods, ρ and an increase in their BRs bill in their second period. The second-period tax, r_{at+1} , is the realisation of a random draw, \tilde{r}_{at+1} from a distribution $f(\cdot)$ over $[\tilde{r}, r]$ at the beginning of period $t + 1$. They disregard that firms can renegotiate rents downwards in response to either tax or demand shock. In their framework, an establishment faces five possible choices: exit (π_E), downsize (π_D), grow (π_G), stay put (π_S) or relocate (π_R).

They consider two scenarios for the firm experiencing a negative shock: downsizing and exiting. They assume that relocation would be costly and firms would not want to relocate. The exit leads to the second-period profit being equal to 0 because firm stops to operate:

$$\pi_{t+1}^2(i) = \pi_E(i) \leq 0$$

If a firm experiences a smaller negative shock, it stays in business but downsizes. Duranton *et al.* (2011) explain that downsizing can occur by subletting some part of the original building unit. They cite Crosby *et al.* (1998:3) to emphasise that it is a common practice. They assume that the firm cannot get a higher return than rent paid to the owner, so that $\underline{b} < b_{at} + r_{a(t+1)}$. Then, a profit function would be:

$$\pi_{t+1}^2(i) = \pi_D(i) = (1 + \rho_i)(p - \underline{b}) - b_{at} - r_{at}$$

Authors do not consider a relocation because they assume that the relocation costs would be extremely high.

Duranton *et al.* (2011) continue explaining firms' decisions to a positive demand shock. Firstly, they consider expanding building space and hiring more employers. The unit rent for extra building space is b_a . The main issue, as according to Duranton *et al.* (2011) is that the firm expanding its building space has to reevaluate their property. Thus, BRs

increase proportionately with rent, so $r_{a(t+1)} = r_{a(t+1)}\delta$, where $\delta > 1$ is the premium to the existing BRs. Then, profit is:

$$\pi_{t+1}^2(i) = \pi_G(i) = (1 + \rho_i)(p - b_{at} - r_{at+1}\delta)$$

Alternatively, they consider the scenario where a firm may stay the same size. Then, profit is:

$$\pi_{t+1}^2(i) = \pi_S(i) = p - b_{at} - r_{a(t+1)}$$

Finally, a firm may incur relocation cost, m , and relocate where the unit rental cost of building equals to \bar{b} such that in equilibrium $\underline{b} < \bar{b} < b_{at} + r_{a(t+1)}\delta$. Then, the profit is:

$$\pi_{t+1}^2(i) = \pi_R(i) = (1 + \rho_i)(p - \underline{b}) - m$$

Then, the researchers define four thresholds: $\rho_{ED}, \rho_{DS}, \rho_{SG}, \rho_{GR}$ which correspond to cases where an establishment is indifferent between exit (π_E) and downsize (π_D), downsize (π_D) and stay put (π_S) and grow (π_G), and relocate (π_R). Thus, provided that the tax, $r_{a(t+1)}$, is not too high and relocation costs, m , are large enough:

$$-1 \leq \rho_{ED} < \rho_{DS} < \rho_{SG} < \rho_{GR}$$

They then discuss each of these scenarios. Given that firms cannot achieve higher returns by subletting and are stuck with their lease, they would be more likely to downsize than exit. They also show that $\frac{\partial \rho_{ED}(r_{a(t+1)})}{\partial r_{a(t+1)}} > 0$ meaning that higher tax in $t+1$ induces more exits. Thus, surviving establishments are those that experienced less negative shocks.

Next, they show that $\rho_{DS}(r_{a(t+1)}) = 0$. A small negative shock would result in more subletting. Whilst establishments that have a positive demand shock (but not large enough to offset the increase in BRs due to revaluation) would prefer to keep their original size instead of expanding, $\rho_{SG}(r_{a(t+1)}) > 0$ with $\frac{\partial \rho_{SG}(r_{a(t+1)})}{\partial r_{a(t+1)}} > 0$ meaning that higher tax would lead to lower employment growth.

Finally, establishments facing substantial positive demand shock would prefer to relocate because the higher tax would imply a more significant gain from relocation, $\frac{\partial \rho_{GR}(r_{a(t+1)})}{\partial r_{a(t+1)}} < 0$.

They assume a competitive land market for new establishments. Thus, firms would keep entering until profit would become zero: $E(\pi_{at}) = \pi_{at}^1 + E(\pi_{t+1}^2) = 0$ and b_{at} adjust

to ensure that it holds in all jurisdictions. From these assumptions come the full capitalisation in the long term because of the new contracts from new entrants and revisited contracts but taxes would not be capitalised in the short term. Thus, this theory removes Fraser's long-term perspective and replaces it with the medium run.

To sum up, for a small positive shock - retains original size, for an intermediate positive shock- it grows, for a sizeable positive shock- relocates. Therefore, they conclude that the tax rate affects the use of building space. They show that higher taxes lead to both a growth slow-down and a selection effect.

They acknowledge that enterprises are heterogeneous. Thus they capture time-varying establishment-specific variables and unobservable time-invariant establishment characteristics.

Estimation techniques used with empirical data is discussed with all empirical studies in Section 3.2. This model forms a basis of the framework, which is presented in Chapter 4.

2.1.5 Hilber's Theory Development

Duranton *et al.* (2011) provided an easy to understand but a simplified framework. For a more complex discussion, this thesis uses Hilber's (2017) review on property capitalisation. Although Hilber (2017) bases his theoretical discussion primarily on the residential property market, his discussion on housing demand price elasticity, local supply constraints and the extent of house price capitalisation may be applied to the commercial real estate market. Some of his insights are valuable and will be applied to the theoretical framework developed here. Hilber's study is on the forefront. There have been published just a few other British theoretical studies related to property tax incentives (Mehdi, 2003). As according to Mehdi (2003), these were mainly not contributing to the theory; rather they are designed for an empirical test. This is evident also with more recent literature, which is presented in the Empirical Review Chapter.

An extension of Brueckner's (1979, 1982 and 1983) framework, which is briefly discussed in Section 2.1.2 (p. 44) is proposed by Hilber (2017). He theorises about the case where spending on public services is below the level where it maximises aggregate housing stock. The willingness to pay for a rise in the expenses of local councils would be higher than the capitalised tax. Therefore, the increase in spending would overcapitalise into house prices. Likewise, he suggests that overspending on local public services would result in less than full capitalisation. Within his framework, total capitalisation of British

government support implies an adequate level of local authorities spending (Barrow and Rouse, 2004 and Hilber *et al.*, 2011).

This thesis further separates two directions from Hilber's reasoning. One further focuses on the UK literature on the supply and demand in the property market, whilst another reviews the adverse effects of the relief.

2.1.5.1.1 The Further Debate around Supply and Demand in the Property Market

Hilber (2017) highlights that researchers often make the explicit assumption of uniform capitalisation as in Duranton's *et al.* (2011) study (discussed above in Section 2.1.4.) This is also discussed by Capozza *et al.* (1996) in the tax subsidies context. Hilber (2017) argues that house price capitalisation estimates are unlikely to be a willingness to pay for amenities as in the benefit view introduced in Section 2.1.2 or fiscal variables when the long-run supply of land for development is quite elastic. He gives many examples of empirical studies assuming that demand for housing is perfectly elastic everywhere. This assumption implies that the elasticity of the long-run housing supply curve is, essentially, irrelevant. Whilst, another stream of the literature, as suggested by Hilber, separates underdeveloped land. They argue that local demand curves are generally downward sloping, but the supply of undeveloped land is similar across locations and inelastic. All previously discussed frameworks use one of these scenarios as well.

Hilber's (2017) discussion should have a few implications for local supply constraints for commercial property. He argues that it should depend on the degree of substitutability of locations, relocation costs and the preference of business owners. The latter is explained by Gibbons *et al.* (2012) who argue that some locations might be more desirable than others just because of some irrational preference of an owner. This is lacking in such economic frameworks as by Duranton *et al.* (2011) (Section 2.1.4) because it is often difficult to quantify those scenarios.

More specifically, they argue that a less elastic housing supply should lead to more substantial capitalisation. Departing from the literature on business rates, Hilber (2017) mentions many American empirical studies (e.g. Saiz, 2010 and Hilber and Robert-Nicoud, 2013) and one British study (Hilber and Vermeulen, 2016). The British study identifies the independent causal effects of three kinds of local supply constraints. They, in line with mainly US studies, show that more regulatory and physically constrained places have a more substantial degree of house price capitalisation because they have less elastic housing supply. Therefore, the magnitude of house price capitalisation is higher in locations that are constrained by either regulations or physical barriers to housing development. He

highlights a few scenarios, firstly, that desired areas may be fully build-up, so supply is inelastic. If it is not the case, he turns to the shape of the curve. In case of a linear curve, it would generate a positive association between the price inelasticity of supply and scarcity of developable land. Further, lobbying and voting may distort a supply curve (Hilber and Robert-Nicoud, 2013). As a product, desirable locations are likely to be more developed and, thus, more regulated, so supply is less elastic.

2.1.5.1.2 Welfare Economics

Finally, Hilber (2017) discusses the unintended effects of capitalisation. He starts by reminding that David Ricardo already in 1817 proposes that government policies may be capitalised into land values and could have unintended consequences. He does so by looking at the Corn Laws passed in England. He argues that taxing imports would increase wheat land. Therefore, benefits would fall into landowners.

Hilber (2011) argues that “Capitalization ... may also have important unintended redistributive consequences and other unintended effects: they may offset the positive incentive effects of certain policy measures.” (p.11). He explains findings from such residential studies as Hamilton (1976) and Wyckoff (1995), who have shown that government support might have adverse consequences to intended recipients. For instance, Wyckoff (1995) uses two-community and three-income model to show that in metropolitan areas with small towns the effect of intergovernmental aid on poor voters should be offset by higher residential housing costs. The other papers reviewed by Hilber (2017) support these conclusions. An important argument on unintended consequences is supplemented with the mechanisms of negative externalities introduced in Section 2.2.1. These are important because the government instead of enhancing small business performance may introduce some barriers for small businesses.

2.1.6 Implications for the Framework

Since 1950s various academics, especially in the US, have been attempting to quantify the tax incidence. This chapter discovered multiple issues with tax incidence and capitalisation. It seems evident that at least some part of the taxpayer’s money is likely to be handed to property owners through the relief. However, the extensive theoretical literature may not help to suggest the extent of the issue and the theories are often not suitable for the UK environment. Evans (1985) makes an important observation that theories developed for the US market do not necessarily apply to other countries. He notes that there are significantly more local authorities within the US and highlights greater

mobility in the US between local jurisdictions. Therefore, the fundamental assumptions or issues within models on capitalisation can be misleading if applied directly to the UK BRs.

As a starting point, this thesis takes the new view of the property capitalisation discussed in Section 2.1.2 and incorporates the extent of capitalisation. It extends this view with British ideas in Sections 2.1.3-2.1.5. The UK view is introduced by Fraser (1984). From this theory, some generalisations could be made. The new entrants have to sign new contracts. Older companies that are renewing their existing tenancy agreements are likely to take the scenario of overcapitalisation in the medium term. On the other hand, the firms that have existing contracts are not likely to be hit by the increase in rents in the short term. These observations are further extended with Duranton's *et al.* (2011) by looking at various scenarios with an aim to predict possible effects.

Very relevant to this thesis is Hilber's (2017) discussion. He maintains that there is no uniform capitalisation. This is supported by the empirical evidence in the Empirical Review Chapter. Local supply constraints for commercial property may impact the capitalisation. The amount of capitalisation should also depend on the degree of substitutability of locations, relocation costs and the preference of business owners. The latter is also evident in the dynamic capabilities theory (Section 2.2.2.3, p. 64). As a result, the thesis leans towards an approach that is capable of controlling for the extent of capitalisation in various areas. In fact, the thesis suggests controlling for these issues by employing indexes on competition as presented in the Framework with Hypotheses Chapter (Section 4.6).

Furthermore, although demand and supply are essential factors for tax incidence, it is difficult to find the right demand and substitution elasticities that should have an impact on the substitution and output (Section 2.1.1). To control for these, the framework proposed in this thesis, inspired by Duranton *et al.* (2011) mimics either a negative or positive shock in demand with different scenarios depending on the relief as well as controls for competition. Furthermore, the proposed framework explores several scenarios where the firm may be influenced to adjust its use of inputs when it chooses a new profit-maximising output level. As defined by Duranton *et al.* (2011) and described in Section 2.1.4, the firm may face five possible choices: exit, downsize, grow, stay put or relocate.

2.2 GOVERNMENTAL INTERVENTION

The previous part of this chapter showed that capitalisation is a substantial issue in property taxation. This issue, together with the lack of well-defined policy objectives, resulted in this thesis questioning why the government chose this instrument. Thus, this section aims to understand the primary reasons why the government chooses tax incentives instead of other alternatives, such as capital or labour subsidies. This is mainly done by looking at theoretical lenses as there are not many empirical papers directly related to either BRs or SBRR. Following the same pattern as in the first part of this chapter, the simplified models, based on the standard neoclassical assumptions, are initially presented (Section 2.2.1). Then, a discussion of theories based on those mechanisms is offered (Section 2.2.2). Empirical papers related to these theoretical frameworks are reviewed in Methodology Review Chapter (Sections 5.1.4, 5.2.3 and 5.3.2).

2.2.1 Fundamental Mechanisms in Standard Neoclassical Theory

This subsection starts with the underlying mechanisms used in the economics related to governmental intervention. It introduces Solow's technological progress and Romer's externalities and further looks at cross-price elasticities. These are essential to understanding the fundamental theories, mainly shaped by the neoclassical thought, that will be introduced in Section 2.2.2.

2.2.1.1 Solow's Exogenous Technological Progress

Romer (2004) defines properties of the growth accounting models in his book 'Advanced Macroeconomics.' These help to understand the relationship between taxation and growth of the company. To understand the key mechanisms, the most basic framework derived by Solow in 1956 is introduced. Solow's model is a pioneering study that leads to a large body of the literature. A more advanced version of the model introduced by Romer has also been well received. There have been numerous different extensions or modifications of the model (e.g. Jones, 1995; Grossman and Helpman, 1991; Aghion and Howitt, 1992).

The simplest version of the growth accounting framework is where Output, Y , to capital, K , and labour, L , is constant over time:

$$Y = f(K, L)$$

If SBRR is not fully capitalised into rents, and capital and labour are increased by ΔK and ΔL units, respectively, the law of marginal product of capital²⁰ illustrates how much output increases if capital is increased by one unit:

$$MPK = F(K + 1, L) - F(K, L)$$

$$MPL = F(K, L + 1) - F(K, L)$$

Combining both equations and if the production function has constant returns to scale (Euler's theorem) results to:

$$\begin{aligned} \Delta Y &= MPK * \Delta K + MPL * \Delta L \rightarrow \frac{\Delta Y}{Y} = \frac{MPK * K}{Y} * \frac{\Delta K}{K} + \frac{MPL * L}{Y} * \frac{\Delta L}{L} \rightarrow \frac{\Delta Y}{Y} \\ &= \beta \frac{\Delta K}{K} + (1 - \beta) \frac{\Delta L}{L} \end{aligned}$$

, where β is capital share and $1 - \beta$ is labour share

Solow (1956) develops a model including another factor, A , which corresponds to the effects of changing technology and often called total factor productivity (TFP):

$$\frac{\Delta Y}{Y} = \beta \frac{\Delta K}{K} + (1 - \beta) \frac{\Delta L}{L} + \frac{\Delta A}{A}$$

$\frac{\Delta A}{A}$ is the change in output that cannot be explained by changes in inputs. Therefore, total factor productivity is estimated as the amount of remaining output growth after accounting for the measured determinants of the growth:

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \beta \frac{\Delta K}{K} - (1 - \beta) \frac{\Delta L}{L}$$

Assuming that the technology takes Cobb-Douglas form:

$$Y(t) = AK(t)^\beta L^{1-\beta}$$

The alteration in the capital stock of the economy ($\dot{K} = \frac{dK}{dt}$) is assumed to be a difference between net investment and depreciation of capital stock, δ . If labour is fixed and the initial capital stock is K_0 , capital evolves as a function of investment:

$$\dot{K} = I - \delta K$$

Further, it is assumed that households choose the amount of total output they consume. Thus, the remainder might be used for consumption. Saving choices of the

²⁰ For the more extensive introduction of these concepts, see Appendix 10.3.1.1.

households suggest an aggregate investment of $I = sY$. If all variables are constant, the combination of the three previous equations result in the evolution of capital taking the following form:

$$\dot{K} = sAK(t)^\beta L^{1-\beta} - \delta K$$

The more prolonged growth of capital, the nearer the economy is to the steady state, K . The capital stock is described with depreciation and gross investment:

$$\dot{K} = 0 \rightarrow sA\left(\frac{L}{K^*}\right)^{1-\beta} = \delta$$

When taxation and later relief are introduced, there are further implications. To simplify equations, it is assumed that K and L are taxed at the same rate ψ which is already after SBRR. Therefore, the disposable income is reduced by $1 - \psi$. The new investment equation is:

$$I = sY \rightarrow I = s(1 - \psi)Y$$

The state uses tax revenue to provide a public good. This public good is assumed to have no direct effect. The previous assumption is followed that labour supply is fixed, so the tax does not affect labour but capital:

$$\dot{K} = s(1 - \psi)AK(t)^\beta L^{1-\beta} - \delta K$$

Implying that the steady-state ($\dot{K} = 0 \rightarrow sA\left(\frac{L}{K^*}\right)^{1-\beta} = \delta$) level reduces to:

$$s(1 - \psi)A\left(\frac{L}{K}\right)^{1-\beta} = \delta$$

Therefore, in this theoretical framework, growth is not affected by taxation and by relief in the long run, but taxation/SBRR has a level effect. Figure 2:6 (p. 58) explains the results. Although gross domestic product (GDP) per worker, Y/L , is likely to increase at a constant rate (straight line in Figure 2:6), the introduction of the SBRR may lead to a reduction of a tax, thus increasing GDP per worker.

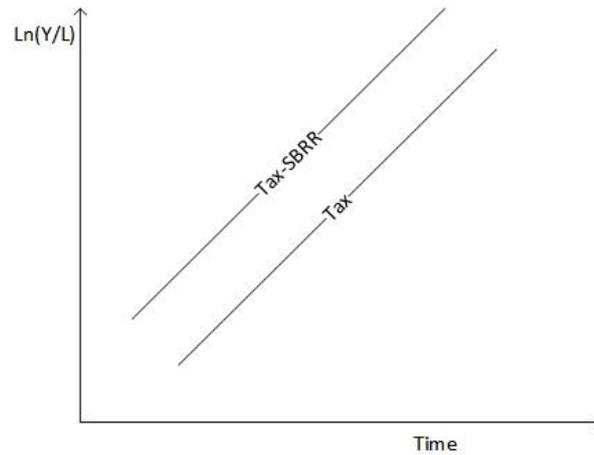


Figure 2:6 Growth and level effects in the Solow's growth accounting model applied to the SBRR case. The model implies that SBRR is associated with increased GDP per worker. Source: author's interpretation.

2.2.1.2 Romer's Externalities

In 1986, Romer introduced his model. He includes, unlike Solow, the external effect of capital. In his framework, capital is believed to include the knowledge required to run the production unit. In Solow's model, it is just the physical production unit.

Therefore, the increase in capital does not only increase capital stock, but also knowledge of this firm and economy. Given that $K = \sum k$, this idea can be captured as:

$$Y(t) = Ak^{\beta}l^{1-\beta}f\left(\sum k\right)$$

Each firm has their effect on the capital stock on their knowledge. Therefore, the externality $f(\sum k)$ is considered as exogenous and treated just like TFP (or A). Production is characterised by constant returns to scale as well as the fact that firms are likely to continue producing under perfect competition. Then, the economy-wide production function is:

$$Y(t) = AK^{\beta}L^{1-\beta}f(K)$$

The model can be finalised by using the general equation, $\dot{K} = sY - \delta K$. To simplify the model, a fundamental expression for externality is assumed, $f(K) = K^{\alpha}$, where $\alpha > 0$. This results in:

$$\dot{K} = sAK^{\alpha+\beta}L^{1-\beta} - \delta K$$

The higher the externality α , the greater the growth rate. When $\alpha = 1 - \beta$, the growth rate is constant. This is an assumption taken by Solow's model, which is why the

resultant suggestion is that no convergence takes place. Another difference from Solow's model is the endogeneity of the growth rate. Despite constant TFP and the size of the population, the capital stock is likely to grow in the long term, but only if externality is sufficiently large. Higher saving rates could be caused by the SBRR and would imply a higher growth rate.

Once the same taxes are introduced in Solow's model, the equation for capital accumulation becomes:

$$\dot{K} = s(1 - \psi)AK(t)^{\beta+\alpha}L^{1-\beta} - \delta K$$

The higher the parameter β would result in a higher growth rate. The growth rate for an economy where $\alpha = 1 - \beta$ becomes:

$$g = s(1 - \psi)AL^{1-\beta} - \delta$$

Thus, this framework accompanies Hilber's view, introduced in Section 2.1.5.1.2, that not only positive, but also negative externalities are lowering α . It suggests that the economy with lower taxes grows faster. Thus, the introduction of a greater multiplier for larger and potentially more productive firms, as carried out to cover the expense of SBRR²¹, might reduce the overall growth.

2.2.1.3 The Cross-price Elasticity of Demand

Previous sections introduced the fundamental mechanisms of how externalities arise. Building on these models, the cross-price elasticity of demand is explained. In a similar way to the price elasticity of demand introduced in Section 2.1.1.1.1, a graphical explanation is provided in Figure 2:7. In this case, the scenario of domestic firms receiving subsidies and gaining competitive advantage in their domestic market, clarifies the cross-price elasticity. Given the standard assumptions on competitive markets, a standard theory advises that possibly less efficient smaller firms may take a share of possibly more efficient larger businesses. Those smaller supported firms may bring less macro benefits to the society.

Figure 2:7 illustrates these relationships. Before SBRR, small firms supplied $Q1$, and large firms supplied $Q3-Q1$. Now, at the price of P , recipients of SBRR trade $Q2$, meaning large firms can sell only $Q3-Q2$ assuming fixed demand. Therefore, it is possible that more efficient, and larger firms suffer at the expense of potentially less efficient smaller firms. The triangle, DWL, represents the deadweight loss to society because possibly more

²¹ Wales do not operate separate multipliers for small and large businesses, see Section 1.4.3 (Introduction and Background Chapter) for more details.

efficient producers are disadvantaged. It shows the over-allocation of resources by small producers owing to governmental intervention. Consumers still pay the same price (P) but the taxpayer's money is used for the relief, so the taxpayer pays more for the goods. Furthermore, non-subsidised firms partly finance the subsidies through taxation (Bergstrom, 2000) and it is possible that they experience negative general equilibrium effects such as an increase in the price of capital (Bronzini and de Blasio, 2006). In addition to this, low ability entrepreneurs might reduce economic growth as they might be less productive and earn lower salaries. These low skilled entrepreneurs might also take the place of more productive entrepreneurs or even cause the entry of even more low-ability entrepreneurs (Ghatak *et al.*, 2007:2).

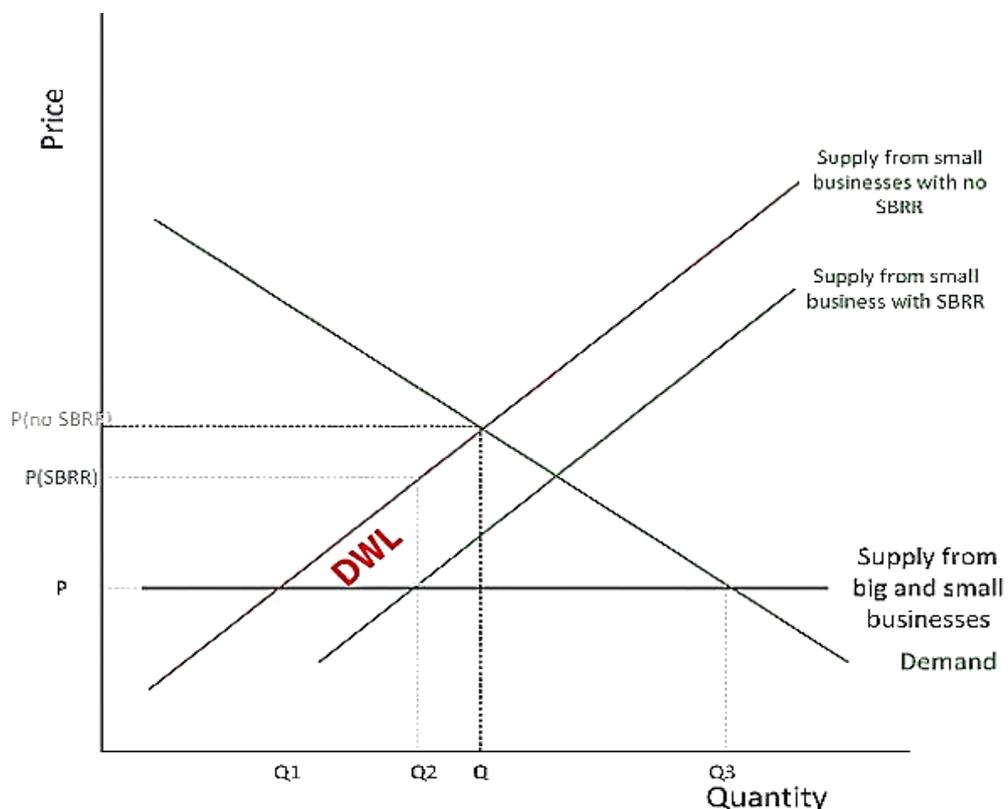


Figure 2:7 Cross price elasticity of demand and Deadweight Loss (DWL). Based on Parkin (2016) and Glenn (2013).

2.2.1.3.1 Deadweight Loss (DWL)

The previous section, 2.2.1.3, showed the importance of the deadweight loss. It is often called a Harberger triangle, in honour of Arnold Harberger, who used similar triangles to measure such inefficiencies as in distortionary taxation. The line between Q_1 and Q in Figure 2:7 (p. 60) is noted as Q_1Q and is the change of quantity as a result of the SBRR.

Elasticity of the demand is the percentage change in quantity because of a 1% change in price, thus:

$$EL_D = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta p}{p}},$$

where ΔQ is the change in quantity and Δp is the change in price.

Rearranging this equation results in:

$$\Delta Q = \frac{\Delta p}{p} Q EL_D$$

Thus, the higher the change in price, the larger the elasticity of demand. However, the change in price is only per unit of SBRR:

$$Q_1 Q = \frac{\Delta p}{p} Q EL_D$$

As a result, all area under DWL in Figure 2:7 (p. 60) is:

$$\frac{SBRR * Q_1 Q}{2} = \frac{1}{2} * SBRR^2 p EL_D,$$

where SBRR is assumed to be the relief rate, the ratio of the tax to the price.

Thus, the size of DWL depends on the SBRR amount and the elasticity of the compensated demand curve, EL_D . SBRR is likely to introduce the DWL to the society, limiting its effectiveness and, therefore, limiting effects on business performance. Unfortunately, the effect is difficult to estimate and may not be isolated in the framework. However, the elasticity of demand is highly affected by various factors. These are discussed in the Framework with Hypotheses Chapter (Section 4.6) and controlled for in the analysis.

2.2.2 Theories Based on Neoclassical Economics

Previous sections uncovered the underlying mechanisms in neoclassical theories around governmental intervention so that it would be easier to discuss the theories based on these mechanisms. Fraser²² (1984:359) together with other neoclassical economists, divide governmental intervention to the property market into four areas: planning control, rent control, tax shelter and land taxation. The latter has often been used by governments to help small businesses (Wolkoff, 1985; Baldock, 1998). Taxes on land and property are

²² His contribution to the literature is highlighted in Section 2.1.3.

particularly attractive owing to relatively easy administration and a rough approximation of ability to pay principle.

In line with the official releases (the Green Book of HM Treasury, 2013) inspired by mainly neoclassical economists such as Stiglitz and Rosengard (2015), this chapter discusses SBRR as any other governmental intervention. They are usually justified either by market failure (Section 2.2.2.1) or equity (Section 2.2.2.2) considerations. The former defines the situation where the unregulated market fails to deliver a Pareto efficient market. The efficiency in the market is perceptible when nobody can be made better off without somebody being worse off. The Green Book (HM Treasury, 2013) adds that the intervention may incur costs and economic distortions. These should be taken in account to assess whether intervention is desirable.

2.2.2.1 Market failure

It is unlikely that the primary aim of the government is to reduce market failure with SBRR. In fact, it seems that SBRR enhances some situations when markets fail. The Green Book of HM Treasury (2013) defines four situations where markets fail: externalities, goods have characteristics of public goods, imperfect information and monopolies. It is important to mention that, as the previously simplified model in Section 2.2.1 (p. 55) showed, the researchers, inspired by such neoclassical economists as Solow, take slightly idealistic assumptions that were introduced in almost every step of the model.

However, the policy might introduce at least some positive externalities. The mechanism as to how they arise is shown in Section 2.2.1.2. Myles (1995:313) defines them as “real variables whose values are chosen by others without particular attention to the effect upon the welfare of the other agents they affect.” In the SBRR context, following Duranton’s *et al.* (2011) specification introduced in Section 2.1.4 and assuming a positive shock in demand and marginal moving costs. An example of positive externality may be an increase in investment in productivity since firms are unlikely to expand concerning employment due to increased costs connected to the loss of relief applied in the previous year. In fact, De Long and Summers (1991) show that investment in equipment should increase the growth of a firm. In 1998, Keuschingg formalises this idea with his equilibrium model, which includes monopolistic competition, product differentiation and free entry. The level of capital accumulation is less than the optimum level because agents take the investment level of competing agents before making investments. Increased investment from all agents should increase welfare in terms of costs and efficiency assuming a competitive market, whereas in an imperfect market, it would create a possible reduction in mark up. Therefore, it would be unprofitable to make the marginal investment. For this

externality to arise, SBRR should be creating new jobs and products. However, it may be arguable whether SBRR is sufficiently large. Even if it is large enough, it is uncertain whether firms would buy capital from the money received. This discussion will be further extended in Section 2.2.2.3 and approached in the Framework.

On the other hand, as the mechanisms show, some negative externalities may also arise. One of the negative externalities is approached in the entrepreneurship literature. Increased capital may enhance Schumpeterian innovative companies that would improve the market with their new ideas. As Schumpeterian pioneering creative destruction suggests (Schumpeter, 1908 and 1939), adaptation to market fluctuations makes the crucial difference between firms that fail and those which survive. The economic rationale in support of the entrepreneurial role of business entry is that new entrants should displace obsolescent and less efficient companies in the process of creative destruction. The ability to adapt to market may increase the chances of survival. Unfortunately, governmental support may reduce the need for adapting to the market fluctuations. This may impede the Schumpeterian creative destruction and enhance the dynamic inefficiency. For instance, Lee (1996) and Harris and Trainor (2005) show that targeting some underperforming firms might make supported firms over-reliant on subsidies, causing a failure in reorganising their activities and improving their performances to the same extent as other companies facing the same competitive market pressures. This relief could be explained by Bergstrom (2000), who state that policy-makers may be focused on maximising political objectives rather than economic efficiency. Moffat (2015) extends the explanation of this problem, suggesting that prolonging the life of plants that are about to close may increase dynamic inefficiency.

In addition to externalities, one of the reasons for failure may be monopolies. In line with the previously described mechanisms around externalities, monopolies would make higher profits at the expense of a loss of allocative efficiency (see Romer, 2012). This would result in higher prices to users and, thus, underconsumed products. SBRR may help to reduce the likelihood of monopolies by lowering start-up and maintenance costs (Felsenstein *et al.*, 1998) and, hence, by enhancing more small firms to enter the market. When markets are complete, firms should be able to borrow the money they need at the interest rate decided by the lender. In a less idealistic world, small companies may be incapable of securing loans from a private sector as they may be considered too risky or their outgoings may be too high. Therefore, the relief may reduce the costs of small business and make them more creditworthy, resulting in the further development and enhanced market efficiency. However, it is worth noting that the government, amongst other support

incentives discussed in Section 1.5 (Introduction and Background Chapter), also provides subsidised loans for businesses through the Enterprise Finance Guarantee which should be more effective in reducing incomplete markets.

2.2.2.2 Equity

In a similar vein, governmental intervention may be justified by equity considerations (the Green Book of HM Treasury, 2013). One of the ways to measure tax equity is the ability-to-pay principle (Pigou, 1906). As defined in Appendix 10.2.1 (p. 267), this states that people should pay taxes in proportion to their ability to pay. However, this might be difficult to measure owing to the heterogeneity of firms. As discussed with other empirical literature in the Empirical Review Chapter, the overall conclusion of official studies such as the Department of Environment (1987 and 1995) is that BRs do not burden businesses. The recent evidence on SBRR (Peck *et al.*, 2014) points out that only a handful of businesses owning small properties complain about the high BRs.

However, it is worth noting that distributional effects discussed in Section 2.1.5 show that vulnerable firms may have even more difficulties when their property receives the relief, (as pointed by Hilber, 2017) in case of overcapitalisation or other negative externalities. By trying to consider their ability to pay, the government may force them to move elsewhere because landlords would increase the rents and they may be unable to sustain their businesses. Also, as according to the mechanisms in Section 2.2.1.3, firms that may be unable to pay the market rate may take the market share from more efficient firms. Furthermore, others argue that targeting some underperforming firms might make supported firms over-reliant on subsidies (Lee, 1996 and Harris and Trainor, 2005) thus their ability to pay would get only reduce over time.

2.2.2.3 Alternatives to Economic Theory (Dynamic Capabilities)

One of the alternatives to the standard theory limited by typical neoclassical assumptions comes from the strategic management literature suggesting a different way to support small businesses. The primary approach to strategic management in the 1980s was Porter's (1980) competitive forces focusing on the defensive position of firms against competitive forces. Later, Shapiro (1989) extends this by looking at market imperfections, entry deterrence and strategic interactions. On the side of this, others (Penrose, 1959; Rumelt, 1984; Teece *et al.*, 1995) have introduced resource-based perspective, claiming that the firm's capabilities, assets, and mechanisms create competitive advantage.

A new stream of the literature has emerged starting with Teece (Teece and Pisano, 1994; TEECE *et al.*, 2008; Teece, 2014). It is defined by Helfat *et al.* (2007:4) as "the capacity

of an organisation to purposefully create, extend, or modify its resource base.” The main idea of this stream of the literature is that many firms operate in dynamic environments where entrepreneurship, technological innovation and global competition are likely to occur (Schreyögg and Sydow, 2010). To overcome this environment, firms develop dynamic capabilities. Strategic management is studied to explain how firms evolve in changing environments and how they sustain a competitive advantage. Researchers often take Teece’s *et al.* (1997) view that dynamic capabilities comprise of the following routines: sensing, coordinating, learning, integrating, and reconfiguring. The alternative is proposed by Eisenhardt and Martin (2000), who argue that dynamic capabilities are “best practice” across the industry. This will be not considered in this thesis as it is unlikely that SBRR could have any influence on the best practice within the industry as it is given irrespective of the industry involved.

Many academics have published various literature reviews on dynamic capabilities that form a basis for this discussion. Wang and Ahmed (2007) provide an overview of general dynamic capabilities theory. Inan and Bititci (2015) focus on the context of micro enterprises. Wilson and Kevill (2017) look at dynamic capabilities theory from the rural microenterprise perspective. Using literature from these and other reviews, the following paragraphs discuss organisational and dynamic capabilities.

The primary definition of organisational capabilities is a capacity to organise its resources, intangible or tangible, to complete an activity or task to improve performance (Grant, 1991; Amit and Schoemaker, 1993; Teece and Pisano, 1994; Helfat and Peteraf, 2003). Operational capabilities literature contains an array of management tools and practices which are applied at larger firms and adapted to SMEs, such as customer relationships management (CRM), Just-In-Time (JIT), total quality management (TQM), continuous improvement (CI), lean production (LP) and totally productive management (TPM).

However, these theories may differ for the micro firms (Devins *et al.*, 2005; Kelliher and Reinl, 2009; Matlay, 1999) or businesses in rural areas (Wilson and Kevill, 2017) that are expected to be the greatest proportion of SBRR recipients. Due to their size and resources, the firms may be incapable of implementing previously mentioned practices. Teece (2014) guides that organisational routines are at the heart of dynamic capabilities. However, when focusing on small enterprises, the standard framework (Teece *et al.*, 1997; Teece, 2007) may not be applicable because in such a setting, decisions are often not taken by the group of managers but by owners (Blackburn *et al.*, 2013). The attitude of the owners should have a far greater impact on the firm’s performance than for the larger organisations

(Faherty and Stephens, 2016). A study by Jayawarna *et al.* (2014:282) shows that there are two ways to increased entrepreneurship. One results from a lack of job opportunities or insufficient skills to secure a job. Arguably, these individuals would not always be capable of improving their operational capabilities.

ONS (2013) estimates that over 85% of UK land is considered to be rural (ONS, 2013). It is important to consider this because rural commercial buildings tend to have lower values, thus are more likely to receive the reliefs. Wilson and Kevill (2017) suggest that rural entrepreneurs face more challenges than their urban counterparts. These comprise, but are not limited to, poor access to broadband, weak transport infrastructure, lengthy commuting for workers, a lack of specialist access to finance and business support (Galloway, 2007; Steinerowski and Steinerowska-Streb, 2012; Warren-Smith, 2014). It is reasonable to question whether unqualified entrepreneurs experiencing so many barriers would be capable of employing its resources, intangible or tangible, to perform an activity or task to enhance performance.

On the other hand, Wilson and Kevill (2017) speculate that firms would be investing the money from the relief in developing dynamic capabilities even in the rural economy. They argue that it is profitable for companies to invest in dynamic capabilities. This seems to complement the theory for larger organisations driven by competition, globalisation and technological development (Helfat and Peteraf, 2009). Thus, firms receiving SBRR would be likely to increase their investment to gain a competitive advantage.

From the discussion above, it is evident that management is a key within the small firm. The general theory would imply that government should directly help to enhance their dynamic capabilities, for example, by supporting broadband or infrastructure projects instead of SBRR. The direct capital gained through the relief could help to overcome liquidity constraints but not increase the dynamic capabilities because building and land are generic rather than a source of dynamic capabilities. However, it may be a resource that businesses command - so dynamic capability may lead them to use their space more efficiently by enhancing productivity. Even though this may be the case, due to the high likelihood of SBRR capitalisation into rents, programmes such as innovation grant schemes would be more beneficial. More specifically, in the context of micro firms, it seems evident that the primary focus should be on the decision maker, therefore a business owner. Then, incentives to undergo training would be a slightly better way to enhance dynamic capabilities within a small firm.

2.2.3 Implications for the Framework

Governments can introduce shocks and distortions to the flat tax through the introduction of loosely targeted reductions, like SBRR. The SBRR²³, depending on the nation and period, reduces the tax obligation in either steps by a given per cent or by setting a maximum tax reduction, which then tapers linearly. For example, in England, for the period 2010-17 the 100% threshold was up to £6,000 rateable value, after which it tapered to zero at £12,000. All these frictions may reduce the proportion and increase the time over which shocks capitalise, consequently creating a period in which SBRR could influence productivity and survival decisions.

More broadly, the macro economic models suggest that SBRR should not impact the economy as it just redistributes the tax. However, they also advise that market share may be taken by potentially less efficient firms receiving SBRR at least in the short term. This section also explained the most fundamental reasons why government would want to support businesses occupying small premises. These are mainly related to the market failure, equity and externalities introduced either by the tax or the relief. If there were some negative externalities introduced by BRs, these would hopefully be offset by the positive externalities from SBRR, but it is unlikely because of mistargeting.

The discussion revealed that SBRR might not be an ideal way to achieve the government's aim "to target help at genuinely small businesses" (Scottish Executive, 2004:1)²⁴. It is apparent that some aspects of the possible market failure may be reduced by the relief, such as monopolies or negative externalities. It is unclear whether this relief addresses the ability-to-pay principle or supports underperforming firms. Although evidence has shown that small firms contribute to employment, GDP and wealth (Section 4.7.2), the standard economic theory suggests that by targeting small businesses without any rationale, the government might further reduce market efficiency (Section 2.2.2). It seems apparent that alternative support incentives could provide better value to the UK government (Section 2.2.2.3).

The macro economic literature in this section helps to further enhance the framework in several directions. It asks to extend the debate introduced in the previous

²³ The Scottish systems does not taper, but has specific, more generous and increasing reliefs within bands. Wales used a simpler framework before 2010 when it aligned with the English SBRR. In England between 2005 and 2010 the relief was 50% for firms with rateable values below £5,000, tapering to zero by £10,000. See the Introduction and Background Chapter (Section 1.4.3) for more detail.

²⁴ This aim was not included in the policy papers but written in a booklet describing SBRR published by Scottish Executive (2004:1).

section on demand. Markets operate together, so both recipients and non-recipients are inter-related and can be affected by the SBRR. The distributional effects discussed in Section 10.1 show that vulnerable firms may have even more difficulties when their property receives the relief, as pointed by Hilber (2017) in case of overcapitalisation or other negative externalities. These mechanisms are introduced in Section 2.2.1.2. By considering their ability to pay and providing relief, the government may push landlords to increase rents. However, in the short term, the market is unlikely to be fully competitive.

Thus, Section 2.2 has not merely explored the primary reasons why the government may consider supporting small firms with tax reliefs, but also further strengthened the framework by suggesting possible scenarios during short, medium and long terms that were adopted in the Framework.

3 EMPIRICAL REVIEW

This chapter aims to uncover the previous research on UK business rates (BRs) and, more specifically, Small Business Rates Relief (SBRR). The overall aim of this thesis is to understand whether SBRR has any effect on firms, in particular with regards to their productivity and survival. Total factor productivity (TFP) is the portion of output not explained by the amount of inputs used in production. Whilst, survival analysis in this setting is a method for analysing the expected duration of time until closure. As illustrated in Figure 3:1, this section extends the theoretical debate on capitalisation produced in the Theory Review Chapter (Section 2.1) by summarising empirical evidence on UK BRs. The chapter starts with the methodology of the literature review (Section 3.1). It then argues that studies with more advanced approaches tended to lean towards full capitalisation in the long term (Section 3.2). However, the chapter also uncovers several research projects which found partial or no capitalisation (Section 3.3). These were, however, mainly either cross-sectional or qualitative studies. Finally, the chapter concludes with the key implications for the framework (Section 3.4).



Figure 3:1 Overview of the Empirical Review Chapter.

3.1 METHODOLOGY OF EMPIRICAL LITERATURE REVIEW

This empirical literature review adopted some features of a systematic literature review (SLR) method. SLR is known to be 'a detailed technology, that aims to minimise bias through exhaustive literature searches of published and unpublished studies and by providing an audit trail of the reviewer's decisions, procedures and conclusions' (Tranfield *et al.*, 2003:209). The SLR methodology has been discussed in detail in the previous literature (see Tranfield *et al.*, 2003; Pittaway *et al.*, 2004; Denyer and Neely, 2004; Denyer and Tranfield, 2008). However, many limitations, such as missing articles with poorly

written abstracts are found (Pittaway *et al.*, 2004). Therefore, it was reasonable to follow Rashman *et al.* (2009) and regard SLR as a guide rather than a strict methodology. As a result, the goal was to achieve the SLR as being 'replicable, scientific and transparent' (Tranfield *et al.*, 2003:209), but the emphasis was not on the quantitative analysis of articles. The aim was to provide conceptual clarity by reviewing theoretical frameworks, empirical findings and methodologies and identifying the areas lacking investigation. In this sense, the approach built on other literature reviews (such as Chandler and Lyon, 2001 and Ferreira *et al.*, 2015) with greater critical analysis of the literature, and also recorded its searches including citations and co-citations. This methodology also enabled the implementation of varying approaches for different sections. This methodology should increase transparency and validity of the sources of material and their evaluation.

Before conducting a study, it is necessary to be aware of what has been already discovered in the discipline's body of knowledge (Hart, 1998; Levy and Ellis, 2006). Initially, the literature review focused on the other literature reviews in the field. Several broad Business Source Premier searches were performed with such keywords as capitalisation, non-domestic property taxation, commercial property taxation, governmental intervention and subsidy. The search was limited to peer-reviewed articles owing to their representation of validated knowledge and high impact (Podsakoff *et al.*, 2005).

Two other approaches were then applied to this literature review. To review the significant papers on the theoretical development of debates on capitalisation (Section 2.1, p. 37) and governmental intervention (Section 2.2, p. 55), a traditional approach, built on already established books or book chapters on urban economics, labour economics and econometrics was adopted. It reviewed the citations and co-citations with the central papers within the field. These were continuously supplemented with various searches in both EBSCO Business Source Premier and Science Direct.

Only several empirical articles on BRs were identified. A search in EBSCO of the term "business rates" was conducted on 2nd August 2017. The search was limited to peer-review articles. Only 15 peer-reviewed articles were found on this topic, and just eight of them were in one way or another related to this study. These were supplemented with other empirical articles co-citing these, all of which were analysed in NVivo.

3.2 FULL CAPITALISATION

In the same vein to the standard literature on capitalisation as discussed in Section 10.1, the vast majority of scholars looking at BRs found full or close to full capitalisation, meaning that the property owners would, in fact, receive the relief. In hand with their findings, this section uncovers the methods used and the issues they encountered.

A substantial British contribution comes from Bond *et al.* (1996). They investigate the effects of changes to BRs on a sample of some 2,964 institutionally-owned commercial properties in Wales and England from 1987 to 1992. Their BRs are measured with data from Investment Property Databank and Valuation Office Agency. In their theoretical setting, they mainly used the mechanisms of demand and supply elasticities discussed in Section 2.1.1.1.1 and provide similar reasoning to Fraser's (Section 2.1.3). Their theoretical framework suggests that some part of BRs will be lifted to the property owners. They argue that the demand for non-domestic properties would be sensitive to price. Whilst, the supply is not likely to be elastic. Their empirical part of the paper estimates this amount.

Their dependent variable is rental values, and independent variables are once and twice lagged BRs. They control for unemployment rates, vacancy rates and year effects, disregarding industrial and office properties since their approach does not provide satisfactory results. They use ordinary least squares (OLS) with instrumental variables (as described in Appendix 4.6) for 1726 retail properties. The instruments are current values of the local economic variables and lagged values of the property-specific variables dated $t-2$ and earlier. This instrumental variable estimation method does not make use of all the available moments conditions (instruments) and does not take into account the differenced structure on the residual disturbance. Their results imply that a £1 increase in BRs bills could decrease property rents by as much as £1 in the long term. In some areas (such as London and the south-east), the authors indicate that the point estimate of this effect is greater than £1, but cannot be estimated precisely. In the short term, they agree that capitalisation exists, 85% in London, 67% in the south-east and 45% in other places. The researchers do not report whether their data satisfied OLS assumptions and ignore such issues as simultaneity as discussed in the Research Design Chapter (Section 6.3.1.1.1).

Later, Mehdi (2003) publishes his PhD thesis on the capitalisation of BRs. He provides a literature review and theories around capitalisation existing before 2003. According to these, he forms the main hypothesis 'that property values will gradually adjust so that total occupation costs between matched pairs of properties will be equalised over time.' (p. 2) To test this hypothesis, he collects data for business properties in six London

boroughs. He considers two properties in close proximity which should provide equal attraction to prospective occupiers, despite being located in different boroughs. The main approach in this thesis is experimental, with matched pairs during two periods, 1973 and 1988 and then once uniform taxation was introduced between 1988 and-1998. He matches properties according to size, location, physical characteristics, building and planning use and technical criteria such as service charge. For the primary analysis 35, 21 and 21 pairs are used and for the secondary, 85, 87 and 32 pairs of industrial, retail and office premises are used. Additionally, for the primary analysis, he uses t-tests and descriptive statistics, while for the secondary data, he uses the internal rate of return. The overall conclusion of the thesis is that the hypothesis is confirmed. The property tax is fully capitalised into property values for all property types. His primary approach using cross-sectional data has a relatively small sample size and instead of real rents, it exploits rateable values. This may not be the best choice owing to infrequent, and at that time, decentralised valuations.

In 2013, Bond *et al.* inspired by the new enterprise zones announced in 2011, conduct a further study with the British data. One of the main features of these zones is the relief of BRs. Bond *et al.* (2013) adopt a hedonic regression approach. Although their approach is very similar to McDonald (1993) and Wheaton's (1984), Bond's *et al.* (2013) study introduces two significant changes. The tax rate can deviate from year to year, and the data covers a broad range of time periods. They suggest that a significant amount of tax savings is captured in more substantial rents charged by property owners. Their dependent variable is rental payment per leased area deflated by a retail price index. They also construct the independent variable by estimating their possible BRs bill per m². They use OLS to estimate their model. They find the BRs variable significant with 2214 observations. However, once the focus is moved to the leases originating during the enterprise zones (1990-1993), the incidence reduces from 0.82 ($p=0.09$) to 0.59 ($p=0.9$).

The researchers do not report whether their data satisfies OLS assumptions. This is concerning given endogeneity issues as discussed in Appendix 4.6. Unfortunately, neither do the authors acknowledge selection issues, which are discussed in a series of papers by Rubin (1977) and the Research Design Chapter (Section 6.3.1.1.2). They seem to limit the lease term to between 12 months and 360 months, which while seeming reasonable, is not necessary valid exclusion criteria since leases may be longer than three years. The authors suggest that the average capitalisation effects should be close to 100%, so all tax incentives from the enterprise zones are received by the property owners. Other scholars looking at enterprise zones find them having a positive impact on employment (Billings, 2009;

Hanson, 2009) but reducing employment in surrounding areas (Bondonio and Engberg, 2000).

A few more recently published studies are in line with Oates' (1969) methodology. For instance, Hilber *et al.* (2011) assess the impact of central government grants on local house prices in England by using a panel dataset of 350 local councils between 2001 and 2008. They produce a macro model and estimate it with fixed effects and instrumenting. The outcome variable in the regressions is a local house price index based on data from the Land Registry. Here the main criticism around the methodology is likely to be with regard to their instruments. They do not report testing whether random or fixed effect estimator is more efficient, for instance, with Hausman test. They maintain that the Labour party may have used the grant system to allocate more money to areas where it dominates the local council even by a narrow margin. Such variables as region-year fixed effects, the labour share of seats and authority type year fixed effects may contribute to productivity and income shocks may be questionable. A counter argument may be the recently published data on UK government debt by Office for Budget Responsibility (2017). They found that actual government debt increased significantly under the Conservative ruling. The finding suggests that government grants are fully capitalised into the residential property values. Also, they acknowledge "that the British grant system has substantial unintended consequences in that it generates a massive redistribution of resources without helping the most disadvantaged individuals as well as the less fortunate in the most disadvantaged places." (p.404) Therefore, they support Hilber's (2017) previously discussed view on unintended consequences in Section 2.1.5.1.2 (p. 53).

Similar to these studies, a vast amount of literature (Heinberg and Oates, 1970; Church, 1974; McDougal, 1976; Reinhard, 1981; Richardson and Thalheimer, 1981; Johnson and Lea, 1982; Yinger *et al.*, 1988; Palmon and Smith, 1998; Barrow and Rouse 2004; Hilber and Mayer, 2009) have reported full (or over) capitalisation. However, these are mainly American studies focused on the residential market. Also, they have generally used either OLS or 2SLS, assumed incorrect functional form, and ignored simultaneity. These, and other issues, especially in the research before 2000, are discussed by Yinger *et al.* (1998). For instance, Reinhard (1981) replicates Oates' (1969 and 1973) studies and chooses a more appropriate functional form. Assuming a 3% discount rate, he implies that the capitalisation is 107% (Oates' estimation is around 61%).

3.3 LESS THAN FULL CAPITALISATION

Studies that use macro modelling tend to find partial capitalisation. For instance, the Department of Environment (DOE) (1987 and 1995) analyse annual monitoring data provided by the DOE and survey 1,000 businesses to find some 40%-50% of the benefits of the rate relief goes to occupiers, with the rest being eroded by incorporation into rents. The methodology might be questionable because they do not account for property prices varying depending on the location, infrastructure and other factors. It may be arbitrary to compare one property to another even if this is taken into account. Later, Bennet (2000) concludes that capital allowances on investment in buildings in enterprise zones resulted in a rise in the rate of return to investors of 7.7-8.7% relative to the base case.

More recently, Regeneris Consulting (2015) explores the evidence on the economic effects of non-domestic rates with aggregate data between 1990 and 2014. They choose only core cities and London markets. They stratify their sample according to the location and type of property (office, retail and warehouse). Only data for the top 50 properties with the highest rateable value for each class, core city and rateable value per year is extracted. They report that to obtain significant results they have to experiment. They replicate Bond *et al.* (1996), which is discussed in Section 3.1. They support Bond *et al.* (1996) with their initial findings with OLS. They find negative coefficients between rents and rates only in the retail sector for Year 2 and three times lagged values. As shown in the dynamic panel data model, Section 4.6 (p. 89) this approach is biased. Unfortunately, they do not test whether they should choose a fixed and random effect model but decide to implement generalised least squares (GLS) estimator. They find statistically significant results only for a subset of the office property sector. It is evident that sampling and the use of techniques are central limitations of this study and results may be biased.

There have been two published studies which directly focus on SBRR. Pidea Consulting (2004) surveys 30 Scottish businesses. They acknowledge that capitalisation may persist and reliefs may be shifted to increased rents. They point out that at least 10% relief (from £300 per annum to £650) may have an impact on a firm, while 5% (from £30 per annum to £200) is too low to contribute to the firm's performance. It is worth noting that just 16 (out of 30) firms were aware of SBRR. Also, the authors show that BRs are not a substantial issue for larger businesses, but a lesser one. However, there are some inherent limitations. It does question businesses directly about the contribution of the extra income and whether it is needed. It would be irrational for a business which receives 50% off their

bill to claim that SBRR is unnecessary. Moreover, they do not consider long-term capitalisation.

Furthermore, qualitative studies tend to disregard capitalisation and question business owners directly. One of the most recent studies directly applicable to SBRR is by Peck *et al.* (2014) who consider Wales. The study takes a qualitative methodology and provides valuable insights into small businesses. Their 2010 study primarily looks at the business perception of the impact of rates relief, generating 391 survey responses from Welsh firms. They also conduct five in-depth interviews across 15 businesses. The authors find that over a third of the micro firms (0-2 employees) on average spend over 10% of their turnover on BRs, while the mean is 18% across all categories. A further critical question surrounds business survival. As Figure 3:2 (p. 76) suggests, the smallest businesses tend to find SBRR contributing to their survival more than larger firms. However, on average, 80% of all businesses conclude that SBRR has been a significant factor in their survival over the last year.

The authors also report responses to the open questions. According to the replies provided in the paper, respondents are positive about the relief. They acknowledge that multiple owners find SBRR to be vital to their businesses' survival: "In the last 12 months it has been crucial for us to remain in business." (p.995). Similarly, many commented on their ability to retain more employees. Furthermore, authors report that the relief has a positive psychological impact: "government is thinking about us" and helps in competition with bigger firms: "It is very important and helps where larger competitors can bully you out of business, anything to keep the smaller independent trader going is a good thing."

It seems evident that reliefs are not so vital for some businesses. Therefore, Peck *et al.* (2014) ask for better targeting. Also, the relief, according to the author, is often seen as a reminder that the tax rate is high: "Rate relief helps but the basic business rate has gone up enormously for the business. The system is flawed. Small businesses are being overtaxed and high BRs do not help the local economy."

It is an important study because it takes and identifies the perspective of business owners. However, the businesses are only observed once, it is unknown who is replying on behalf of the company, and authors do not provide any statistical analysis except descriptive statistics.

Business size		Has the receipt of rate relief been a significant factor in your remaining in business over the last 12 months?			
		not significant	significant	very significant	total
0–1 employees	count	30	29	16	75
	% within category	40.0	38.7	21.3	100.0
2–5 employees	count	67	80	53	200
	% within category	33.5	40.0	26.5	100.0
6–10 employees	count	24	22	8	54
	% within category	44.4	40.7	14.8	100.0
11–20 employees	count	10	5	1	16
	% within category	62.5	31.3	6.3	100.0
More than 21 employees	count	5	5	1	11
	% within category	45.5	45.5	9.1	100.0
Total	count	136	141	79	356
	% within category	38.2	39.6	22.2	100.0

Note: Spearman's correlation = -0.082; p -value = 0.122.

Type of business		Survival significance		
		not significant	significant	total
Post office	count	6	6	12
	% within category	50.0	50.0	100.0
Personal services	count	15	22	37
	% within category	40.5	59.5	100.0
Retail and wholesale	count	40	68	108
	% within category	37.0	63.0	100.0
Accommodation and catering	count	26	67	93
	% within category	28.0	72.0	100.0
Manufacturing, storage, and distribution	count	16	24	40
	% within category	40.0	60.0	100.0
Professional and financial services	count	17	13	30
	% within category	56.7	43.3	100.0
Others	count	15	21	36
	% within category	41.7	58.3	100.0
Total	count	135	221	356
	% within category	37.9	62.1	100.0

Note: Pearson $\chi^2 = 9.576$; p -value = 0.000.

Figure 3:2 Significance of rates for business survival (Peck *et al.*, 2014:992)

Far more substantial methodology is offered by Duranton *et al.* (2011) who look at the impact of BRs on employment and entrants. The latter is not so important for this analysis. Therefore, this summary focuses on the former. The theoretical lens of this study has been discussed in Section 2.1.4. They use a two-factor model. Labour and building space are assumed to be perfect complements. Firms cannot renegotiate rents downwards. Their dependent variable is lagged employment, while independent variables are tax rate, age, industry-year dummies. They solve the main econometric issues by using spatial differencing, time differencing and instrumenting to solve for unobserved time-varying site

characteristics and the endogeneity of local taxation. More specifically, they use within estimator and three sets of instruments; the share of local politicians affiliated with the three largest political parties, the proportion of the three biggest parties if they control the local authority and dummies indicating whether it is controlled by one of the three top parties. As they suggest, the only dataset available in the UK that satisfies their assumptions is the Annual Respondents Database. They merge this dataset with The Ordnance Survey Code-Point data and achieve precise postcode allocation. Starting with 21,813 firms, they reduce their sample to only 4,414 (report employment twice at the same year and establishments have pairs located within 1 km). Thus, the sample may have selection issues as discussed in the Research Design Chapter. In the model, they argue that there is imperfect capitalisation because of the combination of expensive relocation, uncertainty about future taxes and rigid rents. They show an adverse significant relationship between taxes and employment but no effect on the entry of new firms. The main criticism of their piece may be that they look at data from 1984–9 before reforms were introduced. Although this enables them to use their more advanced methodology and test their model, it may not explain the current business rate system.

Generally, the majority of not discussed empirical evidence suggests that some amount of BR is partly capitalised into rents, King (1973 and 1977), Edel and Sclar (1974), Gustely (1976), Rosen and Fullerton (1977), Richardson and Thalheimer (1981), Ihlanfeldt and Jackson (1982), Lea (1982), Goodman (1983), de Bartolome and Rosenthal (1999), Oktem and Huang (2011), and Stadelmann and Billon (2012). While others (Wales and Wiens, 1974; Chinloy, 1978; Gronberg, 1979) have found little or no capitalisation. Older studies often ignore simultaneity, it has too few control variables, uses inappropriate estimation procedure and incorrect functional form. The most common issue with these studies is the misspecification of the tax capitalisation equation. For instance, Chinloy (1978) studies tax capitalisation in Canada. He makes two specification errors. Firstly, he assumes that property taxes apply to the before-tax asset price housing but not market value. Also, he assumes that capitalisation for tax payments and tax credits are similar.

3.4 IMPLICATIONS FOR THE FRAMEWORK

The empirical literature confirmed the importance of tax incidence, introduced in the Theory Review (Section 2.1). It is evident that at least some amount of capitalisation should be expected. Thus, the effects of SBRR on business performance may be relatively marginal. Hilber's (2017) theoretical reasoning suggests that there is no uniform capitalisation since local supply constraints for commercial property may impact the

capitalisation, the amount of capitalisation should also depend on the degree of substitutability of locations, relocation costs and the preference of business owners. The latter is also evident in the dynamic capabilities theory (see Section 2.2.2.3). It seems to be difficult to model without assumptions of substitutability of locations, relocation costs and the preference of business owners. Thus, the framework will not do that; rather it will control for the forces defined in Section 4.6 with examples from Chapter 5.

All British studies dealing with BRs were discussed in this chapter. No studies have been identified that investigate how non-domestic property taxation relates to either survival or productivity. Even though there may be some degree of capitalisation, an interesting insight departing from the standard literature is offered by Peck *et al.* (2014), discussed in Section 3.3. They find that owners may consider SBRR to be an emotional support. Thus, they may feel encouraged to perform better, enhance their productivity and keep their business open. The previous literature on BRs focuses on capitalisation or qualitative cross-sectional policy evaluation and does not go further than employment.

Thus, the thesis so far shows that the government might consider SBRR to be the “second best” (Lipsey and Lancaster, 1956) approach. The rationale to use tax reliefs to enhance market efficiency is based on market failure through the lack of knowledge spillovers or financing constraints (discussed in Section 2.2.2.1) and the ability-to-pay principle (Section 2.2.2.2). It is possible that policy would support high growth firms which create the vast majority of jobs and are the driving force of change (as defined in Section 4.7.2). However, more probable is that the incorrectly targeted policy would, in the short term, help a firm to stay afloat, but would have marginal impact in the long run.

4 FRAMEWORK WITH HYPOTHESES

This chapter aims to introduce the framework leading to the hypotheses that will be tested to achieve the overall aim of this thesis; to understand whether Small Business Rates Relief (SBRR) has any effects on firms, in particular with regards to their productivity and survival. Total factor productivity (TFP) is the portion of output not explained by the amount of inputs used in production. Whilst, survival analysis is a method for analysing data where the outcome variable is the time until the closure.

The thesis adopts and adapts Duranton's *et al.* (2011) BR model in order to establish how tax reductions for small businesses could influence decisions on survival, production and investment. The model is simple, but importantly enables the incorporation of relevant empirical peculiarities of the British tax framework. Duranton's *et al.* (2011) study is discussed in Sections 2.1.4 and 3.1. Changes to their framework are developed throughout theoretical and empirical reviews with particular emphasis on Sections 2.1.6, 2.2.2.3 and 3.4.

Several assumptions are adopted from Duranton's *et al.* (2011) study. The unit rental cost of buildings in jurisdiction a comprises two elements: the building rent, b_a and the local tax, or business rates, r_a . Occupiers pay the tax and SBRR is applied to the property rather than to the businesses. The price, p , for final goods is exogenous, common throughout the country. These are simplified but reasonable assumptions to make for the current business rate environment.

They also assume that establishments could exist for up to two periods and new starters may join at any time. During the first period demand for their goods is normalised to the utility. Therefore, a profit of an establishment i in period one is given by:

$$\pi_{at}^1(i) = p - b_{at} - r_{at}$$

Duranton's *et al.* (2011) attention is to employment, while this study focuses on productivity. Therefore, the main inputs in a typical productivity function (as defined in Section 5.1.2) are also included in this model $prod_{at} = L_{it} + K_{it} + I_{it} + c$, where L_{it} is labour, K_{it} is capital and I_{it} is investment. Period one profit is given by;

$$\pi_{at}^1(i) = p - b_{at} - r_{at} - prod_{at}$$

Furthermore, some differing assumptions to Duranton's *et al.* (2011) are imposed as being more suitable for the current environment. They assumed the perfect competition of the land market. Therefore, establishments keep entering the market until their expected

profit is equal to zero, $E(\pi_{at}) = \pi_{at}^1 + E(\pi_{a(t+1)}^2) = 0$, and b_{at} adjusts to ensure that this holds for all properties and areas. As described in a debate on capitalisation in Section 10.1, a perfectly competitive market would mean that the SBRR is capitalised into rents in both the short and long terms. This is not a reasonable assumption in a BR context.

The Theory Review Chapter showed that uniform capitalisation may not be evident across the country. The capitalisation is likely to be impacted by local supply constraints for commercial property as discussed throughout the Theory Review. Thus, it is assumed that property taxes and expected increments are fully capitalised only into new rental contracts. Otherwise, tax shocks take time to be (possibly partially) capitalised due to heterogeneous levels and type of competition, and market rigidities. From the empirical studies discussed in the Empirical Review Chapter some generalisations were made. Researchers tend to find partial or no capitalisation in the short term and full capitalisation in the long term. Similarly, Fraser (1984) explains in his book that the new entrants have to sign new contracts. Older companies that are renewing their existing tenancy agreements are likely to take the scenario of overcapitalisation in the long term.

On the other hand, the firms that have existing contracts are not likely to be hit by the increase in rents in the short term. Thus, as summarised in Section 2.2.2.3, this framework separates effects in short, medium and long terms so that the model would be more representative to the real market. In Section 4.6, this thesis proposes to control for the heterogeneous capitalisation due to levels of concentration or diversity in small areas.

In general, rigidities include standard contracts, in which rent reviews usually occur at time intervals and are only upward. The annual national tax adjustments are reasonably predictable as they are revenue neutral and reflect inflation. Shocks are likely following the implementation of BR revaluations, which should take place every five years and can both lower and raise the obligation. The new establishments are assumed to sign a lease in t which sets building rent for both t and $t + 1$.

Furthermore, according to Harris (2017), capitalisation should depend on the degree of substitutability of locations, relocation costs and the preference of business owners. Arguably, the first three criteria should not vary significantly across the country. However, the preference of the business owner may be attached to the particular area. Thus, it is assumed that the relocation costs, m , are substantial and exceed the relief, $m_{it} > SBRR_{it}$.

A further differentiator in this model than that of Duranton's *et al.* (2011) is that business rates do not vary across jurisdictions, but varies across times and the rateable

value of the building. Contrary to Duranton's *et al.* (2011), jurisdiction is not assumed to be capable of setting its business rates. These are essential conditions to make the modelling fit for the post-1990s UK environment.

In order to focus more on property taxes, this thesis makes a number of simplifying further assumptions. The supply is conceptualised as;

$$Q_{ijt} = [\beta_{vf}VF_{ijt} + \beta_{of}OF_{ijt}] + \beta_{rs}RS_{ijt},$$

where Q is the output of firm i in nation j at time t , VF are the general variable inputs, (such as labour and materials) OF are other fixed factors (such as machinery, installations or overheads) excluding rented space (RS) which is considered separately. The β 's represent their relative weights in output. All variable and other fixed inputs are taken together as numeraire. Firms exist for up to two periods and can enter at any point. During the firm's first period, demand is normalised to unitary.

Rent and tax are expressed in units of output to relate them directly to price and unit profits. These values represent the input value divided by total output value and as such can reflect changes in productivity. The rents are fixed in both periods to reflect rigidities in the contractual norms. In period two, a demand shock is observed;

$$d_{ijt+1} = 1 + \rho_i,$$

where ρ_i is a realisation from a random draw over a continuous distribution at the beginning of the period. The draw can be positive or negative. This modelling considers responses to the shock and the influence of reliefs.

Additionally, the firm is assumed to experience a shock in their second period. The second-period tax, $r_{a(t+1)}$, consists of a previous tax and any relief if it is available;

$$r_{a(t+1)} = r_{at} -/+SBRR_{a(t+1)}, \text{ where } r_{at} > 0 \text{ and } r_{at} \geq SBRR_{a(t+1)}.$$

This is undertaken in order to simplify the equation. The reasoning is that business rates do not increase much from year to year. To further simplify, it is assumed that the relief is given according to the building value during the valuation, b_a and is not affected by the demand.

4.1 NEGATIVE SHOCK IN DEMAND

Given that between 2007 and 2008 companies experienced an economic downturn, the modelling starts with scenarios as to how a rational firm may behave when it starts receiving SBRR, but is currently experiencing low demand. After a negative shock in demand, $\rho_i > \rho_{i+t}$, as derived in Section 2.1.6, a firm may want to either exit, downsize, relocate or reduce costs of production inputs.

In extremis, a negative shock ($\rho_i < 0$) will lead to firm exit (E) regardless of SBRR:

$$\pi_{t+1}^2(i) = \pi_E(i) \leq 0$$

The level of reliefs could affect exit thresholds, with greater relief adding greater resilience. In terms of total costs, falling demand and output means the fixed BR and reliefs become more salient to firm decisions as the unit fixed costs increase and variable costs change little if a typical flat cost curve is assumed. In which case, firms with reliefs may survive, where counterfactually they would not. This reflects the source of political pressure from small business groups, which in the period since the great recession have put the question of business rates at the top of their list of concerns (Adam and Miller, 2014 and Cabinet Office, 2014).

Another option may be downsizing. This may occur by subletting a part of the original building unit. However, it is assumed that the firm cannot receive a higher return than the rent paid to the owner, so that $\underline{b} < b_{at} + r_{a(t+1)}$. Then, a profit function would be:

$$\pi_{t+1}^2(i) = \pi_D(i) = (1 + \rho_i)(p - prod_{a(t+1)} + \underline{b} - b_{at} - r_{at})$$

The firm that started receiving SBRR and is experiencing a negative demand shock would be incapable of increasing its total revenue, even by lowering its price. It may still choose to sublet their building space, but it could probably do that for less than their rent. However, some reduced overheads from the SBRR may keep profits sufficient to sustain the business. Following the same condition but including SBRR, the new profit function is:

$$\pi_{t+1}^2(i) = \pi_D(i) = (1 + \rho_i)(p - prod_{a(t+1)} + \underline{b} - b_{at} - r_{at} + SBRR_{a(t+1)}),$$

where $SBRR_{a(t+1)}$ is the proportionate reduction in the tax for small firms within a given nation and period.

If a company does not reduce its building space but rather reconsiders its production inputs, it is likely to reduce its investment in productivity by $\kappa\%$, $prod_{at} * \kappa =$

$prod_{a(t+1)}$, where κ is the reduction of the current costs in production inputs. This is likely to reduce the output costs. The new profit function becomes:

$$\pi_{t+1}^2(i) = \pi_p(i) = (1 + \rho_i)(p - prod_{at}\kappa - b_{at} - r_{at} + SBRR_{at})$$

Relocation may be an option for existing firms. As discussed in the Introduction and Background Chapter (Section 1.4.3), UK business rates do not vary between councils. However, property rateable values and rents vary significantly. Also, as defined at the beginning of this theoretical modelling, it is reasonable to relax the assumption about the perfectly competitive real estate market in the short term. The framework looks at two scenarios: when a firm already receives a relief and when relief is just introduced in the land.

If the firm is already receiving the relief, it is unlikely to obtain a better deal elsewhere. The firm would incur relocation cost, m , and relocate where the unit rental cost of building equals to \bar{b} such that in equilibrium $\underline{b} < b_{at} + r_{a(t+1)}\delta < \bar{b}$. Thus, the relocation would not just mean an increase in their rent and business rates but also a loss of SBRR:

$$\pi_{t+1}^2(i) = \pi_R(i) = (1 + \rho_i)(p - prod_{a(t+1)} - \bar{b} - SBRR_{a(t+1)} - m)$$

If the relief is unavailable for the current premises, it is possible that a firm could find a cheaper property and pay lower rent somewhere else. In this scenario, the profit could be defined as:

$$\pi_{t+1}^2(i) = \pi_R(i) = (1 + \rho_i)(p - prod_{a(t+1)} - \underline{b} + SBRR_{a(t+1)} - m)$$

Assuming that just some amount of the SBRR is capitalised into rents and a firm has to increase its indirect expenses, price increases and demand for the goods further decreases. A firm would be likely not just to receive lower rent but also start receiving larger SBRR. Thus, the demand for properties receiving SBRR would increase until perfect market competition. As a result, landlords would potentially increase rents for their more popular premises as discussed in Section 2.1.3.

4.2 POSITIVE SHOCK IN DEMAND

Firms, in essential sectors might experience a positive shock in demand during pre-recession, recession and post-recession periods. If a firm faces a positive shock ($\rho_{ijt+1} \geq 0$), it has four choices. It may want to either grow by investing in building space and employing more people, stay the same or relocate. This depends on the increase in demand.

If a firm wants to expand their building space, it may need to reevaluate their property. They would need larger and potentially more expensive property, which potentially would not receive SBRR. For this reason business rates do not just increase proportionately because the value is larger but also by the relief, which is granted for the previous property, so $r_{a(t+1)} = r_{at}\delta + SBRR_{at}$, where δ is the premium to the existing business rates. This means reliefs would reduce this gain from lower unit costs, given they neutralise the tax costs. Moreover, tighter capacity constraints for small firms and limited scale effects in some industries, would see constraints bite more quickly and may result in increases in variable unit costs which offset the fixed factor or any productivity gains. Thus, the business rates would increase with rent, so that $r_{a(t+1)} = r_{at}\delta$, where δ is the premium to the existing business rates and $b_{at} + r_{at}\delta < \bar{b}$. Also, firms may lose their SBRR (if previously received). Then, the profit is:

$$\pi_{t+1}^2(i) = \pi_G(i) = (1 + \rho_i)(p - prod_{a(t+1)} - \bar{b} - SBRR_{at})$$

A company may not expand its building space but rather employ more individuals. Then they would cost the premium, ϑ , which is between 1 and 2, to the existing investment in either labour or capital. This results in:

$$\pi_{t+1}^2(i) = \pi_I(i) = (1 + \rho_i)(p - prod_{a(t+1)}\vartheta - b_{at} - r_{a(t+1)})$$

If the demand shock is sufficiently positive, a firm may decide to relocate (R) to larger premises. Unit rental and taxation per unit are assumed to be the same or lower than staying in the current premises and producing at the same level or intensifying production. However, such relocation would lead to lower or no reliefs, given the firm will probably now face a higher total initial tax. Hence, in addition to relocation costs (m) there would be extra tax costs for growing small firms. The unit rental cost of the building is lower than the previous rent and equals to \underline{b} , so that in equilibrium, $\underline{b} < b_{at} + r_{a(t+1)}\delta$. It would not just lead to the increase in rent and business rates in real terms (reduction in per unit terms) but also in a possible loss of SBRR:

$$\pi_{t+1}^2(i) = \pi_R(i) = (1 + \rho_i)(p - prod_{a(t+1)} - \underline{b} - SBRR_{a(t+1)} - m)$$

Finally, a firm may stay the same:

$$\pi_{t+1}^2(i) = \pi_S(i) = (1 + \rho_i)(p - b_{at} - r_{a(t+1)} + SBRR_{at})$$

Hence, depending on $SBRR_{at}$ and its induced demand shock, ρ , a firm faces seven possible choices: exit (π_E), downsize (π_D), reduce productivity inputs (π_P), improve the

current building (π_G), increase investment in productivity (π_I), stay the same (π_S) or relocate (π_R).

4.3 NO CAPITALISATION (SHORT TERM)

It is assumed that firms are indifferent between any of these options. Also, SBRR is substantial in their budget and, thus, is significant enough to increase or reduce the profits. The relocation is sufficiently costly. Then profit functions can be sorted according to the preference of the firm.

The positive demand shock for firms with no relief would result in:

$$\pi_R = \pi_G = \pi_I < \pi_S$$

However, firms receiving the relief would have these preferences:

$$\pi_R \leq \pi_G < \pi_I < \pi_S$$

This shows that theoretically, SBRR recipients may be more likely to invest in TFP in the short term. If a firm focuses just on its short-term profit, it is likely to invest in neither property nor TFP but just increase their profit by the amount of the relief. If demand is large and SBRR is substantial, a small rational establishment receiving SBRR would be more incentivised to invest in TFP growth than other firms.

In the case of the decrease in demand, firms that do not receive the relief would have these preferences:

$$\pi_E < \pi_P = \pi_D \leq \pi_R$$

However, once the relief is introduced (enhanced), firms that receive the relief would change their preferences to:

$$\pi_R < \pi_E < \pi_P = \pi_D$$

If the relief is introduced and the enterprise is the first recipient of SBRR for those premises, there should not be any premises which would be much cheaper. This would make enterprises dependent upon the relief and they would be more likely to exit than relocate when compared with non-recipients. Simultaneously, they should be able to increase their cash flow, so immediate recipients are likely to experience higher survival rates. Thus, the rational recipient of SBRR would choose between subletting part of their property and reducing investment in productivity to survive during the downtime.

Furthermore, it is worth noting that a possibly higher expense in t+1 because of capitalisation reduces short-term profits and induces more exits. A greater number of exits also implies that surviving establishments are those that have experienced a less negative demand shock.

On the other hand, non-recipients that have to pay both higher rents and BR would be more likely to relocate than to cut their investment in TFP or downsize. Furthermore, they would be less likely to exit than recipients.

Thus, the following hypotheses are formed:

H1a: During downtime, firms receiving a relief, awarded upon its either introduction or enhancement, are more likely to survive than those that are not receiving the relief in the short-term.

H2a: During downtime, TFP of firms receiving a relief, awarded upon either its introduction or enhancement, is lower than firms that are not receiving the relief in the short-term.

4.4 PARTIAL CAPITALISATION (MEDIUM TERM)

Preferences related to smaller firms receiving SBRR would be valid if a firm is the first recipient or SBRR is yet to be capitalised into rents. As Fraser (1984) suggested, because of the increased demand for SBRR on a recipient's premises, firms may be made to relocate or suffer increased rents. These rents may be even overcapitalised in the medium term, meaning that they may be disproportionately increased (higher than available SBRR) and companies would suddenly be affected by the increase. As discussed in Section 2.1, a full capitalisation is a more likely scenario in the long term. It is reasonable to assume a partly competitive property market with diverse moving costs in the medium term.

In the medium term, firms experiencing a positive shock in demand would have the following preferences:

$$\pi_G < \pi_I < \pi_S < \pi_R$$

In the medium term, non-recipients experiencing a negative shock in demand would have the following preferences:

$$\pi_E < \pi_P = \pi_D < \pi_R$$

However, the SBRR recipients would be likely to suffer a loss because of both relocation expense, m , and increase rents, unlike non-recipients that were more likely to be unaffected by the relief or may be even capable of lowering their rents. On the contrary, if m is very high and the rent is being increased gradually, the effect to recipients would be indifferent to non-recipients. However, if these are very high, the $\pi_P = \pi_D$ might become even lower than 0. Thus, this uncertainty causes to create the following preferences for SBRR recipients:

$$\pi_E \leq \pi_P = \pi_D \leq \pi_R$$

Thus, the following hypotheses are formed:

H1b: During downtime, survival probability of firms receiving SBRR is lower than firms that are not receiving the relief in the medium-term.

H2b: During downtime, TFP of firms receiving SBRR is lower than firms that are not receiving the relief in the medium-term.

4.5 FULL CAPITALISATION (LONG TERM)

As discussed in Chapters 2 and 3, a full capitalisation is a more likely scenario in the long term. Thus, it is reasonable to assume the perfectly competitive market with small moving costs in the long term. Let us disregard both π_P and π_D scenarios as non-substantial for the long-term recession because both are based on the reduction of either building space or investment. If a firm continues to do that, it would have to exit in the long term.

There would be no benefit of $SBRR_{it}$ because firms would be changing locations and demand of properties would increase until the equilibrium where SBRR is fully capitalised into rents. Thus, $b_{a(t+1)} = b_{at} + SBRR_{a(t+1)} = b_{at}$. As a result, smaller firms experiencing recession would be more severely pushed to relocate owing to increased rents by the landlord and more severe competition for their property. This would result in the following priorities:

$$\pi_E < \pi_R$$

However, if relocation costs exceed the relief, firms would be more likely to exit. It is also worth noting that a possible overcapitalisation in the medium term may imply a greater number of exits owing to the increase in demand for properties that may be entitled to claim SBRR:

$$\pi_R < \pi_E$$

The perfectly competitive real estate market would make firms indifferent between investing in property and equipment with the positive shock in demand, $\delta \rightarrow \vartheta$. Given that property and investments in productivity are perfect substitutes, firms want to expand their business to increase their long-term profit, so π_S is also removed from the consideration:

$$\pi_R < \pi_G = \pi_I$$

Although SBRR may not cause firms to invest more into TFP, their previous investment in TFP (e.g. R&D or equipment) may still enhance their productivity. This suggests that first recipients upon introduction (or enhancement) of SBRR during a positive shock in demand or non-recipients during a negative shock in demand may be more likely to receive higher TFP than other firms. Given that many more firms suffered from the recession than had an increase in demand, the overall effect should imply that SBRR reduces TFP in the long term.

Finally, it would be reasonable to assume that they would invest in an appropriate mix, thus maximising their profits to enhance their productivity. Relaxing the assumption that production inputs and building improvements are perfect substitutes, firms may be investing more rationally and improve their productivity in the long term. However, it is worth noting that this highly depends on strategic management as discussed Section 2.2.2.3 (p. 64) rather than the relief.

Thus, the following hypotheses are formed:

H1c: SBRR has no significant impact on survival rates in the long term.

H2c: SBRR has little or no significant impact on productivity in the long term.

4.6 COMPETITION – SHORT, MEDIUM AND LONG TERMS

The framework defined how firms are likely to behave. However, it intentionally did not define the duration of the short, medium and long terms. Standard theoretical models on capitalisation (Section 10.1) and the empirical UK literature (Empirical Review Chapter) often assume uniform capitalisation across the country. This thesis joins Hilber (discussed in Section 2.1.5) and challenges this perception. The thesis argues that the exact time frame of short, medium and long-term effects highly depends on the region and industry.

More broadly, the study by Ross *et al.* (2015) partly applies Bosma's *et al.* (2008) methodology to explain variation in small growing firms across Scottish regions by demand, supply, culture, agglomeration externalities and policy. This is covered in the Theory Review Chapter in how externalities arise (Section 2.2.1.2) and how they may influence businesses (Section 2.2.2). The factors affecting small businesses are reasonable and consistent with previous theories mentioned throughout the thesis (Krugman, 1990; Rittenberg and Tregarthen, 2009) and empirical findings. For example, the entrepreneurial activity across geographic space is illustrated according to the historical perspective (see Figure 4:1, p. 89) and in connection with variations in spatial characteristics, such as knowledge (Obschonka *et al.*, 2015). Such variations might be partly explained by differences in regions. For example, Stuetzer *et al.* (2015) reveal that UK regions with large industries, such as 19th century textile mills in Manchester, have lower entrepreneurship rates and weaker entrepreneurship culture today.



Figure 4:1 Spatial variations in new firm formation rates. 1994-2007 averages. The colour is shaded by the firm formation rates. Where dark black is higher formation rates and white is lower. Source: Fotopoulos (2014:671)

In 1992, Glaeser with colleagues distinguished three types of spillovers that are likely to influence the analysis: specialisation spillovers (Marshall-Arrow-Romer, 1890; 1962; 1986); competition spillovers (Porter externalities, 1990); and diversity spillovers

(Jacobian externalities, 1969). These are often included in many recent studies. For instance, Harris and Moffat discussed in Sections 5.1.4.5.3 (p. 111) and 5.2.3.2 (p. 117), include these indexes that may be used to control the business environment and externalities.

This thesis argues that these indexes will (to some extent) capture the degree of competition across firms for premises and, thus, it is likely to capture the capitalisation at least partly. In other words, it suggests that firms in less competitive areas or industries would have lower capitalisation. For instance, in a case of a rural entity, the property owner would be unlikely to quickly increase rent for those premises because of the demand elasticity in the less competitive areas. The business owner may have a few other options to relocate and the property owner may have no demand for their premises. Thus, the firm would be likely to experience extended short-term effects, as defined in Section 4.3.

On the other hand, those occupying premises in either very urban areas or very competitive areas would be more likely to experience the capitalisation effects much faster because they are likely to experience high demand for their premises. For instance, a tiny corner shop in central London is likely to have their rent increased almost immediately once SBRR is introduced. Thus, the firm would not experience the short-term effects, as defined in Section 4.3.

4.6.1 Marshallian Externalities (Specialisation)

The previous examples suggest that one should separate the effects of rural and urban firms. Thus, to account for the market concentration, this thesis controls for Marshallian externalities. Agglomeration externalities, dating back to Marshall's (1890) 'Industrial District-argument,' are based on asset-sharing, such as the provision of specific goods and services by specialised suppliers and the creation of a local labour market pool sustained by a local concentration of TFP, which may influence production. Spillovers arise from knowledge sharing of firms in the same sector. Feldman and Audretsch (1999) and Paci and Usai (1999) suggested using the production structure specialisation index (PS) to measure Marshallian specialisation externalities. These are simply a proportion of industry employment or output located within local authority related to national industry employment or output:

$$PS_{i,j} = \frac{E_{i,j} / \sum_i E_{i,j}}{\sum_j E_{i,j} / \sum_i \sum_j E_{i,j}},$$

where i is sector, j is industry and E is employment

4.6.2 Jacobian Externalities (Diversity)

Essentially, small firms in different industries may compete for the same premises. In the previous example, the rural entity and urban entity are unlikely to compete for the same premises and this should be controlled for. To control for this effect, Jacobian externalities are estimated. Jacobs (1969) initially argued that knowledge might spill over between complementary rather than analogous industries as ideas established for once sector can be applied in other sectors. Hence, diversity is estimated by summing some different sic codes within the region. Paci and Usai (1999) measured it with their productivity diversification index:

$$PD_j = \frac{2}{(n-1)Q_n} \sum_{i=1}^{n-1} Q_i,$$

where n is the number of regionally residing industries, Q is cumulative employment in sector i , ordered ascendingly by size.

4.6.3 Herfindahl-Hirschman Index (Diversity)

Finally, some firms, especially in more specialist areas, might compete for the same premises nationwide. Some premises might be industry-specific and firms across the UK might compete for these premises. The Herfindahl- Hirschman Index named after economists Orris C. Herfindahl and Albert O. Hirschman is a widely accepted measure of market concentration. Since 1982, the U.S. Department of Justice, the Federal Trade Commission, and state attorneys in general have used the Herfindahl-Hirschman Index. It is usually estimated by squaring the market share of each firm competing in the market. Then, summing the resulting numbers up.

$$HHI = \sum_{i=1}^N s_i^2,$$

where s_i is the market share of firm i in the market, and N is the number of firms.

4.7 OTHER FIRM-SPECIFIC FACTORS

As a product of this theoretical modelling, the following equation should estimate the productivity:

$$\ln A_{it} = \ln GVA_{it} - \ln L_{it} - \ln K_{it} - r_{it} \delta - SBRR_{it} + \varepsilon_{it}$$

Likewise, the following function should predict survival:

$$SP = h_o(t) e^{\alpha_L L^{*\alpha_K} K^{*\alpha_r} r^{*\alpha_{SBRR}} SBRR}$$

However, other issues were identified in the Methodology Review that may bias estimators. The theoretical debate around capitalisation in Section 2.1 started with partial equilibrium analysis emphasising the importance of the elasticity of demand and supply. The vast majority of models presented in this thesis also acknowledges their importance. It is evident that some factors may influence the demand and its elasticity more than others. Similarly, some firms would be more productive than others because of their inherent characteristics. Although the identification of these characteristics is not the primary aim of this thesis, this section aims at reviewing the fundamental forces within the environment of the firms together with inside forces within them, such that these powers could be controlled for during the analysis.

4.7.1 Business Characteristics

From the Methodology Review Chapter, it is apparent that one of the primary reasons for any changes to business performance is its characteristics. The vast majority of studies in the Journal of Productivity Analysis, in one way or another, control for size. However, this is not discussed in this section; rather discussion is on a large stream of literature directly addressing characteristics that should be controlled for.

One of the most popular methodologies employed with microdata is Gibrat's Law of Proportionate Effect (Gibrat, 1931) claiming that firm size and growth should be independent, which is partly supported even by recent studies (Lotti *et al.*, 2009). However, either British (Konings, 1995; Hart and Oulton, 1996) or foreign (Lotti *et al.*, 2009) studies have concluded that Gibrat's Law is not necessarily valid. The more sophisticated method is introduced by Davis and Haltiwanger (1992). This method relies on descriptive analysis and includes growth and death rates to show that new firms create more dynamic jobs than older firms. It is followed by such studies as Baldwin and Picot (1995). Although more advanced techniques have been employed, further studies (Aterido *et al.*, 2009; de Kok *et al.*, 2011; Neumark *et al.*, 2011) have very similar conclusions. This may be explained by Jovanovic's (1982) passive learning model, which claims that entrepreneurs learn most when they enter the market. In contrast, Anyadike-Danes *et al.* (2015) maintain that neither the employment size nor age explains job growth. They believe that the only explanation is a small number of rapidly growing micro firms (see Section 4.7.2, p. 92 for an extensive discussion).

4.7.2 High Growth Firms - Entrepreneurship literature

A phenomenon of high growth firms (HGFs) is defined by OECD (2008:61): 'All enterprises with average annualised growth greater than 20% per annum, over a three-

year period should be considered as high-growth businesses. Growth can be measured by the number of employees'. This definition has been used in multiple studies (Anyadike-Danes *et al.*, 2015; Brown and Mawson, 2015; Bravo-Biosca, 2011; Teruel and De Wit, 2011) and it seems to replace the high-growth metric invented by Birch (1987).

Anyadike-Danes *et al.* (2015) empirical findings are based on Birch's (1979:8) pioneering idea that 'small firms (those with 20 or fewer employees) generated 66% of all new jobs generated in the U.S.' Although Birch's theories (1979; 1987) are criticised by such studies as Dennis and Phillips (1994), small firms are recognised as the main creators of jobs (Anyadike-Danes *et al.*, 2014, 2015; Coad *et al.*, 2014; Cowling *et al.*, 2015; Du and Temouri, 2015). Recently, Anyadike-Danes *et al.* (2009:4) estimate the contribution of HGF to job creation in the UK economy. They show that '11,530 high growth firms were responsible for 1.3 million out of the increase in 2.4 million new jobs in established businesses employing ten or more people between 2005 and 2008'. According to their study, around 6% of all firms create 54% new jobs in the UK. Later, these statistics are confirmed by Anyadike-Danes *et al.* (2015): around 6% of all firms added about 40% of net jobs by 15-year survivors. However, Butcher and Bursnall (2013) show that job creation is evenly spread across different size bands, which contradict Anyadike-Danes's *et al.* (2015) results. These studies provide useful understanding about national HGF populations. However, as Anyadike-Danes *et al.* (2015:22) acknowledge, those firms 'require further analysis ... to understand the process of small business growth.'

The government's policy aimed at small businesses may be discouraging high growth firms, which according to recent evidence are drivers of employment and growth. Firms may be less likely to expand due to even more significant costs associated with a loss of SBRR in case they either improve the existing premises or relocate. Therefore, they have to restrict themselves to existing premises which may limit their investment in equipment and employment. However, it could be argued that firms receiving SBRR may be encouraged to invest more in technology, which should result in higher total factor productivity. On the other hand, recent British evidence points out that there is little evidence of the correlation between investment in R&D and both TFP growth (Harris and Moffat, 2017) and survival (Harris and Moffat, 2016).

4.7.3 Research and Development (R&D)

Researchers tend to assume that investment in R&D is vital for a business to succeed. They often use the Schumpeterian theory of creative destruction where firms have to continuously innovate to sustain their market share (the debate on Schumpeterian creative destruction is presented in Section 2.2.2.1). However, the evidence is diverse. As

shown in the following paragraphs, it is unclear whether investments in R&D would have any effect on productivity and survival. We suggest that this might be because not all R&D projects are successful (e.g. NOKIA's example).

Since the pioneering work of Griliches (1979), productivity studies have considered the technological spillovers to be a side product of R&D activities. The endogenous growth models of Romer (1990) and the quality ladder models of Grossman and Helpman (1991) and Aghion and Howitt (1992) theorise that innovations drive long-term economic growth and aggregate productivity. Many scholars (Medda and Piga, 2014; Ulku and Pamukcu, 2015; Franco *et al.*, 2016) have found R&D to be very influential in the process of productivity. For instance, Franco *et al.* (2016) discover that service regulation reduces R&D efficiency in the manufacturing sector with knowledge production function on OECD industries with a stochastic frontier analysis. An Italian study (Medda and Piga, 2014) results in a very similar conclusion through the use of Tobit and logit regressions. They suggest that a firm's investment in R&D results in productivity gains. However, the approach utilised in this thesis is similar to Ulku and Pamukcu's (2015) study, which considers Turkey with a GMM estimator over the five-year period. They discover that a rise in both the foreign ownership share and technology licensing increases firms' productivity. It is worth noting that the conditional effect of the latter is significant only above a threshold of technological capability. It is questionable whether these results could be applied to the context of Britain because of the different economic conditions.

On the contrary, another stream of the literature (Ilmakunnas and Piekkola, 2014; Chen and Inklaar, 2016; Goya *et al.*, 2016) found that R&D has little or no influence on productivity. For instance, Goya *et al.* (2016) applies Olley and Pakes (1996) estimator to Spanish firms over the period 2004–2009 and finds that R&D expenditures do not have a direct impact on firm performance but spillovers do. Moreover, US study (Chen and Inklaar, 2016) by using a variation of Cobb-Douglas productivity function estimated by FE and GMM fails to find any evidence that knowledge spillovers within the same industry exist within the US. The similar, but more sophisticated approach of Levinsohn and Petrin (2003), is used by Ilmakunnas and Piekkola (2014) on Finnish firm-level data from 1998 to 2008. They find that organisational activity tends to increase TFP, but R&D returns tend to be low.

More macro studies comparing different countries found similar conclusions. For instance, Luintel *et al.* (2014) used various estimates of R&D. They find that human capital, international knowledge spillovers and domestic knowledge stocks are the determinants of domestic productivity across nations. Another study by Cincera and Ravet (2014) looks at subsidies of large EU firms. They find a positive effect of globalisation on firms'

productivity with R&D investment, especially in the US, while an adverse effect of industrial diversification is identified. However, they used pooled-OLS estimates and the sample consisted of mainly large companies. Therefore, it may not be applicable for this research project.

4.7.4 Foreign Ownership and Foreign Direct Investment

Another commonly included variable related to R&D is a foreign direct investment or foreign ownership. These are most often found to be influential by emerging countries as these are likely to adopt a better practice than the more developed economies. Most emerging countries like India (Malik, 2015), Indonesia (Sari *et al.*, 2016), China (Huang and Fu, 2013; Baltagi *et al.*, 2015) report positive effects of foreign direct investment on their productivity. Similarly, several studies in emerging markets such as Turkey (Ulku and Pamukcu, 2015) and India (Girma and Vencappa, 2014) show that foreign ownership increases productivity.

In general, advanced economies tend to have lower effects. One UK study (Harris and Moffat, 2015) fits their GMM model into plant-level-panel data from the Annual Respondents Database covering 1997–2008. They find that most foreign ownership groups have higher than average TFP, but the effect is marginal. They argue that it is because of law number of the foreign firms, which is also expected in the sample used in this thesis as discussed in the Research Design Chapter (Section 6.1.3).

4.7.5 Employees characteristics

Building on the dynamic capabilities theory introduced in Section 2.2.2.3, it is clear that employees and employers may be the driving force behind any increases in TFP and survival. The previous researchers were using several angles and methods to at least partly account for them, more often than controlling for these, they focused on one of the characteristics. Several studies have investigated whether employees' bonuses, nationality and age have any effect on productivity. For instance, Akay and Dogan (2013:123) partly extend Jones (1971:3–21) theory, who suggests that an increase in the volume of labour in the economy will raise the output in all industries. Akay and Dogan add that 'the magnitudes of the increases in some industries are more than others depending on the value of the elasticity of substitution along with factor intensities between industries.' They use a generalised form of the standard specific factors model using 25 US industries. More advanced economies such as the Spanish (Gómez-Déniz and Pérez-Rodríguez, 2015) and the Italian (Bettin *et al.*, 2014) are investigating migrant workers. For instance, the Spanish study (Gómez-Déniz and Pérez-Rodríguez, 2015), observing labour productivity, shows

that immigrants increase Spanish labour productivity significantly. Arguably, this methodology may not be the most appropriate because it does not consider such inputs as materials and capital forming total factor productivity.

4.7.6 Implications for the Analysis

These two Subsections (4.6 and 4.7) attached to the framework suggested that the analysis should control for some key characteristics to not over(under)estimate the causal relationships between the variables. It is evident that some factors may influence the demand and its elasticity more than others. Similarly, some firms would be more productive than others owing to their inherent characteristics. Although identification of these characteristics is not the primary aim of this thesis, this section reviewed the fundamental forces within the environment of the firms together with inside forces, so that these powers could be controlled for during the analysis. The discussion found that the accuracy of the framework is likely to depend on the competition. Furthermore, it emphasised the importance of controlling the key business characteristics, their growth patterns, R&D investment, foreign ownership and foreign investment as well as employees' characteristics.

5 METHODOLOGY REVIEW

The theoretical framework was introduced in the previous chapter. This chapter aims to uncover how this thesis could employ the empirical analysis shaped by the framework. More specifically, to investigate how other researchers approached the productivity and survival analyses so that the approach applied in this thesis would not just be appropriate for the data but also forward-looking. It is worth recalling that the overall aim of this thesis is to understand whether Small Business Rates Relief (SBRR) has any effects on firms, in particular with regard to their productivity and survival. Total factor productivity (TFP) is the portion of output not explained by the amount of inputs used in production. Whilst, survival analysis in this setting is a method for analysing the expected duration of time until closure.

As illustrated in Figure 5:1, this chapter is divided into three major sections. The first (Section 5.1) is devoted to productivity and its estimation. It starts by reporting the results from the systematic literature review on methodologies (Section 5.1.1). It then attempts to find an appropriate functional form for productivity (Section 5.1.2) and discusses how these functions were estimated by other researchers (Section 5.1.3) as well as showing empirical examples appropriate for the microdata (Section 5.1.4). As a result, the chapter establishes that an appropriate functional form is a logarithmic Cobb-Douglas productivity function and it should be estimated with control functions and system-GMM approaches. Then, the focus turns to survival analysis (Section 5.2). This subsection is divided into basic mechanisms (Section 5.2.1), definitions (Section 5.2.2) and some recently applied techniques (Section 5.2.3.1). The preferred method is selected to be the Cox proportional hazard model (Section 5.2.3.2). Finally, the chapter develops into machine learning extensions (Section 5.3). It defines, introduces (Section 5.3.1) and gives examples (Section 5.3.2) of how these approaches were applied in previous studies.

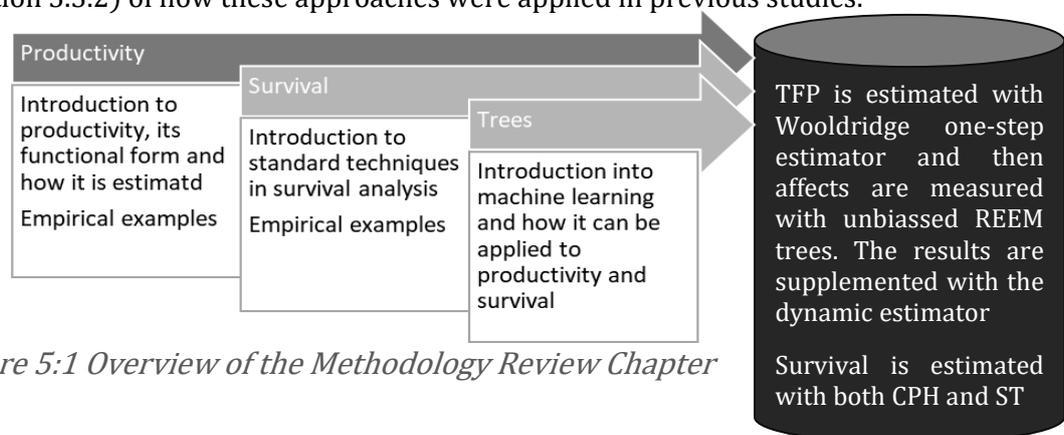


Figure 5:1 Overview of the Methodology Review Chapter

5.1 TOTAL FACTOR PRODUCTIVITY - SYSTEMATIC REVIEW

Origins of productivity measurement can be traced back to seminal papers of Tinbergen (1942), Fabricant (1954), Abramovitz (1956) and Solow (1957) who have decomposed output growth to input growth and productivity residuals. These early studies have mainly focused on aggregate TFP and its role in economic growth. Many textbooks have explained various productivity functions and forms (Besanko *et al.*, 2015). To extend our knowledge of the recent techniques within the productivity estimation, the following section focuses entirely on productivity and how it is estimated in the recent literature. It does not aim to look at established estimators; rather the focus is on the pioneering approaches applied within the field so that either an appropriate extension to the existing method could be chosen or an alternative proposed.

Several articles (Van Biesebroeck, 2007; Eberhardt and Helmers, 2010; Del Gatto *et al.*, 2011; van Beveren, 2012a) are used as a starting point. They provide an overview of the methodological issues when estimating TFP at an establishment level. To look at the most recent techniques applied in productivity estimation, this part of the literature review focuses on publications in the Journal of Productivity Analysis (JPA). This journal publishes theoretical and applied research addressing the measurement, analysis, and improvement of productivity. Given that the aim is to look for pioneering studies departing from the established disciplines, the journal seems to be an appropriate choice. To further our understanding, all articles from this journal published in a period between 2014 and 2017 were coded with NVivo. This analysis is used to estimate statistics and look for forward-looking methodologies. The findings from this analysis are combined with studies from other journals and are also presented in Section 5.1.4.

5.1.1 General Trends in the Journal of Productivity Analysis

First and foremost, an overview of findings is provided to inform about the underlying trends in the JPA. A variation of the parametric Stochastic Frontier approach is the most popular in the Journal of Productivity Analysis. Several empirical and many theoretical papers have discussed many estimation issues like heterogeneity, measurement error in capital and endogeneity, which are detailed in the Research Design Chapter (esp. Section 6.3.1.1). Also, it is evident that authors are choosing techniques according to the assumptions of technology and technical change. All papers have been looking at diverse areas. Thus, their results are not directly applicable to this analysis, rather they indicate the best practice and recent techniques used to estimate and define productivity.

The most popular industry being investigated is manufacturing, with 54 published articles during 2014-2017. Other popular industries are agriculture, finance, education and hospitality. Although productivity analysis stays popular in more output-input manufacturing firms, it seems that a large number of authors are considering the service sector. Furthermore, productivity studies come from emerging, developing and developed countries. The vast majority of studies are from European countries; however, the US, Japan and China also remain popular. There were only very few UK studies published in this journal.

5.1.2 Functional Form

To estimate TFP, first and foremost a functional form should be defined. The Cobb-Douglas functional form has been the most popular among the researchers in the Journal of Productivity Estimation. The 94 articles from this literature review explicitly stated that they were using Cobb-Douglas functional form, while most others were using a variation of Cobb-Douglas functional form, such as the constant elasticity of substitution (CES) which is sometimes used to access the elasticity of substitution. For instance, US researchers (Akay and Dogan, 2013) estimate the elasticity of substitution by using CES production function (as described in Appendix 10.3.1.5) with one mobile factor (labour) and 25 industries of the US to suggest how these estimates describe the general equilibrium of production.

On the other hand, the nested production functions could also be applied to question a relationship between some factors and the critical productivity elements (capital and labour) which may experience different substitution effects. For example, Shankar and Quiggin (2013) use the stochastic frontier approach with a CES specification of technology. Various functional forms are defined in Appendix 10.3.1. Given the nature of the data, namely micro level longitudinal data²⁵, only methods that can deal with microdata will be discussed in order to find an appropriate approach for this thesis.

Usually, an establishment-level production function is a mathematical expression that describes a systematic relationship between inputs and output in an economy (Katayama *et al.*, 2009). The fundamental mechanisms in standard theories based on neoclassical school of thought are discussed in the Theory Review Chapter (Section 2.2.1). In hand with these models, Del Gatto *et al.* (2010) start by quantifying productivity:

$$Y_{it} = A_{it} * F(Z_{it}) \rightarrow TFP = A_{it} = \frac{Y_{it}}{F(Z_{it})}$$

²⁵ For further detail, see the Research Design Chapter, Section 6.1.3.

where Y is the output of a unit (country/industry/firm) i at time t to a $(1 \times N)$ vector of inputs Z and the term A defines how much output a unit can produce from a certain volume of inputs, given the technological level. The state of technology, embodied by the function $F(\cdot)$, is given and common to all enterprises.

Thus, the TFP index at time t is the ratio of produced output and total inputs employed.

5.1.2.1 Cobb-Douglas

The most commonly applied is the Cobb-Douglas productivity function named after C. W. Cobb and P. H. Douglas (1934). The mathematical form of the Cobb-Douglas production function can be given by

$$Y_{it}(L, K) = AK^{\beta_K}L^{\beta_L} \rightarrow Y_{it}(tL, tK) = A(tK)^{\beta_K}(tL)^{\beta_L} = t^{\beta_K+\beta_L}Y_{it}(L, K)$$

This is a preferable choice because Cobb-Douglas productivity function can exhibit any degree of returns to scale: constant ($\beta_K+\beta_L=1$), increasing ($\beta_K+\beta_L>1$) and decreasing ($\beta_K+\beta_L<1$).

It is quite straightforward to show that the elasticity of substitution is equal to 1:

$$MRTS = \frac{\beta_L AK^{\beta_K} L^{\beta_L-1}}{\beta_K AK^{\beta_K-1} L^{\beta_L}} = \frac{\beta_L k}{\beta_K l} \rightarrow \ln(MRTS) = \ln\left(\frac{\beta_L}{\beta_K}\right) + \ln\left(\frac{k}{l}\right)$$

$$SE = \frac{\% \Delta \ln\left(\frac{k}{l}\right)}{\% \Delta \ln(MRTS)} = 1$$

This has influenced scholars to apply the constant returns-to-scale version to estimate the aggregate productivity in numerous countries. The constant β_K is then the elasticity of output with regards to capital input, and β_L is the elasticity of output with regards to labour input.

In the case of multiple inputs, the function takes the following form:

$$Y = \prod_{i=1}^n x_i^{\beta_i}$$

If $\sum_{i=1}^n \beta_i = 1$, then the equation exhibits constant returns to scale. In the constant-returns-to-scale Cobb-Douglas function, β is the elasticity of Y with respect to input x . If β is in the range of 0 and 1, each x should exhibit diminishing marginal productivity. However, any degree of increasing returns to scale can now be incorporated.

With regards to the elasticity of substitution, this could be expressed similarly as with one input (as shown in Appendix 10.3.1) and result in:

$$SE = \frac{\% \Delta \ln \left(\frac{x_i}{x_j} \right)}{\% \Delta \ln(MRTS)} = 1$$

This constraint is the primary limitation of Cobb-Douglas productivity function.

5.1.2.1.1 Technical Progress in Cobb-Douglas Productivity Function

Let's assume constant returns to scale and technological progress occurring at a steady exponential, then a production function with technological progress becomes:

$$Y_{it}(L, K) = Ae^{\theta t} K^{\beta} L^{1-\beta}$$

To study the properties of this function, a logarithmic differentiation is often applied:

$$\frac{\partial \ln Y}{\partial t} = \frac{\partial \ln Y}{\partial Y} * \frac{\partial Y}{\partial t} = \frac{\partial \ln Y}{\partial t} = \frac{\partial [\ln A + \theta t + \beta \ln K + (1-\beta) \ln L]}{\partial t} = \theta + \beta \frac{\partial \ln K}{\partial t} + (1-\beta) * \frac{\partial \ln L}{\partial t}$$

The technical change feature is explicitly modelled, and the output elasticities are specified with the exponents in the Cobb-Douglas.

The Cobb-Douglas functional form cannot include annual improvements directly. If the annual improvement in capital ($e^{\varphi t}$) and labour ($e^{\rho t}$) is added, the Cobb Douglas function would still convert to its previous form:

$$Y_{it}(L, K) = A(e^{\varphi t} K)^{\beta} (e^{\rho t} L)^{1-\beta} = Ae^{[\beta\varphi + (1-\beta)\rho]t} K^{\beta} L^{1-\beta} = Ae^{\theta t} K^{\beta} L^{1-\beta} ,$$

$$\text{where } \theta = \beta\varphi + (1-\beta)\rho$$

However, it is questionable whether the annual improvement in capital and labour could be precisely estimated.

5.1.2.1.2 Trans log Form Cobb-Douglas Productivity Function

Taking logarithmic function from Cobb Douglas productivity function and adding varying intercept as well as further condition ($\beta_{ij} \ln x_i \ln x_j$) produces translog function:

$$\ln Y = \beta_0 + \sum_{i=1}^n \beta_i \ln x_i + \sum_{i=1}^n \sum_{j=1}^n \beta_{ij} \ln x_i \ln x_j, \text{ where } \beta_{ij} = \beta_{ji}$$

The trans log production function incorporates many substitution possibilities among various inputs and can take any degree of returns to scale.

The logarithmic Cobb-Douglas functional form seemed to be an appropriate method to further our understanding since it includes the key inputs and different variations which may help to achieve better estimates. More specifically, the trans log production function seems to be the most appropriate as it can incorporate many substitution possibilities among various inputs and can take any degree of returns to scale.

5.1.3 Estimation Techniques

Once this thesis selected how the productivity function is likely to look, the focus now turns towards the estimation techniques. Figure 5:2 provides a broad classification of the techniques approached in this literature survey. The shape and underlying assumptions of the productivity function influence the choice of estimation techniques. Authors have differing preferences and arguments for using different techniques, implying that none of the estimation techniques are significantly better than others.

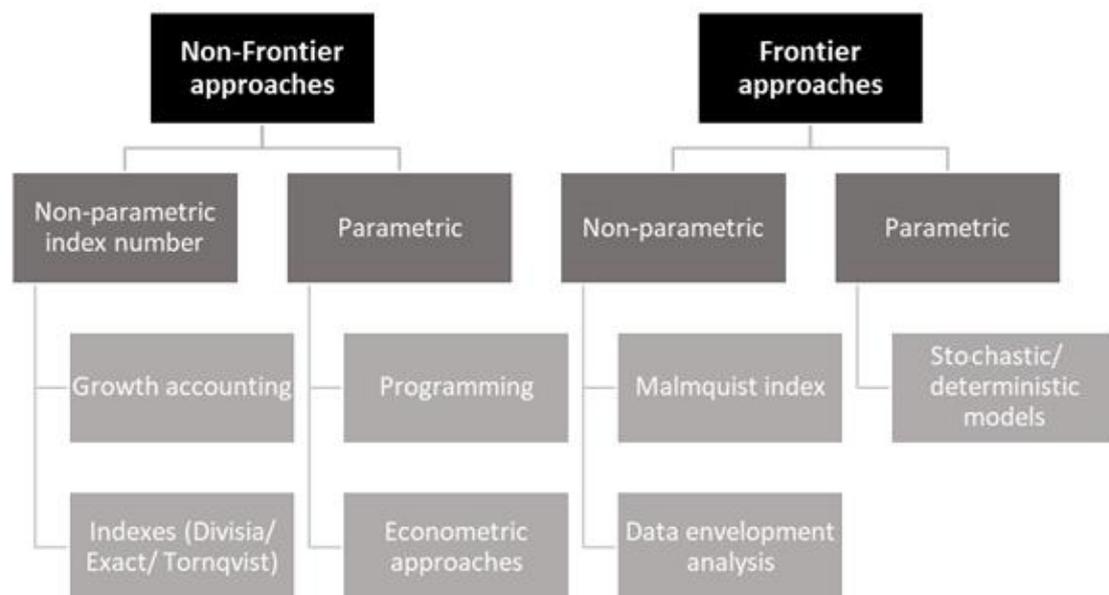


Figure 5:2 Classification of the estimation techniques. Based on publications in the JPA between 2014 and 2017.

Broadly, Del Gatto *et al.* (2011) highlight the main difference between non-frontier and frontier models. The primary reason leading to the implementation of frontier models is their ability to disentangle the main sources of productivity growth, which are technical efficiency and technological change. Technical progress measures the shift of the frontier over time and the change in technical efficiency measures the movement of an economy away from (or towards) the production frontier. Kumbhakar and Lovell (2000) and Kumbhakar *et al.* (2015) have provided an overview of stochastic frontier models. The

primary issue with such models is the degree to which variables are included in the deterministic part of the model (to set the frontier) and to what degree these same variables explain inefficiency and, hence, enter a determinant of the one-sided inefficiency term (Battese and Coelli, 1995). These models do not control for endogeneity and selection biases, which are detailed in the Research Design Chapter (Section 6.3.1.1, p. 158).

Van Biesebroeck (2007) publishes one of the most cited articles in productivity estimation after Cobb Douglas. He uses the Monte Carlo approach to investigate the sensitivity of the most widely used methods, which are data envelopment analysis, index numbers, instrumental variables, stochastic frontiers and semi-parametric estimation. He explores three different scenarios concerning measurement error and simultaneity bias, which is described in the Research Design Chapter (Section 6.3.1.1) and examines their credibility with Monte Carlo.

Van Biesebroeck (2007) suggests using index numbers for cases with small measurement error. GMM estimators are useful for estimating productivity levels. DEA is suitable when returns to scale are not constant and technology is heterogeneous. Parametric approaches are suitable when optimisation or measurement errors are minor. The authors ranked these techniques by the persistence of the productivity differentials between firms (in decreasing order). This is the order they proposed: the stochastic frontiers, GMM, or semiparametric estimation methods.

With the data proposed for this study (see Chapter 6), it seems counterintuitive to assume that variables could have little or no measurement error because of the survey nature and some variables like capital as it may be defined and estimated in various ways. Similarly, some technological heterogeneity should be assumed since all firms may not share the same technology. In this scenario, the author suggested using system GMM estimator.

The technological differences are arguably not too diverse in the UK. Technological change and technical efficiency change in Britain varies. However, the frontier approach may be more applicable to several countries where technology variation within companies is more apparent. Arguably, companies within the same sector can possess similar technology. If the technology is immutable, it does not contribute to productivity improvements. The same effects are present with technical inefficiency. If it does not vary over time, it also does not have any effect on the rate of change of productivity.

The review of techniques showed that frontier approaches are becoming less popular, while the usage of non-frontier approaches seems to be increasing. It appears that

researchers are looking into new ways to employ non-parametric approaches. This literature review did not identify any other paper that used decision trees to explain productivity. Thus, it seems reasonable to complement standard econometric techniques, which are also presented with other empirical examples in the following section, with such machine learning alternatives as Classification and Regression Trees described in Section 5.3. This could not only contribute to the literature on productivity estimation, but also assure the results estimated by one of the econometric techniques.

More specifically, summary statistics presented in Figure 5:3 (p. 104) shows that there were 87 empirical and 35 theoretical papers published between 2014 and 2017 (up to May). Theoretical papers mainly focused on either comparisons or improvements of methodology, which is the reason why they were excluded from further comparisons. Overall, more than two-thirds of these papers were looking at frontier analysis. However, this data shows that non-frontier approaches are becoming increasingly more popular, while frontier techniques seem to lose their popularity. With regards to underlying assumptions of data distribution, non-parametric approaches were most often used, while the popularity of parametric techniques decreased. Furthermore, semi-parametric studies seem to be increasingly more popular. However, none of the 2017 studies were published using this methodology. It is worth mentioning that this review indicates the most used and appropriate methods, rather than the exact figures since just one journal is included in the analysis.

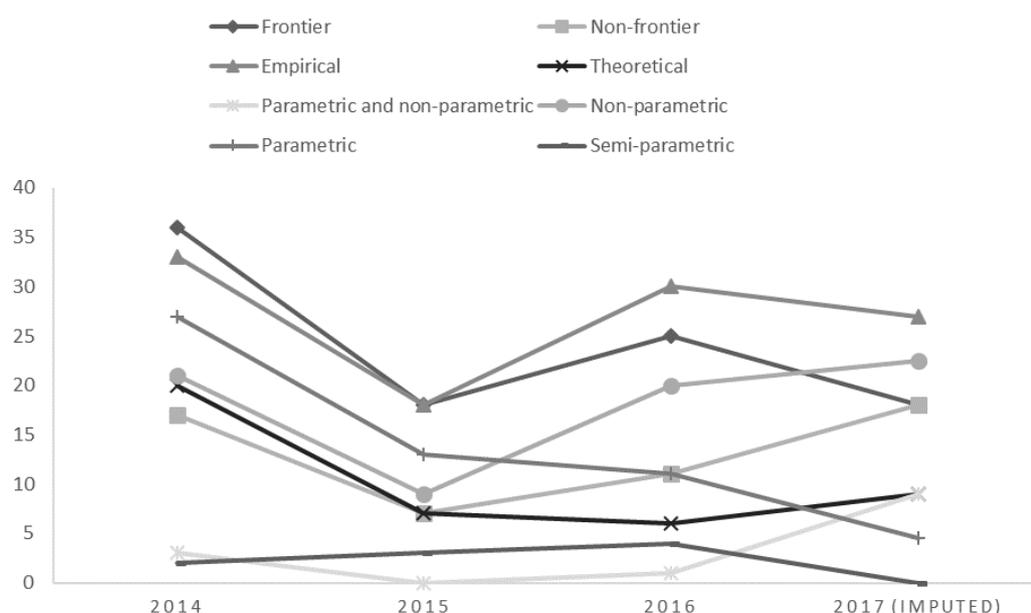


Figure 5:3 Count of articles published in different years by their approach between 2014 and 2017. Counts for 2017 were partly imputed for comparability. Source author's calculation.

5.1.4 Empirical Examples

All studies directly related to UK business rates (BRs) fit within the empirical debate on capitalisation, and are therefore discussed in the Empirical Review Chapter. For this reason, in this section, SBRR is assumed to be merely a cash inflow and greater attention is paid to the approach rather than results. As a result of the data and previous comparison, the focus naturally turns towards the econometric approaches. The underlying mechanisms of these estimators were discussed in Appendix 10.2.2. This section provides several examples of Difference in Difference (Section 5.1.4.1), Ordinary Least Squares (Section 5.1.4.2), Fixed Effects (section 5.1.4.3), Ordinary Least Squares with Matching (section 5.1.4.4) and Instrumental Variable (Section 5.1.4.5) estimation techniques.

The focus is on the approaches rather than findings since no studies have been identified to investigate how non-domestic property taxation relates to either survival or productivity. Other findings are too diverse and do not add much value towards the analysis. For instance, Irwin and Klenow (1996) find no impact on labour productivity of R&D subsidies for U.S. high-tech companies. Whilst, for Japanese forestry, Managi (2010) finds a negative relationship between grants and TFP; Einio (2014) reports no immediate impacts of R&D support programmes in Finland on productivity (although there is evidence of long-term gains). Huang (2015) shows that tax credit use among Taiwanese firms enhances their productivity. Koski and Pajarinen (2015) report that R&D subsidies have no statistically significant impact on labour productivity in Finnish firms during 2003-2010. Given the differing environments of the firms and various issues within the tax setting and estimation, these papers are not reviewed in this section.

5.1.4.1 *Difference-in-Difference (DiD) estimator*

One of the most fundamental methods to analyse BRs is the Difference-in-Difference estimator. This has been employed in various studies, such as Bronzini and de Blasio (2006) which evaluates the income of Italian investment incentives. This is a standard case described in Appendix 10.2.2. They use simple DiD to compare subsidised firms with the rejected applications. They find subsidies to be positive for the recipients. The problem with these analyses is the assumption that the differentials in growth for companies that experienced support would have remained the same to non-supported firms' differentials.

Earlier studies have consisted of simulations with macro data before and after the implementation of policies. For instance, Moore and Rhodes (1974) use the shift-share approach to find the effect of a policy change on investment and employment between 1960 and 1963. They construct a series to simulate what investment and employment would

have been after 1963 without any policy change. This is done by comparing the overall British industry growth rates to the investment and employment levels of each industry. This approach assumes a similar limiting assumption to the DiD estimator. The underlying assumption of this study is that growth rates in the development areas should be the same in the other regions. Canning *et al.* (1987) control for these. They investigate the differences between expected and actual values by exploiting data from before the change in policy. They claim that regional policy in Northern Ireland created 33,000 new manufacturing jobs. However, they also unrealistically assume that the expected and actual values would have continued to rise to the same degree, had there been no change. Thus, the self-selection issue, which will be defined in the Research Design Chapter (Section 6.3.1.1.2) is apparent. Furthermore, estimates are sensitive to the period used to investigate actual and expected values.

5.1.4.2 Ordinary Least Squares (OLS)

To control for these differences in observed characteristics between control and treatment groups, the DiD may be performed with OLS. Bergstroem (2000) analyses the effect on TFP by selective capital subsidies in Sweden. His treatment group consists of firms that were grant recipients in 1989 and the control group is a random sample. Whilst, the growth in output between 1989 and 1990/1993 is a dependent variable in his primary regression. The treatment variable is recorded as the amount of subsidy received in 1989. They estimate their equation with bounded OLS estimator to minimise the influence of outliers. They show that subsidies increase TFP in the short run, but are associated with reduced TFP in the long-term. However, they do not discuss the correlation between the error term and grant. The former comes from differences in unobserved characteristics across control and treatment groups. Furthermore, the correlation between the growth of factor inputs and error term is ignored and endogeneity of control variables is not accounted for, as it should be according to Froelich (2008) or the econometric issues in Section 4.6 (p. 89).

Additionally, Irwin and Klenow (1996) investigate whether R&D subsidies affect US high-tech companies' labour productivity. Their sample consists of 71 firms with annual observations between 1970 and 1993. They compare R&D of companies receiving support with unsupported companies. They acknowledge that businesses may have expected R&D intensity and that is why they received the support. To control for the differences between observations, they include age dummies and estimate their regression with OLS and weighted-least-squares (WLS). It is worth noting that they include the lagged dependent variable. As discussed in Section 4.6, neither OLS nor WLS provides an unbiased estimate

for an equation with a dependent lagged variable. They should include IVs. They find no effect on productivity.

Various simulations with US macro data indicates that capital subsidies are likely to cause lower consumption and lower employment. For instance, Lee (1996) uses multivariate regressions to investigate the effect of industrial policy on gross value added, capital growth and TFP with the data from South Korea. He allows for time and fixed effects. His model is estimated with three-stage-least-squares in order to control for the endogeneity of the treatment variables. Furthermore, weighted least squares are also employed to correct for cross-equation heteroscedasticity in this model. Nevertheless, as Bond (2002) shows, if the error term is autoregressive, the once lagged policy variables are not valid instruments since they are likely to be correlated with the error term. Similarly, Harris (1991) uses simulation to look at the effect of capital subsidies on employment within the manufacturing sector in Northern Ireland. This model includes production, factor demand and industry demand equations. The maximum likelihood is used to estimate the parameters. He uses these parameters to generate estimates of output, labour and capital and finds that although production has increased, employment has decreased significantly. This could be a product of substitution between labour and capital as discussed in Section 2.1.1.1.2. Whilst, Fuest and Huber (2000) suggest that governments should support areas with substantial unemployment by using investment subsidies instead of employment subsidies. Fuest and Huber use a model where businesses have different exogenously determined, productivity shocks or random output. The results indicate that the capital subsidy causes profits to rise. This attracts new businesses and, subsequently, increases aggregate employment. It also indicates the possible effects which SBRR might produce.

More related to this study is Restuccia and Rogerson's (2008) who look at how US policy distortions impact aggregate TFP with heterogeneous plants. It is related to this study as SBRR might increase capital. They use a neoclassical growth model. This model consists of the equal number of the plants that are subsidised and taxed. They find that policies, which create heterogeneity in the prices faced by individual producers, might reduce TFP and output by 30-50%. The major criticism of their approach is that in their setting the technology cannot vary over time.

However, Samaniego (2006) uses a relatively similar technique but allows technology to vary over time. He uses a general equilibrium model with establishment dynamics somewhat similar to the one presented in the Theory Review Chapter (Section 2.1.1.1.2) to quantify the relationship between the rate of embodied technical change and

the rate of entry and exit across industries. This is again relevant to the SBRR because, as discussed in the Introduction and Background Chapter, some politicians with SBRR aimed to target genuinely small or underperforming firms, especially during the recession. His productivity function consists of a capital, exogenous productivity growth factor, labour and idiosyncratic productivity shock, which follows a random walk. It takes the Cobb-Douglas form. He includes several restrictive assumptions such as costly entry depending on the technology acquired. He argues that support may help businesses to sustain their operations only if they are of sufficient value. SBRR may be too small to have a measurable impact. They also conclude that support for underperforming plants may increase the circulation of innovative technologies and increase productivity but reduce their labour productivity, employment and income.

5.1.4.3 Fixed effects

A possible correlation between the error term and the regressor is a problem for the OLS estimator; it is both biased and inconsistent in this setting. This is where the FE-estimator comes in. It provides a way of solving endogeneity problem and does so by using the fact that the individual effect/fixed effect is constant over time²⁶. Kangasharju and Venetoklis (2002) use a standard fixed effect estimator to understand whether Finish subsidies affect employment between 1995 and 1998. Their model includes control variables as well as two-digit level industry and time dummies to remove self-selection and simultaneity issues, which are discussed in the Research Design Chapter (Section 6.3.1.1). The dependent variable is estimated by subtracting the subsidy from the payroll to avoid a correlation between the amount of the grant and the outcome variable. It shows that firms receiving employment subsidies increase payroll by 11% on average. This paper allows subsidies to impact businesses for two successive years; the year they receive support and the following one. The method controls for simultaneity provided the firm's productivity is time invariant. However, productivity is unlikely to be constant over time. Therefore, treatment effect may be underestimated. Also, no attempt is made to overcome issues concerning the endogeneity of covariates. As discussed in Section 4.6 (p. 89), the inclusion of sales is likely to result in endogeneity problems.

5.1.4.4 OLS with matching

Ankarhem *et al.* (2010) used DiD estimator for firms sampled with propensity score matching. No statistically significant returns to equity are found. However, a significant positive impact is evident for a few employment estimates. Recently, King *et al.* (2011 and

²⁶ For further detail, see Appendix 10.2.2.1.

2016) have published such papers as “Why Propensity Scores Should Not Be Used for Matching” and “Comparative Effectiveness of Matching Methods for Causal Inference.” They argue that PSM just increases imbalance, model dependence, and bias. They show in several ways that random pruning applied in PSM increases the level of imbalance. They prove their theoretical point with 100 simulated datasets. The authors recommend using CEM method for larger datasets because of its speed and very natural setting. This is used and further defined in the Research Design Chapter (Section 6.2.3).

5.1.4.5 Instruments

5.1.4.5.1 Control functions

Olley and Pakes (OP) (1996) inspired by Ericson and Pakes (1995) and Hopenhayn and Rogerson (1993) formulate their model to investigate the dynamics of productivity in the US telecommunications equipment industry between 1972 and 1987. To achieve this, they form a two-stage approach. In the first stage, they obtain estimates of TFP by using a high-order polynomial. They estimate the effect on output from labour, capital and a polynomial function of investment and capital. They then use these estimates in the second stage as the dependent variable to estimate the treatment variable. They find that deregulation resulted in an increase in productivity and an increase in entry and exit. The primary limitations of this model are a monotonic relationship between a firm-level decision variable and the unobserved firm-level state variable productivity. The exit is also conditioned on the unobserved productivity. For further information on the OP estimator, see the Research Design Chapter (Section 6.3.1.2).

Levinsohn and Petrin (LP) (2003) improve Olley and Pakes’ (1996) approach by including intermediate inputs instead of investment. This makes assumptions checking easier and, most importantly, intermediate inputs need only to affect current productivity, unlike investment that may be correlated to future productivity. For further information on the LP estimator, see the Research Design Chapter (Section 6.3.1.2).

However, neither OP nor LP allows serial correlation, unobserved heterogeneity (across firms) in prices of labour or intermediate inputs, while only OP rules out unobserved heterogeneity (across firms) in the price of investment or capital adjustment costs. This methodology has been applied in the recent studies (Maiti, 2013; Ilmakunnas and Piekkola, 2014; Malik, 2015; Ilmakunnas and Maliranta, 2016). For instance, Goya *et al.* (2016) investigate innovation spillovers in Spain between 2004 and 2009. They apply a very similar framework as developed by Olley and Pakes (1996). They do not acknowledge

price endogeneity and instead of materials, as suggested by LP, they include investment. They conclude that R&D has no effect to TFP but spillovers do have.

5.1.4.5.2 Other instrumental variable approaches

A more mathematical introduction to instrumental variable approaches is provided in Appendix 10.2.2. Wright (1928) is the first to apply instrumental variables to overcome the endogeneity that arises when estimating simultaneous equations. An advanced model which allows inclusion of more than one model is developed by Theil (1953). This is called the two-stage-least squares method. More recently, Criscuolo *et al.* (2007) investigate how firms are affected by investment subsidies. They use within estimator for matched data from Assistance Management Information System (SAMIS) database, the Interdepartmental Business Register (IDBR) and the Annual Respondents Database (ARD). As an instrument for treatment status, they use dummies representing the different levels of support to which plants are entitled. They call these “synthetic instrumental variables” as they are constructed based on the rule changes and not changes in the area. However, they have to estimate weights as these are not provided by the EU. Additionally, subsidy levels differ among regions. Therefore, they perform ordered probit regression to estimate expected subsidy level. They find that areas eligible for business support create significantly more jobs but have no effect on productivity. Also, the treatment effect exists solely for small firms, but not big businesses.

Finally, Bournakis and Mallick (2018) employ an unbalanced panel of 7,400 manufacturing UK firms during 2004 and 2011. They compare five methodologies: Superlative Index Numbers, System-GMM, OP, LP and Akerberg *et al.* (2015). The mechanisms of the last three approaches will be discussed in detail in the Research Design Chapter (Section 6.3.1.2) but essentially Akerberg *et al.* (2015) critique OP and LP’s assumption on labour being perfectly adjustable and suggest that it should depend on labour productivity. Wooldridge (2009) accommodates their assumption by proposing one stage GMM estimator. It avoids potential correlation between errors in two steps and can produce robust standard errors, unlike other semi-parametric techniques that rely on bootstrapped standard errors. Bournakis and Mallick measure the dependent variable as value added (total sales minus materials/inventories). They use imputation only to employment variable and loose data for other observations. Figure 5:4 shows the estimates produced by all estimators. The first column refers to system GMM dynamic model. Its Sargan test suggests that the instruments were valid. 2-4 columns correspond to OP, LP and ACF. Wald test shows the decreasing returns. Capital is insignificant in OP estimator and ranges between 0.01 to 0.13, whilst labour from 0.33 to 0.56. The authors suggest that ACF

is superior because of its assumption of labour input being dynamic, whilst system GMM is the second-best approach. Bournakis and Mallick later turn to the impact of corporate taxation on productivity within a TFP catch-up framework. They find that higher rates of corporate taxation slow down the rate of TFP growth.

Production function estimates for UK manufacturing firms, 2004–2011.

	GMM-SYS	OP	LP	ACF
k_t	0.11* (0.036)	0.012 (0.012)	0.117*** (0.008)	0.129* (0.07)
l_t	0.530*** (0.060)	0.561*** (0.011)	0.325*** (0.016)	0.437** (0.036)
y_{t-1}	0.797*** (0.033)			
k_{t-1}	0.019 (0.048)			
l_{t-1}	-0.209*** (0.055)			
Constant	0.655*** (0.113)			
Observations	27155	49687	51815	42631
No Firms	6529	9029	9319	6477
Wald test/p value	139.95/0.000	655.4/0.000	687.17/ 0.000	5.41/0.02
AR(1)/p value	-5.178/0.000			
AR(2)/p value	-0.598/0.549			
Sargan/p value	78.593/0.137			

Figure 5:4 Results of various estimators by Bournakis and Mallick (2018:582); the upper table compares coefficients of capital (k), labour (l), lagged output (y) in GMM, OP, LP and ACF methods; the bottom part defines the key characteristics and tests of those models. Source: Bournakis and Mallick (2018:583).

5.1.4.5.3 Generalised Method of Moments

One of the most recent analyses on UK productivity comes from various research papers from Harris and Moffat. They work with Annual Respondents Database and apply GMM-system estimator. They have published recent studies on both Britain's (Harris and Moffat, 2017 and 2015) and Scotland's productivity puzzle (Harris and Moffat, 2016). Furthermore, they look how various factors impact TFP: export and import on the productivity (Harris and Moffat, 2015), Local Enterprise Partnership regions (Harris and Moffat, 2015), FDI (Harris and Moffat, 2013), urban location (Harris and Moffat, 2012), higher education institution-firm knowledge links (Harris *et al.*, 2011) and probably the most importantly, regional selective assistance (Moffat, 2015). All these studies provide an important contribution to a productivity analysis directly related to the UK.

Recently, Harris and Moffat (2017) update their paper on productivity determinants between 1997 and 2008 with data between 2008 and 2012. They investigate plant-level determinants of TFP in the UK between 1997 and 2008 with data from ARD. As in all previously mentioned studies conducted by them, they choose Cobb-Douglas functional form and estimate their model with two-step system GMM introduced by Wooldridge (2009) which correct for serial correlation by using lags, thus, it does not have to impose any functional form. Further discussion of this method is provided in the Research Design Chapter (Section 6.3.1.2). Their dependent variable is real gross output deflated by two-digit ONS producer price indices. Their independent variables are real intermediate inputs (deflated by two-digit ONS producer price input indices), employment, capital (where real value of plant and machinery hires is deflated by producer price index), age, Herfindahl index, industry agglomeration externalities, diversification externalities and many different dummies: single-plant, multi-region enterprise, Greenfield/Brownfield US-owned, Greenfield/Brownfield EU-owned, Greenfield/Brownfield other foreign-owned, outwarded FDI, R&D, assisted area, region, city, industry (two-digit level). These seem to be appropriate and consistent with forces identified in Chapter 4.6.

They explain that the service sector has accounted for the entire decline during the recession. Existing plants in both sectors experienced a decrease in TFP. However, the manufacturing sector has many entrants which offset the total decline. The smallest plants were hit by the recession the most. These results are similar to Field and Franklin (2013), who emphasise the need to include sectoral variations to estimate productivity.

Harris and Moffat's (2017) supplementary material provides estimates of these with data between 1997 and 2012. They separate the service sector and manufacturing to deliver estimates of the effects of other variables. For manufacturing plants, they provide coefficients for plants according to their technical development. All enterprises seem to have the three key variables significant; only high-tech firms are not influenced by employment and med-high technology firms are unaffected by capital. R&D does not seem to matter for highly technological firms, as opposed to the others. On the other hand, single plant enterprises tend to increase productivity for all, just not high technology companies. Thus, it should be apparent that other factors, not just SBRR may be causing growth in SMEs. Additionally, our study may contribute to explaining this result because single-plant enterprises mainly receive SBRR. There are little other benefits that may be causing an improvement in productivity. Foreign ownership dummies and outward FDI investments are mostly insignificant in their model.

Service sectors are grouped according to their knowledge intensity and follow a similar pattern to manufacturing plants. However, they have a few differences. Unlike in manufacturing industries, firms with high knowledge intensity do not experience different patterns. Also, Herfindahl index, agglomeration and diversification externalities are more apparent. They are somewhat more affected by foreign ownership. When it comes to single-plant dummy, firms with average-low knowledge intensity (KI) seem to be less productive, while high KI and other low KI seem to have increased productivity.

Although relaxing some limitations of LP and OP approaches, this methodology brings further restrictions. The DP approach does not need the assumptions that generate invertibility of the variable input demand function; it seems to rely on the linearity of the TFP process, unlike LP.

It is worth noting that numerous attempts have been put forward to solve the UK's productivity puzzle (e.g. Disney *et al.*, 2013; Goodridge *et al.*, 2013; Sargent, 2013; Barnett *et al.*, 2014; Blundell *et al.*, 2014; Riley *et al.*, 2015; Patterson *et al.*, 2016 and Oulton, 2018). However, Harris and Moffat's (2017) seem to address the main issues with their estimator, using more appropriate estimation techniques working with the endogeneity of unobservable variables with more recent data.

5.2 SURVIVAL ANALYSIS (SA)

The previous part of the chapter focused on the productivity. This section discusses survival approaches with an aim to explain survival analysis. To achieve this, the section discusses the most popular tool for studying the dependence of survival time on predictor variables. By concentrating on rates, SA handles different follow-up times, increases statistical power and permits the use of time-changing predictor variables. Multiple articles such as Sainani (2016), Kartsonaki (2016) and Flynn (2012) are devoted entirely to the methodology of SA, which are reviewed in the following paragraphs. The fundamental methods are generally more widely accepted and used. For this reason, rather than conducting the literature survey on survival analysis, this section focuses on the most established method, which is the Cox based regression.

5.2.1 Fundamentals of SA

The description starts with the basics of SA, so that advancements in the approach could be introduced. The advancements made it possible to reduce the amount of limiting assumptions and correct for various estimation flows.

Broadly, SA is the analysis of time-to-event data. The objectives of SA include:

- Analysis of event time patterns
- Comparison of survival time distributions in different groups of subjects
- Judgement as to the degree that specific factors may affect the risk of an event of interest.

Thus, SA examines and models the time it takes for events to occur. These are often called survival times. Time-to-event variables record both whether firms have a binary outcome (died/survived) and when events occurred. This helps to estimate rates rather than just proportions.

When considering the likelihood of survival, an intuitive approach might be to calculate the risk of an event occurring by measuring the proportion of surviving firms after a fixed time. For instance, the percentage of deaths after one year of introduction of SBRR. However, there are fundamental issues with this approach. For example, the period of observation expires, or a firm is removed from the study before the event occurs. Then, these companies cannot be included in the analysis even though these enterprises could have been observed for 10 or more years. These incomplete observations cannot be ignored, but need to be handled differently.

This is called *censoring*, particularly this example and our data takes the most common form called right-censoring. Alternatively, observations are left-censored if their original time at risk is unknown. Observations that are both right and left-censored are called interval-censored. Censoring complicates the likelihood function and the estimation of survival models and is conditional on the value of any covariates in a survival model. Another feature of survival data is that distributions are asymmetric and thus simple techniques based on the normal distribution like OLS cannot be used. We choose the technique depending on the censoring.

Furthermore, one of the primary conditions for the survival functions is that covariates in a survival model and on an individual firm's survival to a particular time must be independent of the future value of the hazard for the individual company. Violating this condition would result in biased estimates. This condition is not violated in this study since the survey is ongoing and data is available until 2016, while the main changes took place around 2005 and 2010.

5.2.2 Main Definitions of SA

Kartsonaki (2016) revisits the definitions of survival functions in clinical studies. These can be easily applied for the business studies. The hazard function is often defined as the probability of closure (or death) in period t , having survived until period t :

$$s(t) = P(T > t), \text{ where } 0 < t < \infty$$

While the probability density function $h(t)$ is the occurrence of events per unit time:

$$h(t) = -\frac{ds(t)}{dt}$$

Then, the cumulative hazard function is the rate at which actions occur for firms that are surviving at the time t :

$$H(t) = \int_0^t \left(\lim_{\delta u \rightarrow 0^+} \frac{P(u \leq T < u + \delta t | T \geq u)}{\delta u} \right) du$$

, where t_i is the time of survival (censoring) and δ_i is a censoring indicator and

Furthermore, Kartsonaki shows the relationship between cumulative hazard function to the survival function. The higher hazard function usually results in the lower the survival probability:

$$S(t) = e^{-H(t)}$$

Finally, she explains that each firm with an observed event time t_i contributes the hazard rate at t_i multiplied by the survival to t_i . Furthermore, each company that is censored at t_i contributes the survival to t_i . To quantify, she assumes that $\delta_i = 1$ for the event that occurred like closure and $\delta_i = 0$ if information about firms is just partly known (censored). Then, for right-censored data, the data for firm, i , can be represented with (δ_i, t_i, x_i) , where x_i are the covariates holding other information on that firm. The likelihood function becomes:

$$L = \prod_{j \text{ had event}} f(t_j) \prod_{k \text{ censored}} S(t_k) = \prod_{i=1}^N h(t_i)^{\delta_i} S(t_i)$$

In general, SA aims to estimate and plot the survival function so that either the survival rates of one group could be investigated or two groups could be compared. The often used estimator is Kaplan-Meier's product limit estimator (Sainani, 2016; Kartsonaki, 2016 and Flynn, 2011). It includes the number of firms remaining in the cohort at different

points and the cumulative number of events that have occurred up to that point. Assuming that $t_1 < t_2 < \dots < t_k$ is the observed event times, $n = n_0$ is the sample size, d_j is the number of firms who have an event at time t_j , where $n_j = (m_j + d_j) + \dots + (m_k + d_k)$ is the number of firms before t_j :

$$S^*(t) = \prod_{j: t_j \leq t} \frac{n_j - d_j}{n_j}$$

Another common practice is to use parametric methods by assuming that survival function takes some shape. Probably the most commonly applied distributions are the exponential, Weibull and log-logistic. However, when the focus is on the death and the origin time is a firm's birth, then using an exponential model is an invalid option as it assumes a constant hazard such as $h(t) = v$, which implies an exponential distribution of survival times with density function $p(t) = ve^{-vt}$. However, the death probability (hazard) is unlikely to be constant with age, which makes this distribution unreasonable for the analysis. Other commonly applied models are logarithmic $\log(h(t)) = v + pt$ leading to Gompertz distribution of survival times and $\log(h(t)) = v + p \times \log(t)$ leading to the Weibull distribution of survival times. These distributions allow a monotonic (either continuously decreasing or increasing) hazard.

However, it is also problematic to argue that the data exactly follows these shapes. Cox (1972) reveals that it is unnecessary to identify a functional form. However, if one wants to assume a functional form for the baseline hazard, one may lose efficiency which is a common sacrifice to take (Moffan, 2015) when the distribution is unknown.

A Cox (1972) proportional hazards model takes the following shape:

$$h(t; x) = h_o(t)e^{\beta x}$$

where $h(t)$ is the baseline hazard, x is a covariate and β is a parameter to be estimated. This variable represents the effect of the covariate on the outcome.

5.2.3 Empirical Examples

Many studies have considered various aspects of business survival. In the same vein to productivity, these studies will only be mentioned (Section 5.2.3.1) rather than detailed since they do not contribute to the theoretical development of the question which this thesis is investigating. No studies looking at BRs or SBRR were identified. Thus, Section 5.2.3.2 will discuss recent empirical studies using preferable approaches described in Section 5.2.1.

5.2.3.1 Overview of Recent Empirical Studies on Survival

There have been many literature reviews published on methodological issues associated with corporate failure prediction models. These include, but are not limited to, Dimitras *et al.* (1996), O'Leary (1998), Tay and Shen (2002), Balcaen and Ooghe (2006), Aziz and Dar (2006), and Ravi and Ravi (2007). More recent micro studies focusing on firm survival (Carr *et al.*, 2010; Coeurderoy *et al.* 2012; Colombelli *et al.* 2013) show the importance of the following conditions: firm size, sector, and innovation intensity. Furthermore, many studies looking at specific factors that impact on firms' performance have been identified. Some look at firm-specific characteristics, such as firm size and age (Evans and Leighton, 1990; Dunne and Hughes, 1994) or founders' individual traits, such as human capital (Colombo and Grilli 2005, and 2009). Others focus on such industry-specific characteristics as the nature of technology (Malerba and Orsenigo, 1999) or entry barriers (Geroski, 1995).

5.2.3.2 Cox Proportional Hazard (CPH) Model

More related to this study is Girma's *et al.* (2007), who employ Irish data in a Cox proportional hazard model to investigate the effect of grants on survival. The control group was matched to the treatment group by using propensity score matching. They conclude that a subsidy lowers the likelihood of closing. However, they did not follow CPH methodology as described by Gelman and Hill (2007). Their probit model lacks consistency with the CHM methodology. Some variables are included in the probit model that are excluded in the CHM model and vice versa. If there were any unobserved determinants of both the outcome and treatment variables that correlate with the treatment and outcome variables, the estimated treatment effect would be biased. Harris and Trainor (2007) use the same Irish data and CPH. They find that treated plants had a 24% lower probability to close. Having used predicted values from a Tobit regression, they find 15% lower probability. However, the treatment variable may be replaced with the predicted values from the Tobit model only if the model is linear (see Bijwaard, 2008) and it is not the case.

More recently, Harris and Moffat (2016) look at plant closure in Britain with particular emphasis on TFP with ARD data between 2002 and 2012. They include their productivity estimation into CPHM (discussed in Section 5.2.1). Other variables they control for are a capital-labour ratio, age, employment, relative plant/employment size, region and dummies of FDI, outward FDI R&D and location. To satisfy the primary hazards assumption, they stratify this model on age, employment, relative employment size and relative plant size.

In a similar manner as productivity estimates (see Section 5.1.4.5.3, p. 111), they provide their regression results for all variables in supplementary material. They produce multiple regressions for manufacturing and service sector. Also, they differentiate between technology in the manufacturing sector and knowledge intensity in the service sector. The main focus is on the firms that have medium to low technology or knowledge intensity as the government aims to provide SBRR for underperforming companies. R&D seems to influence very low and very high technology firms positively, but do not influence the service sector. A more urban location is necessary for medium low technology businesses and high/low knowledge intensity service providers. Unlike in manufacturing industries, FDI and outward FDI seem to predict the probability of survival for the service sector.

The only criticism in this methodology is that the authors used longitudinal data but did not cluster according to the firm's ID. This potentially creates problems because each observation is treated independently from other observations of that firm. Additionally, their productivity is estimated with all variables later included in the CPH model which may introduce bias on the effect of TFP on the survival. Their regression coefficients may be larger than the actual values.

5.3 MACHINE LEARNING APPROACHES

As computing power has grown, complex regression techniques have emerged to analyse data. While this growing set of techniques has proved useful in modelling certain data, it has also enlarged the burden on statisticians in selecting suitable techniques as, for instance, detailed in Section 5.1.3. In response to this growth in complexity, a simple tree system, the Classification and Regression Tree (CART) analysis, has become increasingly popular and is particularly valuable for this interdisciplinary study. None of the studies identified used tree approaches for the questions related to productivity (Section 5.1.3). However, there have been some studies that used CART for survival analyses. Throughout this section, it is argued that these approaches could provide valuable insights by grouping the data and extracting where the effects are the most present. This chapter aims to define CART and provide reasoning as to why this technique may supplement both productivity and survival estimation.

There have been several literature reviews conducted on the development of decision trees (Loh, 2008; 2011, 2014; Merkle & Shaffer, 2009; Strobl *et al.*, 2011). Leblanc and Crowley (1995) review survival trees up to 1995, while Hamad *et al.* (2011) presents a more updated non-technical account of the developments in tree-based methods for the

analysis of survival data with censoring. They acknowledge that the research on survival trees has taken three directions: multivariate and correlated survival data (Fan *et al.*, 2005 and 2006), ensemble methods with survival trees (Ishwaran *et al.*, 2004 and 2008) and time-varying covariates and time-to-event variables measured on a discrete scale (starting with Hamad *et al.*, 2011). The latter is central to this study (see Sections 5.3.1.2.1 and 5.3.1.2.1).

This literature is used for the basis of this section, which aims to describe fundamental CART techniques and their appropriate extensions for this study. To achieve this aim, the section starts with the fundamental concepts. Once they are introduced, it continues with the main mechanisms used with decision trees (Section 5.3.1) and survival trees (Section 5.3.1.2). Simultaneously, these are compared with usual regression techniques (Section 5.3.1.1). Finally, the section develops into examples where these trees were implemented.

5.3.1 Introduction to decision trees

The underlying approach depends on the structure of the outcome variable. The more straightforward version of the tree is classification, where the outcome variable might be classified (e.g. binary outcome) would be organised (or classified) into groups by the outcome variable. On the other hand, when the outcome variable is continuous, the data will be exploited to predict the outcome, so employing the regression trees. Thus, the basis of the split in classification trees is homogeneity by categorising based on similar data and, then, filtering out the extreme values to make it more consistent. In the second case with continuous variable, a regression model is fitted to each of the independent variables, isolating these variables as nodes where their inclusion decreases error. A visualisation of this process is presented in the Figure 5:5 (p. 119).

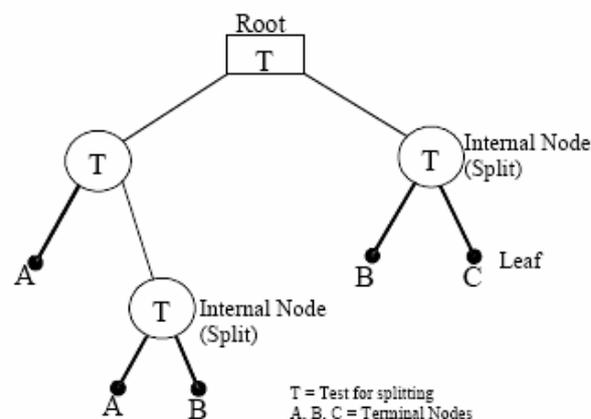


Figure 5:5 Structure of the CART. Source: Majid (2014:4).

5.3.1.1 Comparison with the Regression and Definitions

The trees are proposed to be used instead of the more usual regression style approaches because of how it splits the data. In the regression approaches, one equation is usually developed to represent the whole data (see Sections 5.1.4 and 5.2.3). In the CART setting, *recursive partitioning* is the method by which CART operates. Broadly, it operates by subsequently dividing the data into smaller portions to isolate the most important variables. The data is partitioned into sections where variable interactions are evident with some significance level. More specifically, the CART algorithm uses the recursive partitioning to generate a tree where each node (T in Figure 5:5) represents a cell of the partition. A *node* represents a single input variable (in Figure 5:5, it is noted as T) and a split point on that variable, assuming the variable is numeric. A simplified model that is applied to that cell is only attached to each cell.

This is relatively similar to conditional modelling. Once we go down the nodes that a particular variable is conditioning on, the final split or node is referred to as a leaf. *Leaf* nodes (also called terminal nodes) of the tree contain an output variable (y) which is used to make a prediction. In Figure 5:5, A , B , and C are each terminal nodes (*leaves*), implying that this is the final split. Any further splitting does not clarify an adequate amount of the variance in describing the outcome variable. Finally, *The Gini Impurity* is an impurity-based criterion that measures the deviations between the probability distributions of the target attribute's values. This has been used in various works such as Breiman *et al.* (1984).

5.3.1.1.1 Mathematical explanation

Morgan and Sonquist (1963) were the first to publish a regression tree algorithm. Their approach uses binary splits with a single covariate. As mentioned in Section 5.3.1.1, ordered continuous covariates are split with a constant, while categorical per their values. For continuous variable, there are $(n - 1)$ such splits on X . For categorical variable having m distinct observed values, there are $(2m - 1)$ splits of the form $X \in A$, where A is a subset of the X values.

Let the parent node be split as S and the left, L , and right, R , be subnodes as well as y be a response value in node S and \bar{y} is the average response values in node S . For regression trees, the sum of squared errors (SSE) is used to measure the heterogeneity of a node S :

$$I_S = \sum_{i \in S} (y_i - \bar{y})^2$$

Then, after splitting into L and R , the decrease of heterogeneity of S is:

$$\Delta I(S, L, R) = I_S - (I_L + I_R)$$

It selects the split that minimises the sum of the impurities in the two children nodes. Splitting stops when the decrease in impurity is lesser than a fraction of the impurity at the root node. The node sample mean is the predicted outcome variable value in each terminal node. The result is a constant estimate of the regression function.

Messenger and Mandell (1972) apply these ideas to classification trees, in which the outcome variable becomes categorical. They choose splits to maximise the sum of the number of observations in each category. The *Gini index* of diversity or entropy is often used to reflect the impurity of a node, which defines the node splits where each split maximises the decrease in impurity. Let G be categories in the data, $\pi_S(g)$ be the proportion of the observations from the G^{th} category in node S and n_S be the number of cases in node S . Then, the Gini index is

$$I_S = \sum_{g=1}^G \pi_S(g)[1 - \pi_S(g)]$$

and the entropy is:

$$I_S = \sum_{g=1}^G \pi_S(g)[-\ln(\pi_S(g))]$$

Taking any of these I_S , the decrease of impurity of node S after the split is defined by $\Delta I(S, L, R) = I_S - (I_L + I_R)$. The chosen split for each node is the maximising $\Delta I(S, L, R)$. This process is repeated until the largest possible tree is obtained and no more nodes can be split.

5.3.1.1.2 Random forests

A large decision tree may lead to large prediction variance. Breiman (1996), Buhlmann and Yu (2002) and Friedman and Hall (2000) use the bootstrap aggregation method to solve the overfitting problem. This is called bagging and is a basis for random forests. By averaging results from bootstrap samples, bagging smooths the response surface and hence reduces the prediction variance. However, a straightforward interpretation is impossible as there is now no single decision or regression tree. Instead of the tree, the variable importance is often estimated. The method is used for sensitivity analysis and is further discussed in the Research Design Chapter (Section 6.3.3).

5.3.1.2 Survival trees

The chief issue with applying statistical techniques like CPM to closure prediction (as detailed in Section 5.2.3.2), is that such assumptions like the similar baseline hazard function for the whole model, are often invalid in practice, which makes these techniques theoretically invalid (Nishitani *et al.*, 2014). On the other hand, there are many improvements in these methodologies such as stratification to avoid the violation of the previously mentioned assumption.

More recently, several studies have shown that more creative techniques, such as Decision Tree (DT), Artificial Neural Networks (ANN), Support Vector Machine (SVM), and Case-Based Reasoning (CBR) can be applied for closure prediction (Olson *et al.*, 2012; Tsai and Wu, 2008). The principal advantages of these techniques are the ability to extract knowledge from training samples automatically and to estimate without assuming certain data distributions.

The concept of using tree-structured data analysis for censored data has been established around the 1980s with Ciampi *et al.* (1981) and Marubini *et al.* (1983). Gordon and Olshen (1985) are known to publish the pioneering paper comprising the primary elements of survival trees. They used impurity reduction based on KM curves as their splitting rule, cost-complexity pruning and cross-validation as their pruning rule and implemented the estimation with STREE.

Inspired by Gordon and Olshen's (1985) ideas on the log-rank statistic, Ciampi *et al.* (1986) employed the Akaike Information Criterion (AIC) for choosing the tree size. AIC is related to the log-likelihood by adding a penalty built on the number of parameters. The algorithm begins at the root node with all observations. It searches through all possible binary splits with the covariates to select the most accurate one with regards to splitting criteria (usually an impurity measure). In the CART, the procedure is constantly repeated on the children nodes until a stopping criterion is met. Then, to find a suitable subtree, a pruning and selection method is employed.

In the survival setting, the predictor is an ensemble shaped by joining many survival trees. Ishwaran *et al.* (2008) term the typical method to analyse survival with random forests as random survival forests (RSF). These extensions of the random forest approach to SA offer an appropriate technique to shape risk prediction models. In this method, a group of survival trees is grown and the splitting is executed by maximising the log-rank statistic in each node. The predictions are estimated by averaging the cumulative hazard estimates in the leaves, as estimated by the Nelson–Aalen estimator. This bypasses the need

to impose constraints on the distributions (e.g. parametric or semi-parametric). It allows for accurate prediction as well as helps to deal with high-level interactions and higher-order terms in variables (Ishwaran *et al.*, 2008).

5.3.1.2.1 Survival trees with longitudinal data

Returning to the Cox proportionate hazards model: $\alpha(t|x) = \alpha_0(t)s(x)$ with $s(x) \geq 0$, where $\alpha_0(t)$ is the baseline hazard, Leblanc and Crowley (1992) construct a tree representing the relative risk function, $s(x)$. Their algorithm splits the covariate space based on a rule that maximises the reduction in the one-step deviance realised by the split, which is defined as the difference between the log-likelihood of the saturated model and the maximised log-likelihood. The baseline cumulative hazard function is estimated by the Nelson-Aalen estimator.

None of the previous methods (Bacchetti and Segal, 1995; Huang *et al.*, 1998; Xu and Adak, 2002; Bertolet, et a., 2012) dealing with time-varying indicators can be implemented in the secure lab (Fu and Simonoff, 2015) and are not based on the two established and widely used survival tree methods. Thus, they are not discussed here. Fu and Simonoff (2016) have proposed an extension of Leblanc and Crowley's (1992) model with new survival trees for left-truncated and right-censored(LTRC) data with time-varying covariates. These are modifications of Cox Regression.

As previously described, the Cox proportionate hazards model can be defined as: $\lambda(t|x) = \lambda_0(t)s(x)$, where t is the observed event/censored time, x is the vector of covariates, $s(x) \geq 0$ and $\lambda_0(t)$ is the baseline hazard.

Leblanc and Crowley (1992) construct a tree representing the relative risk function, $s(x)$. Fu and Simonoff (2016) introduced survival trees for left-truncated and right-censored data. One of the proposed trees is based on previously defined CPH. The following definitions are based on their notations.

Assuming that T^* is the set of leaves (or terminal nodes), S_h is the set of observation labels, $\{i: x_i \in x_h\}$ for observations in the region x_h corresponding to node h . $\lambda_0(t)$ is the baseline hazard and $\Lambda_0(t_i)$ cumulative hazard functions. Furthermore, the hazard function, $\lambda_h(t) = \theta_h \lambda_0(t)$, is assumed to be true and θ_h is the nonnegative relative risk of node h . As a result, the full likelihood function could be written:

$$L = \prod_{h \in T^*} \prod_{i \in S_h} (\theta_h \lambda_0(t_i))^{\delta_i} e^{-\Lambda_0(t_i) \theta_h}$$

Then, Leblanc and Crowley (1992) estimate θ_h by:

$$\theta_h^* = \frac{\sum_{i \in S_h} \delta_i}{\sum_{i \in S_h} \Lambda_0(t_i)}$$

where Λ_0 is estimated using all data at the root node by the Nelson-Aalen estimator. Thus, the observed number of events divided by the expected number of events in node h assuming observations in node h are randomly sampled from the root node.

Let $L_h(\text{saturated})$ be the log-likelihood of the saturated model and $L_h(\theta_h^*)$ is maximised log-likelihood with $\Lambda_0(t)$ known. Then, the deviance for node h is $R(h) - 2[L_h(\text{saturated}) - L_h(\theta_h^*)]$. The splitting criteria is to reduce the deviance residual: $D_{parent} - \{D_{left\ daughter\ node} + D_{right\ daughter\ node}\}$ where $D_h = \sum_{i \in h} d_i$ with the contribution of the i^{th} observation is:

$$d_i = 2 \left[\delta_i \ln \left(\frac{\delta_i}{\Lambda_0(t_i) \theta_h^*} \right) - \delta_i + \Lambda_0(t_i) \theta_h^* \right]$$

It is similar to Poisson regression which is used to fit trees with popular method called rpart trees in R. The Research Design Chapter (Section 6.3.2.2) will further show how this approach was used for this analysis.

5.3.1.3 CART with longitudinal data

There have been no methods or articles identified dealing with productivity by using machine learning approaches. It is likely that this is because until recently the machine learning data has been incapable of accommodating longitudinal data. Recently a few scholars have provided some regression (Sela and Simonoff, 2012) and boosting (Pande *et al.*, 2017) extensions to the decision trees. These seem to be a useful supplement for productivity estimators.

CPH model, as discussed in Section 5.2.3.2 (p. 117) can cluster on ID so that dependence of the observations could be established to estimate more precise standard errors. However, this is not possible with tree-based methods. Hamad *et al.* (2011) and Sela and Simonoff (2012) have provided an overview of the developments within machine learning methods that allow better estimates to be achieved with longitudinal data. Segal (1992) and De'Ath (2002) are the first to attempt to apply a regression tree methodology for longitudinal data. As Sela and Simonoff (2012) point out, these trees are not suitable for the estimation of forthcoming periods because they use a single set of attributes for all observational periods, thus removes the capability of observing time-varying attributes

after the initial period. A few further extensions of this model have been proposed (Larsen and Speckman, 2004, Hsiao and Shih, 2007) with one or more limitations.

Other methodologies have emerged throughout the years. Lee (2005 and 2006) and Lee *et al.* (2005) partition by estimating a parametric model with maximum likelihood at each node. Once estimated, they partition on the residuals from estimation. Their method is unable to predict forthcoming observations and is dependent on a single set of characteristics for all periods. Abdolell *et al.* (2002) use a longitudinal outcome variable to identify clusters grounded on a single attribute. Ritschard and Oris (2005) employ classification trees for such data. They consider lagged response values as potential predictors, but they do not consider them to be inherently multidimensional.

More recently, two different random forests extensions dealing with longitudinal data have been identified: The Random Effects Expectation Maximization (REEM) trees introduced by Hajjem *et al.* (2011) and Sela and Simonoff (2012) and advanced by Fu and Simonoff (2016). They use longitudinal and cluster unbalanced data with time-varying features. While Pande *et al.* (2017) and Miller *et al.* (2017) have introduced boost multivariate trees to fit a flexible semi-nonparametric marginal model for longitudinal data, both methods seem to provide more efficient results. However, the REEM methodology is easier to implement in the Secure Lab. Thus, it is further discussed in the Research Design Chapter (Section 6.3.1.3).

5.3.2 Empirical examples

Jabeur and Fahmi (2014) compare three approaches: Discriminant Analysis, Logit model and Random Forest to predict corporate financial distress. They look at three years (2006-2008) of 800 French SMEs, consisting of 50% healthy and 50% defaulting firms. Unfortunately, they do not extend the analysis and use rather basic models. However, they suggest that the random forests technique is better than the alternatives. In general, machine learning approaches are becoming increasingly more popular in many fields, but the literature review could not identify any studies dealing with either firm survival after governmental intervention or taxation in general. The clear majority of literature comes from the environmental science journals.

Weinblat (2017) uses data from nine EU countries, including the UK, to ascertain which firms become high growth firms as defined in Section 4.7.2. They apply standard random forest estimation. They use a confusion matrix, ROC curve to validate their results and variable importance rankings to see which variables are thought to be the most influential. Surprisingly, their results suggest that high growth firms are larger and older

than other companies, which are contra-intuitive given the previous literature as discussed in Section 4.7.2. The central criticism of this study is that it does not exploit the longitudinal nature of the data. It treats each year's observations as separate. Thus, the resulting estimate may be biased.

During the co-citation analysis of the REEM approach, there have been six articles identified. These articles are mainly related to biology (Rudolph *et al.*, 2012; Jones *et al.*, 2014; La Sorte *et al.*, 2015) but also other fields such as healthcare (Ali *et al.*, 2018) and politics (Bassetti *et al.*, 2018). None of the published studies are related to the research question this thesis is investigating. For instance, Bassetti *et al.* (2017) show that some economic correlates of Islamist political violence matter differently when they are considered in a particular path. They use a similar methodology to the one described in the Research Design Chapter (Section 6.3.1.3). They have three dependent variables for separate models and eight independent variables. They use two tests to access both the stability and predictive capacity of the REEM. Firstly, they exclude one observation and fit the model using the remaining data. Ideally, the data should stay stable. Also, they implement a k-fold validation method to compare the predictive capacity of the trees with OLS.

5.4 IMPLICATIONS FOR THE ANALYSIS

An advancement in data analytics has drawn researchers to more and more sophisticated approaches that do not require limiting assumptions and correct for various estimation flows. This chapter provided some examples of how these approaches were employed in various settings. From both of these, it seems evident that the OP- LP approach and GMM estimator should provide an appropriate estimate of TFP.

Similarly, the long-lasting non-parametric Cox Proportionate Hazards (CPH) approach is being gradually improved with various extensions. An advancement in survival analysis made it possible to reduce the amount of limiting assumptions and correct for various estimation flows. Various extensions help to satisfy assumptions and use it with longitudinal data. This section provided an overview of how CPH is derived. It is one of the most frequently applied techniques for the survival analysis due to its non-parametric nature and theoretical foundations discussed in this section.

Finally, in order to test the Framework and thoroughly capture the complex clustered nature of the data, the empirical methodology is to employ the Sela and Simonoff (2012) and Fu and Simonoff (2015) Random Effects Expectation Maximisation (REEM)

decision tree algorithm for productivity analysis and the Fu and Simonoff (2017) Survival Tree (ST) algorithm, which accounts for left truncated and right censored observations, for the survival analysis. These allow the data to define non-parametrically the interaction of effects, whilst also controlling for firm-level differences.

6 RESEARCH DESIGN

This chapter presents the chosen methodology to achieve the primary aim of the thesis, which is to understand whether Small Business Rates Relief (SBRR) has any effects on firms, in particular with regards to their productivity and survival. Total factor productivity (TFP) is the portion of output not explained by the amount of inputs used in production. Whilst, survival analysis in this setting is a method for analysing the expected duration of time until closure. The chapter builds on the Methodology Review, which provided an overview of various techniques applied to productivity and survival analysis to select the most appropriate approaches. For the productivity analysis, control functions, system GMM and unbiased REEM trees seemed to be the most appropriate. The survival analysis was suggested to be performed with Stratified Cox Regression and Survival Trees. In both cases, more traditional approaches are combined with some machine learning alternatives which provide further insights into both productivity and survival. Various extensions of these models help to satisfy assumptions and are used with longitudinal data.

More specifically, to explain how this analysis was conducted, the chapter is split into three broad areas. The first is devoted to epistemological considerations (6.1). The second part (6.1.3) describes datasets, data management and matching. This matched data is used in models and estimation techniques that are presented in the third part (6.3), which starts by reviewing established and more recent issues with control estimators and derives a model to estimate total factor productivity (6.3.1) that deals with simultaneity, selection and omitted price biases. As a result, TFP is estimated with Wooldridge's (2009) approach, which is supplemented by unbiased REEM trees (Section 6.3.1.3) to identify any effects of SBRR on TFP. To strengthen these results, an alternative approach is also employed. The dynamic form of productivity with not just standard variables, but also previously discussed additional variables are estimated with a system GMM estimator (Section 6.3.1.4). Finally, the chapter also reviews the survival estimation (Section 6.3.2). It discusses the Stratified Cox Proportional Model (6.3.2.1) and survival tree (6.3.2.2) methodologies. They were chosen because of the left-truncated and right censored data.

6.1 PHILOSOPHY OF KNOWLEDGE

The purpose of this section is to reflect upon ontological and epistemological issues relevant to the research on business rates. To achieve this purpose, this chapter begins with an overview of how big data has shifted paradigms (Section 6.1.1). This is followed by a

review of issues within economics so that the relative merits of post-positivism and positivism can be weighted (Section 6.1.2) to choose the most suitable epistemological stance for this research project.

6.1.1 Big Data

Economics and other social sciences have experienced a significant shift in computational nature. As a result, there have been continued discussions about the change in paradigms. Kuhn (1962) emphasises that the worldview and knowledge exist at one moment in time. In contrast to Kuhn's perception that paradigms are evolving because of particular phenomena, Hey *et al.* (2009), inspired by Jim Gray, demonstrate that paradigms advance because of data. They classify four paradigms according to the period and term the fourth exploratory science. They establish that data-intensive statistical exploration and data mining are today's science. Similarly, others (Kelling *et al.*, 2009; Miller, 2010) have argued that data-driven science should form a new paradigm because this type of epistemology could help to extract new knowledge. Furthermore, an increasing number of researchers (Bollier, 2010; Floridi, 2012; Mayer-Schonberger and Cukier, 2013) have claimed that big data should affect how business is conducted, knowledge shaped, and governance enacted. For instance, Kitchin (2014) highlights the opinions of several professionals (Anderson, Prenky, Dyché, and Clark) who have claimed that big data could solve challenges even without theories. They reason that big data could create more comprehensive and extensive interdisciplinary studies that would be less limited to theories.

6.1.2 Positivism versus Post-positivism

In the period from Comte, through logical positivism and the Vienna Circle, to critical rationalism and operationalism, philosophy of knowledge in economics has experienced numerous variations and modifications. Post-positivism has become increasingly popular in economics. It has incorporated ideas of Feyerabend's methodological pluralism, falsificationism (Popper), and fallibilism (Hetherington, 2000). The central practical implication would be an assumption that sophisticated statistical methods are not sufficient to create scientific knowledge. Post-positivists have maintained that social sciences need more deliberative and integrated methods. On the other hand, the advantage of abundant information could create some valuable knowledge. For instance, Duranton's *et al.* (2011) methodology relies on secondary data and improves the understanding of business rates. This understanding could be as equally significant as interviews, for example, from Mehdi's (2003) study, or theoretical discussions about the possible effects on business rates such as those by Williams (2011) or Smith (2015). It may

be further questioned whether the compound understanding which could not be incorporated in today's relatively sophisticated statistical modelling with big data (Kitchin, 2014) is required to answer the calls for evidence concerning business rates (Bond *et al.*, 2013; HM Treasury, 2015 and 2016; Muldoon-Smith and Greenhalgh, 2015).

A critique of positivism could be valuable since it is often oriented towards a more comprehensive and elaborate description of a phenomenon and the relationships within it. Some of these issues were discussed by von Mises. In 1933, a period when the social sciences and economic policy were experiencing confusion, von Mises argued that the core intellectual errors of protectionism, socialism, statism, racism and irrationalism were against economic logic. This was also identified by other scholars who criticised the reductionist nature of positivism owing to such factors as an absence of neutral knowledge, dualistic thinking (Henriques *et al.*, 1998), ethical aspects (Schratz and Walker, 1995) and a focus on statistical approaches (Cradwell, 1980). This implies that the easy to understand deductionist models similar to those presented in the Theory Review Chapter should be looked at with caution. They provide a good indication for the majority of cases, but might not be accurate for all cases.

6.1.3 Theory-driven versus Data-driven

As computing power and the amount of information have grown, complex techniques focusing on data-driven modelling can provide an alternative to predetermined and reductionist models. The contradiction that could potentially arise is that data evaluation provides legitimate results without them being subjected to theory restrictions and is applied with less explicit criteria. Whilst in the theory-driven standard positivist modelling, data evaluation is legitimised in the context of a well-formed theory. The data-driven techniques, such as REEM trees, do not require a theory base and can deal with the previously mentioned shortcomings and methodological errors inherent in neoclassical economics (Adam and Westlund, 2013). Thus, the results are expected to be more dynamic, complex and sophisticated (Kitchin, 2014:3).

However, it could be erroneous to focus only on data. Although data-driven modelling does not impose additional assumptions, it still requires contextualisation on existing knowledge; it may be limited in scope and may produce only one kind of knowledge (Crampton *et al.*, 2012). While these algorithms enable rich representations of complex economic systems and advanced reasoning capabilities, a key challenge is finding the right balance between leveraging computational resources and applying theory because the data may capture interactions that do not necessarily provide meaningful insights into the questions addressed. Having said that, the whole data about a phenomenon can be included

in the modelling and even those irrational, according to our current understanding, interactions may be worth acknowledging.

As a result, this research project follows the paradigm of positivism but employs both data-driven and theory-driven modelling in an attempt to gather a complete understanding of the phenomenon. Given all criticism of positivism, it may seem reasonable to suggest that data-driven modelling could at least partly reduce the drawbacks of positivism. The availability of both larger datasets and more sophisticated techniques should result in greater complexity. Although Hutchison's (1941) positivist seeks to reduce a phenomenon to universal and abstract principles and tends to fragment human behaviour, data-driven reasoning may help to act against this reductionist nature by including predetermined relationships within the analysis.

Overall, as a researcher, I adopt the belief that the world of social interactions exists independently of what I perceive it to be; it is a broadly rational, external entity and responsive to scientific modes of inquiry. Also, I believe that data analysis may be useful both before and after theory development. The combination of both could not only advance the knowledge of Small Business Rate Relief but also answer recent calls for evidence concerning this topic.

6.2 DATA

This section aims to describe how the data was chosen, modified and cleaned when appropriate. It starts by reviewing the datasets used by UK researchers on topics related to BRs since the methodology depends on the available data sources. This review influenced the choice of the datasets which are described in Section 6.2.1. The section then expands on the key variables that were used in both survival and productivity analyses and how such issues as missingness and computation errors were solved (Section 6.2.2.4).

6.2.1 Datasets

Previous studies suggested that macro-level analyses, particularly in TFP estimation, is being replaced by the micro-level analyses. The Empirical Review discussed several UK papers dealing with issues related to BRs. These studies used various secondary data sources. These included the Census of Production (Mair, 1987), the Department of Environment floor-space data, Central Statistics Office estimates from county national and level gross domestic product (GDP) components (Bennett and Krebs, 1988), Inland Revenue Survey of Personal Incomes and Return of Rates (Blair, 1989; Mair, 1990), Ireland Revenue Valuation Agency and Investment Property Databank (Bond *et al.*, 1996),

Valuation Office Agency data (Bond *et al.*, 2013), Chartered Institute of Public Finance and Accounting data (Hilber *et al.*, 2011) and a variety of local government financial statistics. Throughout time, aggregate data was replaced by the more extensive micro datasets. This shift is due to the benefits of estimating TFP with micro-level data. It permits the direct comparison of an outcome variable across treated and control groups and, therefore, facilitates the estimation of treatment effects. More specifically, Del Gatto *et al.* (2011) argue that aggregate analysis plays a significant role in comparative, cross-country studies but micro analysis permits the investigation of TFP patterns at a deeper level, controlling for issues like not perfectly competitive markets, increasing returns, and different firms.

This analysis directed towards using the Annual Respondents Database (ARD). Most recent papers related to both BRs and TFP often employed the ARD. One of the most theoretically and empirically sophisticated studies uncovered in the Empirical Review Chapter was by Duranton *et al.* (2011) which employed the ARD. Likewise, the recent and extensive estimates of TFP prepared by Harris, Moffat and their co-authors in various papers reviewed in the Methodology Review were based on the ARD.

Given the longitudinal structure and breadth of the ARD dataset, this would enable the estimation of TFP and survival at the micro level but only until 2008. In fact, the Office for National Statistics (ONS) Virtual Microdata Laboratory (VML) and the University of the West of England extended this dataset by combining several other datasets to achieve better coverage and a better fit for productivity analysis. The new dataset called Annual Respondents Database X (ARDx) now contains harmonised variables from 1998 to 2015 with 42,000-65,000 annual observations. Thus, the following paragraphs will describe ARDx by focusing on its structure and introduce other two data sources²⁷ that were used to supplement ARDx. The correct procedures required by the UK Data Service to access and report on this data were undertaken owing to the sensitive nature of the data.

6.2.1.1 Annual Respondents Database x (ARDx)

Not only the coverage, but also the variable base made ARDx the preferable dataset. As an extension of the ARD, the ARDx has a rich variable base (289-402 variables). It includes such chief variables in TFP estimation as labour, estimated capital, investment, materials and, most importantly, BRs expense. The surveys also cover diverse sectors; construction; retail; motor trades; catering and allied trades; wholesale; property; service trade sectors and from 2000 agriculture (partly), hunting, forestry and fishing. From an

²⁷ Sections 6.2.1.3 Business Structure Database (BSD) and 6.2.1.4 Prices Survey Microdata (PSM).

administrative perspective, the ARDx is created by combining two datasets, Annual Respondent Database with data from 1998 to 2008 and the Annual Business Survey (ABS) supplemented with employment data from the Business Register and Employment Survey with data from 2009. These datasets are described in the following paragraphs to understand the ARDx dataset better and to highlight some possible mismatch between pre and post-2008 data.

The pre-2008 data in ARDx mainly comes from ARD. ARD²⁸ consists of two surveys, employment (ABI1) and financial information (ABI2). These were standardised into a single consistent format and linked by the Inter-Departmental Business Register (IDBR). ARDx starts in 1998 because ABI's (1998-2008) structure was more similar to ABS (2008-2016). These two datasets can be combined because they have similar sampling procedures, structure and questions as well as the ability to be linked with IDBR, which have only existed since 1997.

More recent (post-2008) data in ARDx comes from the Annual Business Survey (ABS). The Office for National Statistics (ONS) sends this postal survey to around 62,000 businesses in Great Britain each year. It is the most extensive business survey currently conducted by the ONS in terms of the combined number of respondents and variables it covers from around 600 different questions asked. The details of these businesses, registered for Value Added Tax (VAT) and/or Pay As You Earn (PAYE), are obtained from the ONS's Inter-Departmental Business Register (IDBR). In a similar manner to ARD, the ABS's population of legal units is stratified by SIC (2007), employment, and country using the information from the IDBR.

With regard to the sample procedures, both ARD and ABS include all large businesses and smaller businesses are sampled. The estimation might suffer some bias as smaller firms may receive a shorter form, which may not necessarily require detailed breakdowns of totals. Thus, for specific variables, the values may be acquired from third-party sources (e.g. HMRC) or estimated rather than returned by respondents. Approximately 60,000 - 75,000 businesses were surveyed each year between 1998 and 2008 (and ~15,000 between 1973 and 1997) by using a postal survey method.

Although the survey provides substantial coverage, there are some inaccuracies. For instance, linking datasets brought several different variables reporting similar or closely linked figures. One of them is employment. The employment figures are present from all three sources. The ONS produces many different measures of employment,

²⁸ Also called Annual Business Inquiry (ABI).

including the Workforce Jobs and Annual Population Survey/Labour Force Survey. However, ONS recommends using the Business Register and Employment Survey (BRES) for the information on employment by detailed geography and industry (ONS, 2017). The most reliable recent (2009-2015) employment data in ARDx comes from the BREST, which is aimed at updating local unit information and business structures on the IDBR. This postal survey has approximately 80,000 sampled businesses covering approximately 500,000 sampled local units each year.

Overall, the data owners have used variable names from the ABS. They advise that names may not be the same, but the survey is mainly consistent with the ARD. The variables may be divided into three types according to their information source:

- IDBR-based information about the reporting unit
- Respondent's answers to the ARD and ABS surveys
- Employment data from BRES.

6.2.1.2 Inter-Departmental Business Register (IDBR)

ARDx is preferable because it is cross-checked with administrative data. There are larger and more up to date data sources, but these cannot be accessed by non-civil servants without special permission. All ONS datasets consist of IDBR reference numbers. These are anonymous but unique reference numbers assigned to business organisations. Their inclusion helped to combine various datasets required to achieve the objectives. For merging purposes that will be described in Section 6.2.2, it is important to define different identifier levels at IDBR to merge ONS datasets. The IDBR can be grouped into three types: administrative, statistical and observation units. Figure 6:1 illustrates the principal relationships. The reporting and statistical units can be used for matching since they have unique identifiers. To estimate more precise effects, the data in this analysis was limited to firms having only one local unit. Thus, although there would be unique identifiers for each of the groups (reporting unit, enterprise group, enterprise and local unit), they would refer to the same information.

If this limitation was not imposed, as Figure 6:1 illustrates, the reporting unit would provide information on behalf of the company and have its identifier (ruref). This information would be assigned to statistical units. They are a group of legal units under joint ownership which is called an Enterprise Group (Entref). An Enterprise can be defined as the smallest combination of legal units (based on VAT and PAYE records), whilst, a local unit is an enterprise or part of a company situated in a geographically identified place.

Finally, administrative units refer to VAT trader and PAYE employer information supplemented with incorporated business data from Companies House.

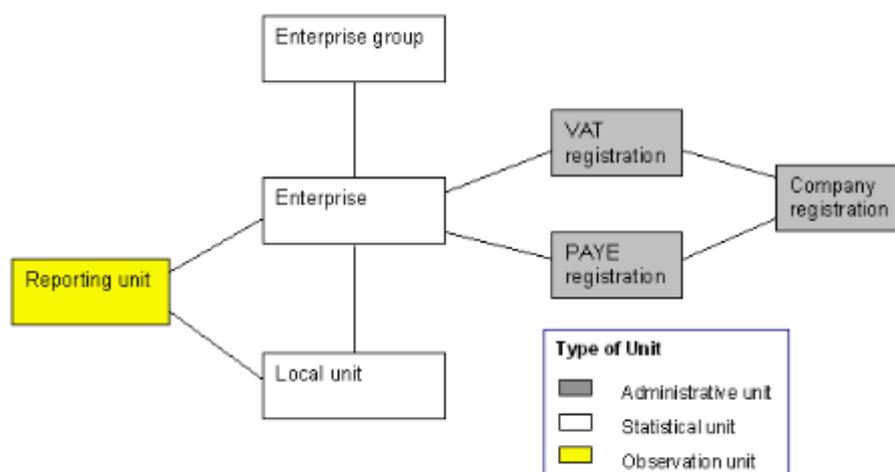


Figure 6:1 Relationships amongst reporting units, enterprise groups, enterprise and local units. Source: ONS (2017:3).

6.2.1.3 Business Structure Database (BSD)

The ARD/ABS sampling scheme involves selecting all largest businesses with a progressively reducing fraction of smaller firms. Thus, ARD_x would often consist of several small business observations. To obtain precise values for the years when those firms were not included in the ARD/ABS scope, ARD_x data was combined with the Business Structure Database (BSD). BSD seemed to be an appropriate dataset to fill those gaps as it covers almost the entire UK business population. It includes up to four million enterprises and up to 5.5 million local units. However, only several variables are available: employment, turnover, standard industrial classification, legal status, foreign ownership, birth, death. Employment includes business owners, whereas 'employees' measures the number of staff, excluding owners. The birth and death variables are particularly useful for the survival analysis, although it should be noted that for businesses which commenced trading before 1973, their birth date would be set to 1973. Furthermore, the extensive coverage was used to derive competition indexes (Marshallian externalities, Herfindahl index, Jacobian externalities) described in Section 6.2.2.6.

In addition, unlike in the IDBR, BSD only consists of enterprise and local unit identifiers. There is no reporting unit reference number. Thus, instead of reporting unit level, the enterprise unit level had to be used in Section 6.2.2.

6.2.1.4 Prices Survey Microdata (PSM)

ARDx provided primary variables and BSD was employed to extend the coverage of the characteristics of firms. However, these datasets did not include any means of controlling for the price increases and decreases within the estimators. The usual way to solve these issues would be to deflate values with GDP estimator. This thesis proposed a more sensible way to deflate with the Prices Survey Microdata (PSM) which is used to estimate the exact values for the specific firms as described in Section 6.2.2.3.

In general, the PSM is used to produce the Retail Prices Index, the Consumer Prices Index and associated price indices. All other previously described datasets were mainly derived by the postal survey, but to gather information on the PSM, the ONS uses two basic price collection methods. One of them is a local collection, which is implemented in about 150 locations around the country with around 110,000 collections. Collectors must visit the outlet, but prices for some items may be collected by telephone. Another type of collection, called the central collection, is when the prices are collected centrally.

6.2.1.5 Summary of the Datasets – ARDx, PSM and BSD

Table 6:1 provides the summary of the datasets discussed in this section. The analysis is based on the U.K. Office of National Statistics (ONS) Annual Respondents Database X (ARDx) first released in July 2016 combined with Business Structure Database (BSD) and Prices Survey Microdata (PSM). The ARDx combines two existing surveys, the Annual Business Inquiry (1998-2008) and the subsequent Annual Business Survey (2009-2015) which representatives of businesses are legally required to complete, and produces high response rates. It is a census of firms with 250 plus employees and a complex stratified sample across size, sector and region of smaller firms. The sample framework is constructed using administrative data on employment and turnover from PAYE and VAT registrations. Importantly, for the purpose of this theses, it captures information at both the enterprise and local unit levels. However, Small Business Relief and several indexes needed to be derived as described in Section 6.2.2.6.

This data source was combined with the BSD to acquire the annual observations of smaller firms that were not included in the ARDx sample in some years, and as such fills in some missing variables. The BSD contains an annual release of a small number of critical variables on all VAT registered UK firms or those which employ at least one worker and are complementary to the above business surveys.

The ARDx and BSD do not directly provide controls for input price changes, required for the estimates of TFP. To control for omitted price bias (as defined by Van

Beveren, 2010), the PSM data is used to deflate values with detailed information on regional and sector level prices rather than deflating using the inherently biased national GDP.

It is worth noting that the first column in Table 6:1 reveals that different datasets have varying reference levels. For instance, PSM data has only an enterprise level identifier (entref), but PSM holds only reporting unit identifier (ruref). These identifiers would be different for the same firm and cannot be merged directly with each other. Thus, both datasets had to be merged firstly to ARDx. The merging procedures are described in the following Section 6.2.2.

Dataset	Levels	Number of annual observations	Number of variables	Years covered	Sampling
ARDx	LUREF, RUREF,	42-65k	289-402 at RUREF	1998-2014	Stratified
ARD	ENTREF	60-75k	level	1973-2008	
ABS		47-49K		2008-2015	
BSD	ENTREF	~4mln	~20	1997-2016	Total
PSM	RUREF	Confidential	~10	1996-2016	Stratified

Table 6:1 Summary of the datasets used in the thesis. Source: ONS(2017).

6.2.2 Data Management

This subsection starts by describing the primary processes of merging within and across datasets. This is followed by a description of data techniques implemented to prepare the data for analysis. All cleansing was done in R with such packages as data table, tidyr, dplyr and feather. The latter was used to quickly save large datasets and then read them in, while the former three packages helped to investigate, modify and fill the gaps in the data. They were seen to be superior for big datasets because of their higher speed, efficiency and accuracy over other available software in Secure Lab, for example, STATA or SPSS.

6.2.2.1 Business Structure Database (BSD)

The data processing started with BSD as it had the most extensive coverage of the administrative level variables. As discussed in Section 6.2.1, the administrative data was always preferable as the data was crosschecked with other sources. The following variables were taken from the BSD: turnover, employment, region²⁹, postcode, number of local units,

²⁹ Indicating whether a firm is based in North East, North West, Merseyside, Yorkshire & Humberside, East Midlands, West Midlands, East of England, London, South East, South West, Wales and Scotland.

sic codes, enterprise zone codes, birth and death years. BSD consisted of too much data to work with at once. Thus, a few strategies were employed to reduce the amount of data.

BSD had separate datasets for each year. These were merged and a year variable was introduced according to the file name. A similar procedure was employed for local unit level data at BSD to extract postcodes and, simultaneously, administrative districts that were used in the analysis. Having done this, these two extracts were merged by *entref* and year. Also, all values that consisted of either a space or dot within those identifiers were marked as not available (NA) or missing. All duplicate entries were then removed. These were not substantial and were duplicated because of marginal differences in values. This resulted in the final sample of 6,795,298 observations (547,917 individual firms). As Figure 6:2 (1st step, p. 139) reports, the number of firms were steadily increasing. However, owing to the possible increase in deaths and decrease in births during the post-recession period (as described in the Introduction Chapter, Section 1.2), the number of observations decreased since 2010. This is not the final dataset and was only used to estimate indexes described in Section 6.2.2.6 as well as to fill annual observations of firms that had some unreported data for the years in which they were not included in the ARDx scope.

The data was then limited to companies comprising of only one local unit. This is a slightly different approach than that employed by such academics as Harris and Moffat (2017) or Duranton *et al.* (2011), who approximated productivity inputs by proxying them on employment. One unit was an appropriate choice for this analysis because SBRR is granted mainly to businesses which have just one building, with some exceptions of several buildings with a very low rateable value (RV) as defined in the Introduction and Background Chapter (Section 1.4.1), RV weakly corresponds to the rental value. This also reduced the need to work at the local unit level. Thus, the real values can be used instead of approximated variables based on either employment or turnover, while tracing back data to local units as undertaken in such studies as Duranton *et al.* (2011) or Harris and Moffat (2017). This resulted in the reduction of the sample size to 6,230,916 observations (530,923 individual firms). As Figure 6:2 (2nd step, p. 139) shows, the data was proportionately reduced over the years.

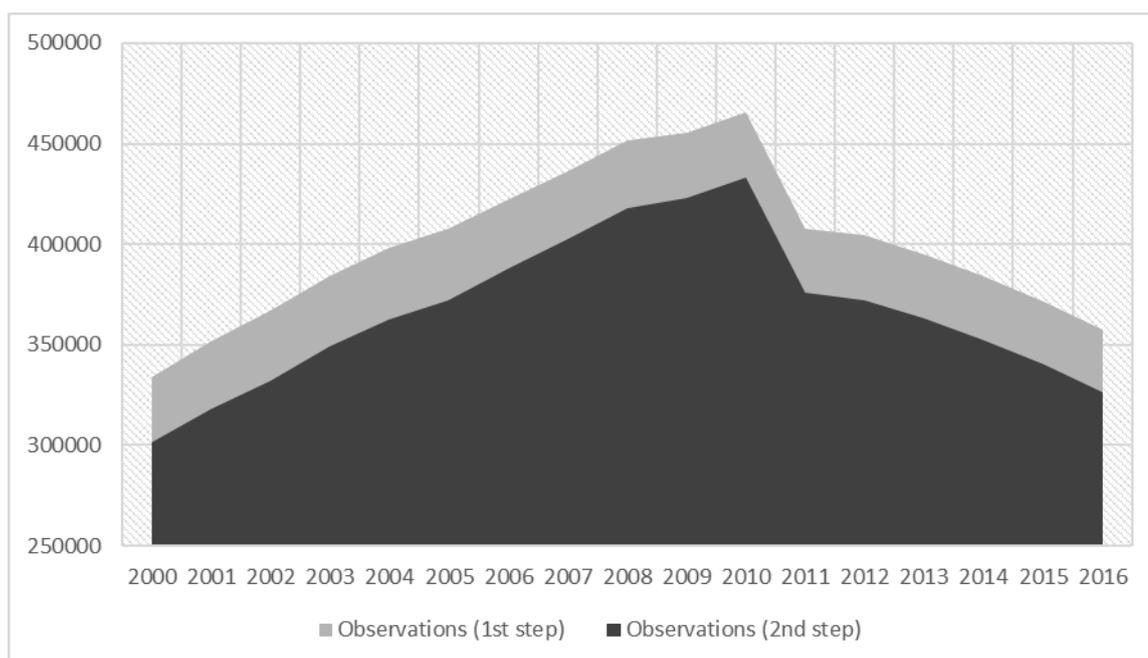


Figure 6:2 Spread of observations over 17 years in BSD. 1st step refers to the number of observations after initial cleaning, 2nd step refers to the number of observations when the data was limited to companies comprising of only one local unit. Source: BSD data.

6.2.2.2 Annual Respondent Database – X (ARDx)

Only some variables were extracted from BSD (as described in Section 6.2.2.6). The clear majority of variables were extracted from the ARDx dataset (described in Section 6.2.1.1). To exploit longitudinal data and control for the time-varying effects, annual observations from both enterprise, reporting and local unit levels (see Section 6.2.1.2 for the definition) were combined into three separate files.

The key variables were taken from ARDx: year, reporting unit identifier (ruref), enterprise group identifier (entref), region³⁰, legal status³¹, turnover, sector, gross product, intermediate consumption, wage expense x2, gross salaries x2, gross value added (GVA) at market, factor and basic prices, acquisitions, disposals, R&D, direct investment, subsidies x2, total net taxes, sales of own production. Some variables (employment, wage expense, gross salaries and subsidies) were available in several formats as they were included in several different surveys, as discussed in Section 6.2.1.

³⁰ Indicating whether a firm is based in North East, North West, Merseyside, Yorkshire & Humberside, East Midlands, West Midlands, East of England, London, South East, South West, Wales and Scotland.

³¹ Indicating whether a firm is company, sole proprietor, partnership, public corporation/nationalised body, central government, local authority or non-profit body or mutual association.

The ARDx's primary identification is reporting unit identifier (ruref). Thus, enterprise group identifier (entref) was sometimes either empty or consisted of a dot. These were believed unreasonable and set as not available (NA) values. Similar steps were performed for SIC and region variables. After inspection of the sample of these variables, it was assumed that they were most probably a transcription error because non-matching entref would only appear once and similar enterprise level identifier (entref) would have matching values in the following and previous years. It is unlikely that a firm would sell its single unit and repurchase it only a year after. These identifiers were believed to be unreasonable and replaced by the most frequently entered value of that company from 2000 to 2015. Also, several duplicate observations were removed.

After these modifications, the initial ARDx sample consisted of 2,247,152 observations (396,172 unique entrefs). Observations were not evenly distributed throughout years and a large proportion of observations were from 2015 as shown in Figure 6:3 (p. 141). As expected, the sample was significantly smaller than from BSD data.

6.2.2.3 Prices Survey Microdata (PSM)

PSM was used to estimate the deflators employed in the TFP estimation. The dataset was used to propose a novel approach dealing with bias introduced by omitted prices which will be more extensively discussed in Section 6.3.1.1.3. The approach is novel because instead of using GDP or sector deflators, it estimated more precise and more individual deflators.

The survey was provided in three different files which were merged into one file. Annual observations were then estimated by obtaining an average of all supplied monthly observations according to the company and index numbers. These were further averaged according to the company and year, so that one annual deflator per company could be estimated and applied to ARDx data. This resulted in 95,171 observations (17,728 unique entrefs). Figure 6:3 (p. 141) compares the sample size of PSM to ARDx (after cleaning) over the time. It is evident that the sample size of PSM is much smaller and fluctuates more than ARDx.

PSM holds only reporting unit identifiers. Thus, PSM had to be firstly merged to the ARDx before any modifications (e.g. still keeping firms with two or more local units) to obtain more precise estimates. If unavailable in ARDx, those observations were removed. Given that it was a relatively small number of observations, further estimations took place that were believed to provide more accurate results than the industry deflators or GDP.

Several groupings were used to estimate the deflators if they were not available for that particular firm in PSM sample. Firstly, firms were grouped according to year, SIC and region and deflators to approximate missing deflators within those groups. Firms were then grouped again, but instead of full SIC classification, just two-digit SIC classification was used together with year and region to approximate still missing deflators. For those firms that the previous groups were still unable to approximate the deflators, another grouping just according to the full SIC classification and year was performed. Finally, two other groupings were made with regards to region and year as well as just year to approximate the deflators. There were still several values within the sample for which GDP was used as a deflator.

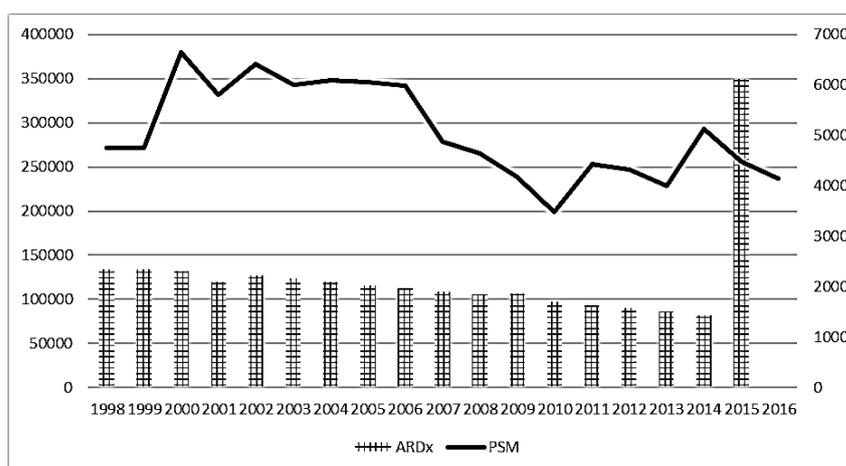


Figure 6:3 The number of observations in ARDx (scale on the left) versus PSM (scale on the right). Source: PSM and ARDx data.

6.2.2.4 Missing Values

The three datasets used in the analysis were described in the previous sections. It was evident that ARDx had variables that were needed for the analysis, but did not survey small firms each year. To acquire annual observations, ARDx was merged with BSD resulting in many missing values. To deal with these missing values, both manual and automated imputation techniques were employed. The following paragraphs describe the key variables and how they were modified to reduce not available (NA) values and ensure that the data was appropriate.

6.2.2.4.1 Sector

SEC 78200, 78300 were excluded because these classifiers referred to employment agencies. They were likely to distort the analysis by providing too large employment numbers. Also, there were several missing sector variables. These were looked at manually

and either erased or set to the most relevant sector by looking at previous observations. As Figure 6:4 (p. 143) indicates, the sample was reduced by 51,142 observations.

6.2.2.4.2 Legal Status

As discussed in the Introduction and Background Chapter, some sectors were entitled to different reliefs or unentitled to any reliefs at all. Only companies classified as a company (including Building Society), sole proprietor and partnership were entitled to receive SBRR. Companies that at least one year were classified as public corporation, nationalised body, central government, local authority, non-profit body or mutual association were disregarded from the survey. As Figure 6:4 (p. 143) shows, restrictions imposed on legal status removed 51,142 observations.

6.2.2.4.3 Birth Year

If unavailable in BSD, the birth year was considered to be the first recorded entry year in BSD so it can date back to 1970s.

6.2.2.4.4 Postcodes

A few postcodes were missing. It was assumed that if the postcode is missing, a company stayed in the same location. Thus, the previous postcode was used.

6.2.2.4.5 Death Year

For purposes of survival analysis, another variable, *death_imp*, was created to show the last year enterprise was observed on BSD. Also, given that SBRR was introduced in 2003³² and the analysis focuses on the firms that were alive at any period between 2002 and 2015, the other firms that failed before or during 2002 were removed. As Figure 6:4 (p. 143) shows, the sample was reduced by 14,725 observations.

6.2.2.4.6 Employment and Turnover

Variables were highly populated and seemed to be reasonable. When turnover was equal to 0, the values were inspected and either kept as 0 or replaced with a mean of the previous and leading values.

6.2.2.4.7 Region

If the region variable was missing, but the postcode has not changed from the previous year, the same region was assigned.

³² Business Rate Reliefs were first introduced in Scotland in 2003, England in 2005 and Wales in 2007.

6.2.2.4.8 Business Rates

Firstly, observations of firms that reported their BRs bill as 0 up until 2009 were investigated because before 2009 there were no 100% reliefs. These 110,483 observations were suspected to be inaccurate. Thus, these values were changed to NAs. Having done this, the firms that did not have at least two observations of BRs were removed. At least two observations had to be filled to estimate any change or causalities. As Figure 6:4 (p. 143) shows, this limitation reduced the sample size by 5,036,819 observations. The resulting sample size consisted of 840,037 observations with 60,109 individual firms. Several conditions then had to be satisfied for the BRs to be imputed. These conditions were made according to periods of revaluation and rules defined in the Introduction and Background Chapter (Section 1.4.3).

Average business rate expense was imputed for those firms that did not relocate or invest anything in their buildings and were within revaluation periods because their business rate expense was unlikely to be changed. More specifically, the data was divided into three periods according to revaluations: up to 2004, 2005-2009 and 2010-onwards. The average BRs were estimated for each company over those periods. Then, for those firms that did not invest in the acquisitions or disposals of buildings and did not change their addresses, NAs in the initial figures were replaced with previously estimated averages from the data between revaluations. If there were still some NAs for the period of 2002-2015, these companies were excluded from the analysis. As Figure 6:4 (p. 143) shows, this significantly reduced the sample to 125,434 observations (removed 715,055 observations) or 11,418 individual firms. However, this was believed to be an essential reduction to estimate the precise effects.

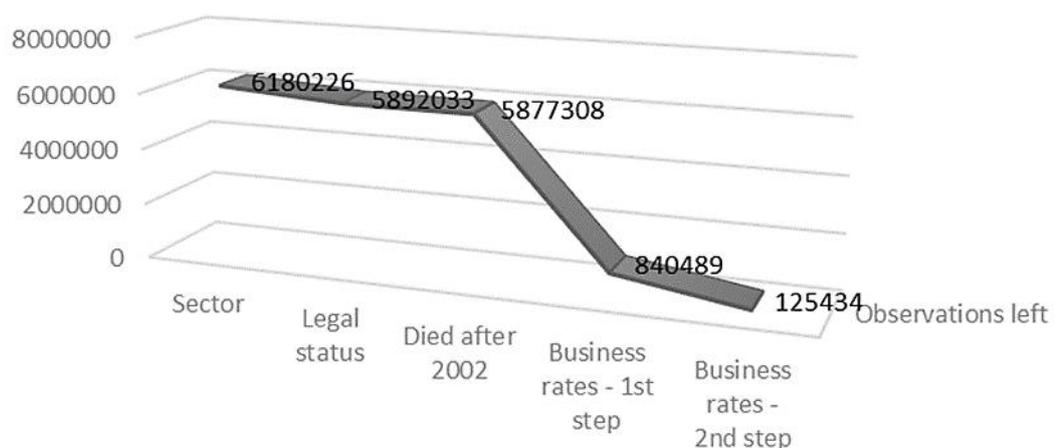


Figure 6:4 Sample size after reductions: sector, legal status, death, and business rates. Source: ARD_x, PSM and BSD data.

6.2.2.4.9 *Foreign Ownership*

A dummy variable taking a value of one when the ultimate ownership was not British and 0 otherwise was created. Missing values were replaced by 0 because it was assumed that companies which were based in the UK and did not report their ultimate foreign ownership, were more likely to be British since the vast majority of small firms comprising of only one local unit were likely to be British owned. The missing values were less than 1% of the data.

6.2.2.4.10 *GVA after Salaries and Intermediate Consumption*

There were multiple missing observations in materials. ONS has already derived intermediate consumption (or materials as in productivity function). However, almost half of the values were still missing. This could be explained by investigating how ONS derived this variable. It was derived by deducting total purchases by the increase in the value of materials, stores and fuel stocks, the value of insurance claims received and goods bought for resale without further processing. This analysis was different because it assumed that when any of these three variables were unavailable, they would be equal to zero. This resulted in a substantial reduction of unavailable values. It seemed reasonable that when a firm did not report its insurance claims, for example, but did report its increase in materials, it should be recorded as materials.

6.2.2.4.11 *Intermediate Consumption, Rent, Investments, Capital, GVA*

To estimate causalities, at least two values needed to be non-missing. Thus, companies that had just one observation were removed. This reduced the sample size by the amount given in Figure 6:5. Overall, the vast majority of observations were removed due to NAs in intermediate consumption.

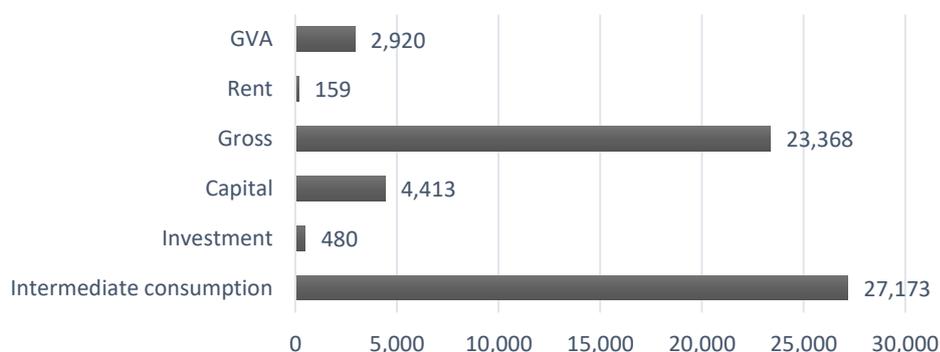


Figure 6:5 Deducted observations because of only one available observation. Note that some modifications may remove the same values. Source: author's calculations.

6.2.2.5 Imputation of Missing Annual Observations

Merging BSD with ARDx created many not available values within the datasets as presented in the Results Chapter (Section 7.1) as some smaller firms were not included in the scope of ARDx each year. To estimate values for missing years, multiple methods were available, such as EMB algorithm or predictive mean matching method. Secure Lab did limit the capacity to compute NAs with the most sophisticated methods. Therefore, rather than focusing on methods, this chapter will consider packages available in R to implement these methods, so that the most appropriate approach could be selected.

The bootstrapped predictive mean matching approach was used for both Wooldridge's TFP and dynamic TFP estimation and Cox Regression, but simpler time series imputation was employed for the unbiased REEM and survival trees. It is worth acknowledging that the automated imputation was attempted to be kept to a minimum and applied only to variables that were unlikely to be very important. The key variables on firm characteristics (location, size with regards to employment and turnover) from BSD and SBRR were not imputed in this manner.

6.2.2.5.1 Basics of Imputation

The methodology depends on the missing data mechanism. There are three types of mechanisms: missing completely at random (MCAR), missing at random (MAR), and not missing at random (NMAR). ARDx sampling procedure discussed in Section 6.2.1.1 implies that the data should follow MAR mechanisms. One-stage stratified or systematic random sampling was used for all large businesses surveyed, whilst a subset of medium and small businesses sampled. In other words, selecting all the largest businesses each year with a progressively reducing fraction of smaller businesses.

Another assumption to make when imputing data is its distribution. Some techniques (parametric) require to define the distribution (usually normal distribution) before the analysis; other techniques may not have this limiting assumption about the distribution and they are classed as non-parametric. For methods that use linear regression, dependencies are assumed to follow a linear pattern. Rubin (1987) proposes how to impute values with MAR patterns:

- Use many variables, including dependent and any other variables that may help to explain the values
- Create several imputed datasets
- Run analysis on several imputed datasets
- Combine and weight estimates to take uncertainty into account.

This thesis used Rubin's (1987) advice when coefficients were found inconsistent during dynamic productivity estimation discussed in Section 6.3.1.4. The approach was to firstly estimate a thousand samples by imputation and then perform the estimation with all thousand samples. Finally, the coefficients and standard errors were averaged to find the final estimates. This was believed to reduce the measurement error significantly.

6.2.2.5.2 *Imputation in R with Advanced Methods*

It was challenging to identify an appropriate MAR imputation technique. Moritz *et al.* (2015) acknowledged several different methods of data imputation in R. They classified these into imputation based on random forests (*missForest*), maximum likelihood estimation (*mvnml*), expectation maximization (*mtsd*), nearest neighbourhood observation (*yaImpute*), predictive mean matching (*BaBooN*), conditional copula specifications (*CoImp*), and finally the sophisticated multiple imputation methods with such packages as *MICE*, *missForest*, *Hmisc* and *mi*. These were preferable for this analysis and are discussed in further detail in the following paragraphs.

One of the most popular methods is Buuren and Groothuis-Oudshoorn's (2011) Multivariate Imputation via Chained Equations (MICE). MICE generates multiple imputations. As the authors define, it "imputes an incomplete column (the target column) by generating 'plausible' synthetic values given other columns in the data." It individually processes each column, predicting it from all the others and, in hand, reducing uncertainty in missing values. Suppose one has variables: $x_1, x_2, x_3, \dots, x_k$. If x_1 has NA values, then it will be regressed on other variables x_2 to x_k . The missing values in x_1 will be then replaced by predictive values obtained. Therefore, it does not assume normal distribution like Amelia but rather can include multiple types of variables. More specifically, numerical variables are estimated with predictive mean matching, binary variables with logistic regression, factor variables with Bayesian polytomous regression and ordered with the proportional odds model. In practice, the method may be difficult to implement because it does require the inclusion of all variables likely to impact the variables being imputed. It does assume the probability that a value is missing depends only on observed value and can be predicted using them. Unfortunately, this approach was too data intensive for the capacity within the ONS Secure Lab.

A slightly different methodology was adopted. The package, *mi*, or multiple imputations with diagnostics builds numerous imputation models to predict NA values by using the predictive mean matching approach. For each observation in a variable with NA value, an observation with the closest predictive mean to that variable is found. The observed value from this "match" is then used as the imputed value. A more advanced

package using a similar technique is Hmisc. It has two functions, `impute` and `aregImpute`. The former imputes values using a simple statistical method such as mean, max, median or mean. Whereas `aregImpute()` uses bootstrapping to additive regression and predictive mean matching to impute values. In Frank H. E.'s (2013) words

“[the] R package version 3.6-3. ‘aregImpute’ takes all aspects of uncertainty in the imputations into account by using the bootstrap to approximate the process of drawing predicted values from a full Bayesian predictive distribution. Different bootstrap resamples are used for each of the multiple imputations, i.e., for the ‘i’th imputation of a sometimes missing variable, ‘i=1,2,... n.impute’, a flexible additive model is fitted on a sample with replacement from the original data and this model is used to predict all of the original missing and non-missing values for the target variable.”

Given the discussion above, the `mice` and `aregImpute` functions are compared. The data was divided into 75% and 25%. For the group with 75% of data, values were imputed and compared the accuracy with real values for the 25% of data. `aregImpute` provided 15% more accurate estimates than the MICE package and, as a result, was a preferable approach for imputation. As a result, this imputation approach was used to estimate missing values for matching purposes. To accommodate time and enterprises identifiers, some variations were exploited within the imputation formula. Firstly, imputation was run by looping through separate enterprises and including all variables discussed in Section 6.2.2.4. However, it seemed reasonable that changes in inputs and outputs of other firms may help to predict the missing values. Thus, the imputation was performed on all cleaned data but only with the inclusion of variables that were likely to have an impact on the missing values. The key variables, following ONS suggestions, were taken from BSD. They had sufficient coverage and were likely to be precise predictors: turnover, employment, region, sector, legal status. A separate function was run for each variable that has NAs.

Without bootstrapping, this method seemed to be inappropriate to be used after matching since estimated variables essentially included some effects from the other covariates. More specifically, those imputed values were likely to account for some of the variances in the more causality based approaches discussed in Section 6.3. Thus, by not estimating multiple samples, the serial correlation could not be controlled. Instead, Steffen Moritz's (2016) more simplistic `imputeTS` package was used as this is especially designed for univariate time series imputation. It offers several different algorithm implementations depending on several distances: linear, spline, stineman or kalman. To isolate firms, the imputation was run separately for each firm. All methods (linear, spline, stineman or kalman) provided very similar imputations. The fastest to impute these large datasets was

with automated imputation, which is the reasoning for its use for tree estimation. The bootstrapping for the trees with longitudinal data was not performed since the new approaches were not equipped to use bootstrapping. Nevertheless, the bootstrapped multiple imputations was employed with all other methods (Wooldridge's TFP estimation, dynamic TFP estimation, Cox Regression).

6.2.2.6 Deriving variables

The theoretical framework suggested that various factors including externalities may influence the small businesses. Some of these factors may not be quantified directly. To account for these, some variables had to be derived by using other variables. These essentially are related to competition and high growth firms as defined in the Framework with Hypotheses Chapter (Sections 4.6-4.7).

6.2.2.6.1 Marshallian externalities (specialisation)

Feldman and Audretsch (1999) and Paci and Usai (1999) suggested employing the production structure specialisation index (PS) to measure Marshallian specialisation externalities. Marshallian externalities (described in the Framework with Hypotheses Chapter, Section 4.6.1) are a proportion of industry output located within local authority related to the output of the national industry. Employment is often used to estimate PS. However, this study is unique as it uses turnover in estimation. This is more appropriate owing to several factors. Firstly, highly populated (non zero) turnover and very low employment by the firms. Furthermore, the focus of the study was to find relationships between SBRR and TFP and productivity is related more to output and turnover than employment. It is of course in line with the conception of the index:

$$PS_{i,j} = \frac{T_{ij} / \sum_i T_{ij}}{\sum_j T_{ij} / \sum_i \sum_j T_{ij}},$$

where i is region, j is industry and T is turnover

6.2.2.6.2 Herfindahl- Hirschman Index (diversity)

The Herfindahl-Hirschman Index (HHI) was described in the Framework with Hypotheses Chapter (Section 4.6.3). It was calculated by squaring the market share of each firm competing in a market and then summing the resulting numbers. The HHI is then:

$$HHI = \sum_{i=1}^N s_i^2,$$

where s_i is the market share of firm i in the market, and N is the number of firms.

6.2.2.6.3 *Jacobian externalities (diversity)*

Jacobian externalities were also described in the Framework with Hypotheses Chapter (Section 4.6.2). Instead of market concentration, the focus now centres on the different market players. The diversity is estimated by summing different SIC codes within the region. Paci and Usai (1999) measured it with their productivity diversification index (PD):

$$PD_j = \frac{2}{(n-1)Q_n} \sum_{i=1}^{n-1} Q_i,$$

where n is the number of industries in region j , Q_i is the cumulative turnover up to industry i , when ordered by ascending size.

The index, bounded by zero and one, increases with variety. As opposed to PS, location rather than the industry is the focus for analysis. Incremental firm-level innovation is aided by access to examples from a diverse set of industries within a small area. The index is positively linked to urban areas with their greater density of firms, although at the two-digit postcode level it will show a reasonable degree of variation within given urban areas. Urban areas naturally tend to be more diverse and as such, SBRR may have less of an effect as wider competition for locations sees any relief rapidly capitalised.

6.2.2.6.4 *High Growth Firms (HGF)*

The Framework with Hypotheses Chapter (Section 4.7.2) suggested that recent evidence points out to a small number of firms outperforming others. Thus, following the OECD (2007:61) definition, HGFs are those firms that had average annualised growth by employment greater than 20% per annum, over a three-year period for firms with more than ten employees. A dummy variable was created taking the value of 1 if a firm experienced employment growth higher than 20% per annum, over a three-year period between 2003 and 2016 and had at least ten employees, and 0 otherwise.

6.2.2.6.5 *SBRR*

The variables were derived according to rules imposed by English, Scottish and Welsh governments that are reviewed in the Introduction and Background Chapter (Section 1.4.3).

6.2.2.6.5.1 *SBRR in England*

ARDx provides neither rateable value nor SBRR. ARDx includes the amount paid on BRs. The reported BRs figure was combined with the descriptions in Non-Domestic Rating (Small Business Rate Relief) Orders issued by the Scottish, Welsh and British governments

and its multiple amended versions that were detailed in the Introduction Chapter. BRs are estimated by multiplying rateable value (RV) with the multiplier. If a property is eligible, then, reliefs should be deducted from the BRs bill:

$$BR = RV \times m \times (1 - SBRR),$$

where BR is business rates paid, RV is rateable value and m is a multiplier

It is complex to estimate SBRR from BRs since the relief is shifting according to RV. The first step is to deduct a possible interval, which is the range over which the relief is paid (either £5,000 or £6,000), from RV. The result is then divided by the decrease of relief related to an increase in RV. This number is estimated by dividing interval value by maximum relief available in a percentage form $\left(\frac{int}{max \times 100}\right)$:

$$1 - SBRR = \left(1 - \left(\max - \frac{RV - int}{\frac{int}{max}}\right)\right) = 1 - 2 \times max + \frac{RV \times max}{int}$$

if $BR > \text{£}0$ & $RV \leq \text{£}12,000$ and where max is a maximal relief available and the int is the range over which the relief is paid (either £5,000 or £6,000).

Combining both equations yields:

$$RV^2 + RV \times \frac{int(1-2 \times max)}{max} - \frac{BR \times int}{max \times m} = 0$$

Given that maximal relief during 2005-2010 in England is equal to 0.5 (so $1 - 2 \times max = 0$), the equation becomes relatively straightforward to estimate:

$$RV = \sqrt{\frac{BR \times int}{0.5 \times m}}$$

By combining the first and last equations, SBRR in England between 2005 and 2010 can be estimated by solving the following function:

$$SBRR = 1 - \frac{BR}{m \times \sqrt{\frac{BR \times int}{max \times m}}}$$

During 2010-2014, there were further changes and maximum relief was increased up to 1, so another quadratic equation for this period has to be expressed:

$$0 = RV^2 + RV \times \frac{int(1-2 \times max)}{max} - \frac{BR \times int}{max \times m} = RV^2 - RV \times int - \frac{BR \times int}{m}$$

The solution to this quadratic function is:

$$RV = \frac{int \mp \sqrt{int^2 + 4 \times \frac{BR \times int}{m}}}{2}$$

Given that the minus provides a negative result, there is only one solution for this function. This combined with the first equation, results in the following function:

$$SBRR = 1 - \frac{2 \times BR}{m \times \left(int + \sqrt{int^2 + 4 \times \frac{BR \times int}{m}} \right)}$$

Given the reforms discussed in the Introduction and Background Chapter (Section 1.4.3), Table 5:3 was established to show how SBRR was estimated from BRs. The small business multiplier was created to cover SBRR costs. Therefore, the difference between these two was not regarded as a relief. The questionnaires were asked to be returned either by May or within two months of business year end. Thus, it seems reasonable that relief that took place, for instance, the period between April 2005 and March 2006 would be recorded in the 2005 survey.

Table 6:2 (p. 152) summarises how the SBRR has been estimated for each year in the UK and Wales after 2010. Between 2005 and 2010, properties with RV of £5,000 or less were able to claim 50% (or 0.5 in Table 6:2) reduction. Properties with RV of between £5,001 and £10,000 were subject to a tapering discount ranging from 0% to 49.99%, on the basis of 1% relief for every £100 of RV. The following formula was derived at the beginning of this section to estimate the relief: $1 - \frac{BR}{m \times \sqrt{\frac{BR \times int}{max \times m}}}$. More recently (between 2010 and 2015), properties with RV up to 6,000 were entitled to 100% (or 1 in Table 6:2) reliefs. Properties with RV of between £6,001 and £12,000 were subject to a tapering discount ranging from 0% to 100%, on the basis of 1% relief for every £60 of RV. The following formula was derived in the beginning of this section to estimate the relief $1 -$

$$\frac{2 \times BR}{m \times \left(int + \sqrt{int^2 + 4 \times \frac{BR \times int}{m}} \right)}$$

RV \ Year	2005-2009	2010-2015
RV ≤ 5,000	0.5	1
5,000 < RV ≤ 6,000	1	
6,000 < RV ≤ 10,000	$\frac{BR}{m \times \sqrt{\frac{BR \times int}{max \times m}}}$	1
10,000 < RV ≤ 12,000		$\frac{2 \times BR}{m \times \left(int + \sqrt{int^2 + 4 \times \frac{BR \times int}{m}} \right)}$
12,000 < RV		

Table 6:2 Summary of the SBRR estimation. Values are in a numeric expression, e.g. 0.5 corresponds to 50%. Source: Non-Domestic Rating (Small Business Rate Relief) Orders

6.2.2.6.5.2 SBRR in Scotland and Wales

SBRR for other years and countries of the UK were far easier to estimate as reliefs were fixed for some groups of rateable values. In Wales (up to 2010), the reliefs were retrieved in straightforward steps (see Table 6:3). For instance, properties for which the RV is lower than 6,500 but higher than 5000, would not receive any relief in 2007 and then 25% (or 0.25 in the Table 6:2) SBRR in 2008-2009.

RV \ Year	2007	2008-2009
RV ≤ 2,000	0.5	0.5
RV ≤ 5,000	0.25	0.25
RV ≤ 6,500		
RV > 5,000		

Table 6:3 SBRR in Wales before 2010. Values are in a numeric expression, e.g. 0.5 corresponds to 50%. Source: Non-Domestic Rating (Small Business Relief) (Wales) Orders.

Scotland applied a similar approach to Wales (up to 2010) as illustrated in Table 6:4 (p. 153). However, Scottish reliefs were far higher than in the rest of the UK and were introduced in 2003.

Year RV	2003- 2004	2005 - 2007	2008	2009	2010- 2014
$0 \leq RV \leq 3,000$	0.5	0.5	0.8	1	1
$3,000 < RV \leq 3,500$	0.4				
$3,500 < RV \leq 4,000$		0.4			
$4,000 < RV \leq 4,500$	0.3				
$4,500 < RV \leq 5,000$		0.3			
$5,000 < RV \leq 5,750$	0.2				
$5,750 < RV \leq 6,000$		0.2			
$6,000 < RV \leq 7,000$	0.1				
$7,000 < RV \leq 8,000$		0.1			
$8,000 < RV \leq 10,000$	0.05		0.05	0.4	0.5
$10,00 < RV \leq 11,500$	0.05	0.05	0.2	0.25	
$10,000 < RV \leq 12,000$					
$12,000 < RV \leq 15,000$					
$15,000 < RV \leq 18,000$					
$18,000 < RV$	0.05	0.05	0.2	0.25	0.25

Table 6:4 SBRR in Scotland. Values are in numeric expression, e.g. 0.5 corresponds to 50%. Source: Non-Domestic Rate (Scotland) Orders.

6.2.2.6.5.3 SBRR Dummy - First Recipients

The Framework with Hypotheses emphasised the need to introduce a dummy variable to isolate firms that were the first recipients of the enhanced or introduced relief. This should help to isolate the short-term effects with no capitalisation. It takes the value of 1 when a firm was the first recipient of the relief and it continued being in the same premises (excluding new enterprises and those that relocated). The relief became available in 2003 in Scotland, 2005 in England and 2007 in Wales.

Furthermore, another dummy variable was introduced, taking the value of 1 when a firm was the first recipient of the enhanced relief and it continued being in the same premises (excluding new enterprises and those that relocated). Thus, as according to the Introduction and Background Chapter, 2010 in England and Wales, 2008 in Wales and 2003, 2005, 2008, 2009, and 2010 in Scotland.

6.2.2.6.5.3.1 SBRR Dummy - Matching

For CEM matching, described in Section 6.2.3, a new variable was created. This dummy variable is equal to 1 when a firm received the relief at least twice between 2005 and 2015 and 0 otherwise. Firms had to receive SBRR at least two years as several issues were identified with firms receiving the relief only for one year. Companies that were suddenly receiving the relief just for one year between 2005 and 2015 were perceived

likely to misreport their BRs. Usually, a single zero was reported in one year, but in the year before and after substantial BR expenses were reported.

After a more careful investigation, an exemption from this rule was introduced for the firms reporting different postcodes before and after the year they received the relief, providing they received the relief once. This applied to 15 firms and were also included in the recipients' group during matching.

6.2.3 Coarsened Exact Matching

It was evident from the Methodology Review Chapter that to deal with selection issues defined in Section 6.3.1.1.2, matching should be performed. As Ho *et al.* (2007) and Iacus *et al.* (2008) advised, the primary goal of matching is to make data less model dependent, biased and inefficient. In productivity analysis, it is often a preferable method to reduce selection bias. Matching involves pruning observations that have no close matches on pre-treatment covariates in both the treated and control groups.

As discussed in the Methodology Review Chapter, the preferable method is Coarsened Exact Matching (CEM). It was preferable not only as a result of its speed, flexibility and natural setting, but also because it overcomes the recent criticism of Propensity Score Matching (PSM), which is introduced in Methodology Review Chapter (Section 5.1.4.4). CEM does not use random pruning applied in PSM which was proved to increase the level of imbalance.

CEM was discussed in detail by Iacus *et al.* (2009) who also published a package called CEM that will be used for the matching in R. This is a monotonic imbalance bounding matching method (or maximum imbalance between the control and treated groups). The broad mechanism behind CEM is to group each variable by recoding so that practically similar values are assigned the same value. The problem dictates the size of groups. The machining algorithm is then applied to these groups to find the matches and to remove unmatched units. Finally, the pooled data is removed and the original values of the matched data are retained. Iacus *et al.* (2009) explain the method in statistical terms. They show that the sample average treatment effect on the treated (SATT) could take the following shape:

$$SATT = \frac{1}{n_T} \sum_{i \in (T_i=1)} TE_i, \text{ where } TE = Y_i(T_i = 1) - Y_i(T_i = 0)$$

This is derived if Y_i is the dependent variable for unit i , T_i is a treatment variable (to simplify initially assuming that it is dichotomous), and X_i is a vector of pre-treatment control variables, TE is the treatment effect; while $Y_i(T_i = 1)$ is always observed and $Y_i(T_i = 0)$ is always unobserved. The latter is estimated with Y_j from matched controls

(which $X_i \approx X_j$), either directly, $Y_i^*(T_i = 0) = Y_j(T_j = 0)$, or via a model $Y_i^*(T_i = 0) = g(X_j)$. It is important to note that this method requires the assumption of no confounding effects (or no omitted variable bias) (Iacus *et al.*, 2011). Although it is an important assumption to make, the vast majority of matching methods used for analysing observational data including previously discussed PSM and other methods of causal inference do require the same assumption.

6.2.3.1 Variables

Some may argue that SBRR may be considered to be assigned to the firm in an "as good as random" manner since there is randomness in the assignment variable and the firms cannot perfectly manipulate their treatment status especially if relocation costs are high. However, as the framework suggests, they may base their decisions according to BRs. Thus, it is assumed that the SBRR is not entirely randomly assigned but is based on BRs which are estimated according to the building and land value as described in the Introduction and Background Chapter (Section 1.4.1). Thus, one should control for pre-treatment variables.

As discussed in the Introduction and Background Chapter (Section 1.4.3), reliefs for small firms were given in different years for individual UK countries. Thus, matching was performed on one year before the introduction of SBRR in each country. All matching was performed on imputed datasets to ensure that firms that did not report some variables at that year (e.g. 2002 in Scotland) but reported in other years could also be matched to other firms. The imputation process is described in Section 6.2.2.5.

However, several enterprises were born once SBRR was introduced. They may not have any observations without reliefs. The framework suggests that new enterprises would not receive any benefits from receiving the relief because they would have to sign new contracts, which most probably would include increased rents because of capitalisation. As discussed in the Theory Review (Section 2.1) and Framework with Hypotheses Chapters, this would imply that higher rents may offset the increase in SBRR. Also, given that the reliefs were applied after the year, the first year's performance was unlikely to be affected by the relief. Thus, for firms that were born after SBRR introduction, their first year was used for matching. Similar variables and approaches as in general matching were applied.

Given that the matching was performed before the SBRR was available, the key variables defined in the Framework with Hypotheses Chapter were included. That is, age, employment, sector, legal status, labour productivity, turnover (nominal), materials deflated, GVA deflated, investment deflated, rent paid were included in CEM. The key

variable used for matching was defined as a dummy variable taking the value of one if a firm receives at least some relief during 2003 and 2015, and 0 if a firm receives no relief at all. In statistical terms, the CEM equation takes the following shape:

$$SBRR_t = \gamma_1 X_{t-1} + error_t,$$

where t is the starting year of the relief (which is taken as 2003), SBRR takes the value of 1 if the firm received reliefs between 2003 and 2015 and 0 if the firm received no reliefs during that time. A vector of variables X includes age, employment, sector, status, turnover/employment, turnover, materials, GVA, investment, rent.

6.2.3.2 Implementation

Iacus *et al.* (2009) define a three-step procedure to implement a CEM algorithm: coarsening, control variables, sorting units into strata, *pruning groups*. *These will be detailed in the following paragraphs. They highlight that "following these three steps, the researcher can apply any method to the matched data that they might have to the raw data to estimate the causal effect, with the addition of weight that equalises the number of treated and control units within each stratum."* Therefore, having implemented these three steps, the causal effects will be computed with models explained in the following chapters.

The coarsening is an inherently substantive act, almost similar to the measurement of the original variables (Iacus *et al.*, 2009). Coarsening helps to set the maximum level of imbalance based on forecasts rather than actual results and set a bound on the degree of model dependence and the SATT estimation error. Multiple temporary datasets are created according to automated or manual criteria. This was carried out manually for some numeric variables which were included in the matching so that indistinguishable values are grouped and assigned the same numerical value. Levels should be ordered in the original dataset. Therefore, some variables were ordered by using the command 'ordered' in R. Other dummy variables and sector variable were kept unchanged.

For numerical variables, the 'cutpoints' option was added for the command 'cem.' For example, turnover and employment cut points were chosen according to the EU SME definition (as in Table 6:5, p. 157). Slightly more complicated was the work with other continuous variables. Therefore, these were cut in two parts by looking to their third quartile. The slightly different approach was taken for age variables. The population of ARDx has more larger firms than smaller ones. The previously imposed limitation of at least two observations further enlarged a probability of choosing the larger firms. Thus, instead of the third quartile, the first quartile was chosen for the age variable since younger firms are expected to outperform older ones. All coarsening at this stage is employed only during

matching to find the closest matches of recipients and non-recipients. The final dataset from matching does not include intermediate values.

SME defined as	Employees	Turnover (in millions)
Micro	≤ 10	$\leq \text{€}2$ (£1.72)
Small	≤ 50	$\leq \text{€}10$ (£8.6)
Medium	≤ 250	$\leq \text{€}50$ (£43.01)
Big	>250	$> \text{€}50$ (£43.01)

Table 6:5 SME definition by EU (Commission Recommendations, 2003)

6.3 MODELS AND ESTIMATION STRATEGIES

The previous section described the data, variables and matching. This section aims to derive models and explain the estimation techniques that were applied to that data. Subsection 6.3.1 starts by reviewing established and newer issues with control estimators and derives a relatively standard model to estimate productivity (Section 6.3.1.2) that deals with simultaneity, selection and omitted price biases (defined in Section 6.3.1.1). To identify any relationships between TFP and SBRR, the estimated productivity is further analysed with unbiased REEM trees (Section 6.3.1.3). The GMM estimator is also employed, which includes not just standard variables (GVA, labour, capital and either materials or investment) but also previously discussed additional variables on the characteristics of a firm (Section 6.3.1.4) to control for the effects discussed in the Theoretical Framework such as competition, HGF dummy and investments in R&D. Finally, the chapter also reviews the survival estimation (Section 6.3.2). This discussion shows that the more established Stratified Cox Proportional Model (Section 6.3.2.1) should be employed, supplemented by survival trees for left-truncated and right censored data (Section 6.3.2.2). The first approach is taken due to its semi-parametric nature and ability to control for serial correlation between firm's observations as well as to stratify on variables not satisfying the proportionate hazard's assumptions, while the latter was used because of its ability to partition the data space into smaller sections where variable interactions are more explicit.

6.3.1 Productivity Estimation

The Methodology Review Chapter (Section 5.1) directed towards using a control function approach to estimate TFP as it deals with simultaneity and selection biases, discussed at the start of this subsection 6.3.1.1. This section then develops with how these issues are overcome with Olley-Pakes' (OP) approach and its extensions (Section 6.3.1.2). The Wooldridge's GMM estimator should solve these issues and provide an appropriate estimator. Once it is clear how TFP is estimated, unbiased REEM trees are discussed in

Section 6.3.1.3. This is followed by the dynamic estimator introduced to supplement the results by providing broader insight.

6.3.1.1 Issues in Productivity Estimation

6.3.1.1.1 Endogeneity of Input Choice or Simultaneity Bias

Marschak and Andrews (1944) raised the issue of simultaneity bias more than 70 years ago. They suggested that characteristics of the firm determine inputs in production. If a firm has prior knowledge of its productivity, then inputs may be determined by previous beliefs about the expression of its productivity (Olley and Pakes, 1996). This will encompass unobservable information on management capacity to planned production interruptions for repairs, upgrades or training. Econometricians cannot have reliable estimates of these inputs because firms might adjust them, which creates endogeneity of inputs (Griliches and Mairesse, 1995) or correlation between the level of inputs determined and unobserved productivity shocks. As suggested by De Loecker (2007), a positive productivity shock could increase variable inputs as they can capture a greater market share, so the equation becomes:

$$E(x_{it}\omega_{it}) > 0, \text{ where } x_{it} = \ln L_{it}, \ln M_{it} \text{ and } \omega_{it} \text{ is TFP}$$

If uncontrolled, the impacts of the bias may differ according to parts of the equation. Beveren (2012) discusses a situation where coefficients for variable inputs are biased upward, and the capital coefficient is biased downward. Also, Levinsohn and Petrin (2003) look at two-input production function with labour being variable and capital – quasi-fixed. They conclude that there is a positive correlation between labour and capital, with the capital coefficient biased downward.

OLS cannot be used since it asks for inputs to be exogenous, i.e. independent of the company's efficiency. Academics such as Griliches and Mairesse (1995) have suggested dealing with this issue with fixed effects and instrumental variables which are introduced in Appendix 10.2.2. The more recent semi-parametric models directly address this issue. These are mostly based on Olley and Pakes (1996), Levinson and Petrin (2003) or either extensions or modifications of De Loecker (2007), Van Biesebroeck (2007), Wooldridge (2009) and Katayama *et al.* (2009) and Akerberg *et al.* (2015). The Methodology Review suggested that the vast majority of studies, which acknowledge simultaneity bias (e.g. Maiti, 2013; Goya *et al.*, 2016) have used semi-parametric approaches. For instance, Goya *et al.* (2016) adopt Olley and Pakes to account for both selection and simultaneity biases. They look at the impact that R&D and intra- and inter-industry externalities have on the performance of Spanish firms.

6.3.1.1.2 *Endogeneity of Attrition or Selection Bias*

Another substantial issue is endogeneity of attrition. In statistics, self-selection bias arises when subjects select themselves into a group, causing a biased sample with nonprobability sampling. This highly depends on the data available. There are two standard ways to show issues within self-selection into the treatment group. One of them is the standard econometric approach (discussed by Angrist and Pischke, 2009) and another is Rubin's (1973, 1974 and 1977) potential outcomes approach.

If one wants to estimate the average effect of treatment on treated (ATT), one could estimate:

$$y = \alpha + \beta D + \varepsilon,$$

where y is the outcome variable, α is an intercept that should equal to the mean of outcome variable for the firms that did not receive the SBRR (or treatment). β measures ATT and ε is an error term.

If $Cov(D, \varepsilon) = 0$, then OLS would estimate an unbiased estimate of ATT. However, this assumption does not hold if there are any omitted variables (Heckman, 1979) which would result in $Cov(D, \varepsilon) \neq 0$. For this reason, in order to be sure that $Cov(D, \varepsilon) = 0$, one has to control for all observable variables that may cause improvements. Therefore, OLS entirely depends on the specification of these variables. However, these missing variables are not usually known before the treatment.

Another problem is unobservable variables that determine outcome variables and treatment status. This would impose that $Cov(D, \varepsilon) \neq 0$.

Relaxing the assumption that the impact of treatment on the dependent variable is similar across observations. Heckman *et al.* (1997) are followed so that β can be:

$$\beta = E[b(X) + b|D = 1],$$

where b is the observation returns to treatment.

If this holds, then $Cov(D, \varepsilon) = 0$.

The simplest method to find the ATT is the difference in difference (DiD) estimator. This is determined by deducting the difference in the mean of the dependent variable between the start year and end year for the treatment group. The following condition should be satisfied for DiD be appropriate technique:

$$E[y_{it}^0 | D_{it} = 1] - E[y_{it^*}^0 | D_{it} = 1] = E[y_{it}^0 | D_{it} = 1] - E[y_{it^*}^0 | D_{it} = 0],$$

where t is a period of time later than t^* .

It states that the difference between t and t^* for the control group is similar to the difference in the treatment group if they did not receive SBRR.

Another possible approach is the fixed effect estimator. As described in Appendix 10.2.2.1, within estimator removes the time-invariant effects, so that OLS would provide unbiased estimates. However, the issue with this approach is that $Cov(D, \varepsilon) = 0$ should hold. If SBRR is awarded when firms are performing better or worse, this assumption is not satisfied. It is likely that firms which occupy premises with a lower rateable value may be performing worse than their counterparts.

One of the ways to solve this issue is to employ a matching estimator. In other words, to create an almost identical control group to the treatment group. To achieve this, several assumptions have to be satisfied (Rosenbaum and Rubin, 1983). Firstly, the following assumption should hold:

$$y^0 \perp D | X$$

Having created y^0 condition upon X , the distribution of the dependent variable across control and treatment groups with no treatment should be independent. If this holds, the results should be entirely attributable to the treatment. However, as previously suggested, it is impossible to include all variables to achieve this outcome. Therefore, given that the values before the treatment are available, they were used for matching in this thesis.

Another assumption is that X should not be a perfect predictor of treatment:

$$P(D = 1 | X) < 1$$

Thus, there should be some observations that received and did not get the relief for all X s.

These assumptions are satisfied with CEM matching approach, described in Section 6.2.3.

This bias is especially extreme with balanced panels. Although the problem has been identified already around 1965 by Wedervang. Until Olley and Pakes (1996), TFP is still being estimated by ignoring all firms that exit or enter over the same period to construct a balanced panel. However, many theoretical (Jovanovic, 1982; Hopenhayn, 1992) and empirical (Dunne *et al.*, 1988, Farinas and Ruano, 2005) studies have shown that firms' exit patterns reflect their initial productivity. Even though unbalanced samples may consider entry and exit, fundamentally inputs are made conditional on firms' survival (Olley and Pakes, 1996). Thus, if a firm has previous knowledge about their productivity before exit, this would possibly create a correlation between capital and the residual. Furthermore, larger firms (e.g. monopolies) with a larger capital base may require less efficient production processes to survive than smaller companies.

This could cause a biased estimation of all key production function variables. As Beveren (2012) describes, the capital coefficient may be biased downwards because of a negative correlation between error term and capital. Thus, using a balanced panel and overlooking exits could result in firm-level TFP estimates being biased upwards. As discussed in the Methodology Review Chapter (Section 5.1.4.5.1), Olley and Pakes (1996) are the first to include this into their model explicitly.

6.3.1.1.3 Omitted-price Bias

The vast majority of studies have used industry deflators to estimate firm-level prices. This is widespread practice as firm-level prices of inputs and outputs are usually unavailable to the researcher (Van Beveren, 2010; De Loecker, 2007). To use industry level deflators, researchers have to assume that firm-level price variation does not depend on the input coefficients. This assumption often does not hold in reality. As Van Beveren (2012) explains:

$$\widetilde{r}_{it} = p_{it} + y_{it} - \overline{p}_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + (p_{it} - \overline{p}_{it}) + \omega_{it} + u_{it}^q,$$

where \widetilde{r}_{it} is deflated sales, p_{it} is firm level prices and \overline{p}_{it} industry level price deflator. All variables are in logarithmic form. It is evident in the equation that:

$$E(x_{it}(p_{it} - \overline{p}_{it})) \neq 0, \text{ where } x_{it} = (l_{it}, m_{it}, k_{it})$$

In other words, a bias is introduced in the input coefficients because unobserved firm-level price differences are likely to be correlated with input choice.

From the Theory Review Chapter, it is evident that how demand and supply frameworks assume that inputs and output are likely to be positively correlated, and prices

are likely to be negatively correlated. For this reason, as Beveren (2010) explains, the bias for the coefficients of labour and materials are negative. He draws attention to Foster's *et al.* (2008) article. Foster starts by supposing that an efficient producer is capable of lowering its prices. If this producer's output is deflated by industry average, TFP would be underestimated. Likewise, the firm that charges a price such that $p_{it} > \overline{p_{it}}$, the TFP would be overestimated because higher output prices would wrongly suggest a higher output for a given amount of inputs. This is supported by Foster's *et al.* (2008) with data on the manufacturing sector. The omitted price bias may be controlled by using quantities of output rather than sale price if data is available as it is done by Foster *et al.* (2008).

Van Beveren (2010) further shows that input prices could be firm-specific because of the imperfect competition in the input market. Thus, if a firm can get lower prices than the industry average, industry level deflators will lead to underestimate its inputs so that TFP would be biased upwards. Therefore, the bias introduced by using industry deflators is the opposite to the simultaneity of input choice.

In a similar vein, De Loecker (2007) suggests that input prices are reflected in higher output prices. This highly depends on the firm's markup. Katayama *et al.* (2009) oppose De Loecker's position by pointing out that adjustment costs will lead to different prices across firms included with varying levels of capital.

As Van Beveren (2010) and De Loecker (2007) highlight, industry price indexes or inflation are most often applied as deflators as the researcher does not have access to firm level prices.

The solution proposed in this thesis is to deflate the price on company purchase price growth rather than inflation. ONS data from the PSM survey helped to approximate deflators more precisely. Although the sample size of PSM is far smaller than ARD-X and significantly smaller than BSD, it is still believed to approximate deflators more accurately than the gross domestic product (GDP), for example. The exact steps undertaken to merge and estimate deflators are described with other datasets in Section 6.2.2.3.

6.3.1.2 Control Functions

The empirical examples related to control functions were already reviewed in the Methodology Review Chapter (Section 5.1.4.5). This section describes the mechanisms behind those models. It bases its discussion on pioneering papers by Olley and Pakes (OP), Levinsohn and Petrin (LP), Akerberg *et al.* (ACK) and Wooldridge's developments. The equations are adopted from Rovigatti (2018), who also published 'Prodest,' a package which was used to estimate productivity.

The discussion of control functions is based on the Methodology Review Chapter providing insights into a preferable functional form (Section 5.1.2) and estimation techniques (Sections 5.1.3, 5.1.4 and 5.3). The logarithmic Cobb-Douglas functional form was identified as a suitable choice as it includes the key inputs and different variations which can improve estimates. The translog production function can incorporate many substitution possibilities among various inputs and can take any degree of returns to scale. Thus, modelling starts with the following productivity function:

$$\ln GVA_{it} = \beta_0 + \beta_k \ln K_{it} + \beta_l \ln L_{it} + \omega_{it},$$

where $\ln GVA_{it}$ is logarithmic GVA, $\ln K_{it}$ is logarithmic capital, $\ln L_{it}$ is logarithmic employment and ω_{it} is total factor productivity. Thus, the first step is to approximate ω_{it} which can also be expressed as:

$$\omega_{it} = \ln GVA_{it} - \beta_k \ln K_{it} - \beta_l \ln L_{it}$$

Firstly, it is essential to introduce the pivotal Olley-Pakes (OP) estimator because it deals with the correlation between inputs and productivity term (ω_{it}). Firm investment levels are exploited as a proxy variable for ω_{it} . One must make several assumptions, as in the clear majority of control function-based estimators.

The first assumption is that the investment function ($\ln I_{it}$) is determined by the dynamic inputs ($\ln K_{it}$) and observed TFP (ω_{it}). It is invertible in ω_{it} and monotonically increasing in ω_{it} .

The second assumption is that the state variables such as capital ($\ln K_{it}$) at the time (t) is predetermined at a period before ($t-1$) but labour ($\ln L_{it}$) is non-dynamic. Their choice at the time (t) does not influence future or after the firm productivity shock realisation.

Under the first two assumptions, the investment is orthogonal to capital in t such that $E[\ln I_{it} | \ln K_{it}] = 0$, forming the following production function:

$$\omega_{it} = f^{-1}(\ln I_{it}, \ln K)$$

Under the monotonicity assumption, the control function may be specified by inverting the investment function:

$$\omega_{it} = f^{-1}(\ln I_{it}, \ln K) = h(\ln I_{it}, \ln K_{it})$$

Combining this function with Logarithmic Cob Douglas productivity function yields:

$$\ln GVA_{it} = \beta_0 + \beta_k \ln K_{it} + \beta_l \ln L_{it} + h(\ln I_{it}, \ln K_{it}) + \varepsilon_{it} = \beta_l \ln L_{it} + \varphi(\ln I_{it}, \ln K_{it}) + \varepsilon_{it},$$

$$\text{where } \varphi(\ln I_{it}, \ln K_{it}) = \beta_k \ln K_{it} + h(\ln I_{it}, \ln K_{it}) = \beta_k \ln K_{it} + \omega_{it}$$

This equation is a partially linear model identified only in $\beta_l \ln L_{it}$. It could be found by estimating by a linear regression of n^{th} order polynomial φ^* .

The third assumption is that the time-varying part of the TFP follows a first-order Markov process:

$$\omega_{it} = E(\omega_{it} | \Omega_{it-1}) + \xi_{it} = E(\omega_{it} | \omega_{it-1}) + \xi_{it} = g(\omega_{it-1}) + \xi_{it},$$

where Ω_{it-1} is the information set at the period before ($t - 1$) and ξ_{it} is the shock in productivity. ξ_{it} is uncorrelated with productivity ω_t and with $\ln K_{it}$.

Given the third assumption, β_k is estimated by reshaping the model for $\ln GVA_{it} - \beta_l^* \ln L_{it}$ conditional on $\ln K_{it}$:

$$\ln GVA_{it} - \beta_l^* \ln L_{it} = \beta_0 + \beta_k \ln K_{it} + \omega_{it} + \varepsilon_{it} = \beta_0 + \beta_k \ln K_{it} + E[\omega_{it} | \omega_{i(t-1)}] + \varepsilon_{it} + \xi_{it} = \beta_0 + \beta_k \ln K_{it} + g(\omega_{i(t-1)}) + e_{it},$$

$$\text{where } e_{it} = \varepsilon_{it} + \xi_{it}.$$

Being $\omega_{it}^* = \varphi_{it}^* - \beta_k \ln K_{it}$, the previous equation becomes:

$$\ln GVA_{it} - \beta_l^* \ln L_{it} = \beta_0 + \beta_k \ln K_{it} + g(\varphi_{i(t-1)}^* - \beta_k \ln K_{i(t-1)}) + e_{it}$$

$g(\cdot)$ can be left unspecified and estimated non-parametrically. Also, $g(\cdot)$ may be assumed to follow a random walk, then the equation can change to:

$$\ln GVA_{it} - \beta_l^* \ln L_{it} = \beta_0 + \beta_k (\ln K_{it} - \ln K_{i(t-1)}) + \varphi_{i(t-1)}^* + e_{it}$$

and

$$e_{it} = \ln GVA_{it} - \beta_l^* \ln L_{it} - \beta_0 + \beta_k \ln K_{it} - g(\varphi_{i(t-1)}^* - \beta_k \ln K_{i(t-1)})$$

And the true β_k^* value.

OP further discusses selection bias arising due to participants dropping out of the sample in a rather systematic way (non-random). Less productive firms may be more likely to close than more productive firms. Thus, they suggest a firm is likely to continue operating when its productivity level surpasses the lower bound $X_{it} = 1 \leftrightarrow \omega_{it} \geq \omega_{it}^*$, where X_{it} is a

survival variable and ω_{it}^* is industry variable. They suggest accounting for it by including not just the state variable but also X_{it} :

$$\ln GVA_{it} - \beta_l^* \ln L_{it} = \beta_0 + \beta_k \ln K_{it} + E[\omega_{it} | \omega_{i(t-1)}, X_{it}] + e_{it}$$

OP suggests correcting for this bias by adding to $\ln GVA_{it} - \beta_l^* \ln L_{it} = \beta_0 + \beta_k (\ln K_{it} - \ln K_{i(t-1)}) + \varphi_{i(t-1)}^* + e_{it}$ an estimate of the unconditional probability of remaining active in the market:

$$\ln GVA_{it} - \beta_l^* \ln L_{it} = \beta_0 + \beta_k \ln K_{it} + g(\varphi_{i(t-1)}^* - \beta_k \ln K_{i(t-1)} - Pt_{i(t-1)}^*) + e_{it},$$

where $Pt_{i(t-1)}^*$ is the fitted surviving probability that could be found with such estimators as a discrete choice model on a polynomial of the $\ln K_{it}$ and $\ln L_{it}$.

For this study, it is useful to discuss some extensions of Levinsohn and Petrin (LP) (2003) because their extension of the OP model reduces the likelihood of violating the second assumption. The presence of capital adjustment costs could violate the monotonicity, making the investment function non-invertible. Investments are often not decided at each point in time, but accumulated for several years before being made all at once. Therefore, they included intermediate materials instead of investment in production function:

$$\omega_{it} = w(\ln M_{it}, \ln K_{it})$$

Now, the first two assumptions change to:

First assumption. Firms know their productivity shock and according to the demand they adjust the level of intermediate inputs. $\ln M = f(\ln K_{it}, \omega_{it})$ is the intermediate input function. It is invertible in ω_{it} and monotonically increasing in ω_{it} .

Second assumption. Capital ($\ln K_{it}$) at the time (t) is predetermined at a period before ($t-1$) but labour ($\ln K_{it}$) is static, so their choice at t does not impact future and after the firm productivity shock realizes.

Now, the intermediate input demand is orthogonal to capital in t such that $E[\ln M_{it} | x_{it}] = 0$ and m_{it} can be invertible, thus the productivity is:

$$\omega_{it} = h(\ln M_{it}, \ln K_{it})$$

Adding this to the general Cobb-Douglas function:

$$\ln GVA_{it} = \beta_0 + \beta_k \ln K_{it} + \beta_l \ln L_{it} + \beta_m \ln M_{it} + h(\ln M_{it}, \ln K_{it}) + e_{it} = \beta_0 + \beta_l \ln L_{it} + \varphi(\ln M_{it}, \ln K_{it}) + e_{it}, \quad \text{where } e_{it} = \varepsilon_{it} + \xi_{it}.$$

This equation can be non-parametrically approximated by estimating $\varphi(\ln M_{it}, \ln K_{it})$ with n^{th} order polynomial or by local linear regression. The residual function e_{it} can be defined:

$$e_{it} = \ln GVA_{it} - \beta_l \ln L_{it} - \beta_k^* \ln K_{it} - g(\varphi_{i(t-1)}(\beta_m^*) - \beta_k \ln K_{i(t-1)})$$

Given firm's response to the technology efficiency shock, e_{it} is not a combination of pure errors anymore because intermediate input variable is likely to be correlated with the error term.

The GMM estimator may then be built by using the residuals e_{it} and the matrix of moment conditions $E[e_{it}, z_{it}^k] = 0, \forall k$, where k is the index of the instrument vector $z = [\ln K_{it}, \ln M_{i(t-1)}]$. Then, β_k^*, β_m^* may be consistently estimated with:

$$[\beta_k^*, \beta_m^*] = \underset{\beta_k^*, \beta_m^*}{\operatorname{argmax}} \left\{ \sum_k \left(\sum_i \sum_t e_{it} z_{it}^k \right)^2 \right\}$$

Building on this, Akerberg *et al.* (ACF) propose that the labour coefficient can be estimated in the first stage only when the free variables display variability autonomously of the proxy variable. This being false may cause collinearity in the 1st stage estimator. As a result, the function may not be identifiable. In the LP setting intermediate inputs and labour are allocated at t implying that materials and labour are both chosen as a function of productivity and labour:

$$\ln M_{it} = m(\omega_{it}, \ln K_{it})$$

$$\ln L = l(\omega_{it}, \ln K_{it})$$

Given the monotonicity condition, it could be rewritten as:

$$\ln L = l[h(m_{it}, \ln K_{it}), \ln K_{it}]$$

First assumption. The proxy variable policy function, $p_{it} = p_{it}(\ln K_{it}, \ln L_{it}, \omega_{it})$, is determined by the dynamic inputs ($\ln K_{it}$) and observed TFP (ω_{it}) and static inputs ($\ln L_{it}$). It is monotonically increasing in ω_{it} .

Second assumption. Capital ($\ln K_{it}$) at the time (t) is chosen at time $t - b$. The labour input ($\ln L_{it}$) is selected at time $t - \zeta$, where $0 < \zeta < 1$. Whilst, the free variables are decided at time t when the firm productivity shock is realised.

Under these assumptions, the shock (ε_{it}) is removed from the output $\ln GVA_{it}$ in the first estimation, so the policy function can be merged to the CD productivity function:

$$\ln GVA_{it} = \varphi_{it}(p_{it}, \ln K_{it}, \ln L_{it}) + e_{it},$$

$$\text{where } \varphi_{it}(p_{it}, \ln K_{it}, \ln L_{it}) = \beta_k \ln K_{it} + \beta_l \ln L_{it} + h(p_{it}, \ln K_{it}, \ln L_{it})$$

Once φ_{it} is recovered for any candidate vector (β_l^*, β_k^*) , the residuals can be obtained:

$$\omega_{it}^* = \varphi_{it}^* - \beta_k^* \ln K_{it} - \beta_l^* \ln L_{it}$$

Exploiting Markov chain assumption obtain residuals, ξ_{it} with the moment conditions, $E[\xi_{it}, z_{it}^*] = 0, \forall k$, where k is the index of the instrument $z = [\ln M_{i(t-1)}, \ln L_{i(t-1)}]$.

Wooldridge (2009) replaces the two-step estimator by employing Generalised Method of Moments (GMM) estimator. It overcomes the identification issue in the first stage as featured by ACF with a problem of labour input being dynamic. Wooldridge's (2009) method is preferable for this estimation because of its simplicity. It is possible with this method to estimate all coefficients in one stage by using GMM estimator. Additionally, this one-step method made it easier to obtain standard errors with no bootstrapping.

The estimation of (β_l, β_k) is addressed in the first stage by OP/LP under the assumption:

$$E(\varepsilon_{it} | \omega_{i(t-1)}, \ln L_{it}, \ln K_{it}, \ln M_{it}, \ln L_{i(t-1)}, \ln K_{i(t-1)}, \ln M_{i(t-1)}, \dots, \ln L_{i1}, \ln K_{i1}, \ln M_{i1}) = 0$$

Taking back to $\varphi(\ln L_{it}, \ln K_{it}) \equiv \beta_0 + \beta_k \ln K_{it} + h(\ln L_{it}, \ln K_{it})$, then $h(\cdot)$ can be estimated with those moment conditions with no functional form.

The second stage assumption uses previously defined Markovian distribution. Assuming that there is no correlation between productivity shocks and current values of both, labour and intermediate inputs, as well as following LP's approach, the functional form becomes:

$$E(\omega_{it} | \ln L_{i(t-1)}, \ln K_{i(t-1)}, \ln M_{i(t-1)}, \dots, \ln L_{i1}, \ln K_{i1}, \ln M_{i1}) = E(\omega_{it} | \omega_{i(t-1)}) = f[h(\ln K_{i(t-1)}, \ln M_{i(t-1)})],$$

where similarly as it was for $h(\cdot)$ no functional form is imposed for $f(\cdot)$.

It leads to two functions to identify (β_L, β_k) :

$$\ln GVA_{it} = \beta_0 + \beta_k \ln K_{it} + \beta_l \ln L_{it} + h(\ln M_{it}, \ln K_{it}) + v_{it}$$

$$\ln GVA_{it} = \beta_0 + \beta_k \ln K_{it} + \beta_l \ln L_{it} + f[h(\ln K_{i(t-1)}, \ln M_{i(t-1)})] + \eta_{it},$$

where $\eta_{it} = \xi_{it} + v_{it}$

Using nth polynomials again and $\ln K_{it}$ and $\ln M_{it}$ may be estimated. Assuming linearity, the functional form would be: $h(\ln M_{it}, \ln K_{it}) = \alpha_0 + k(\ln M_{it}, \ln K_{it})\alpha_1$.

Implying $f(\omega_{it}) = \delta_0 + \delta_1[k(\ln M_{it}, \ln K_{it})\alpha_1] + \delta_2[k(\ln M_{it}, \ln K_{it})\alpha_1]^2 + \dots + \delta_G[k(\ln M_{it}, \ln K_{it})\alpha_1]^G$.

Then, to simplify for illustration purposes, it may be assumed that $G=1$ and $\delta_1 = 1$. Thus, substituting equations yields:

$$\ln GVA_{it} = \alpha_0 + \beta_k \ln K_{it} + \beta_l \ln L_{it} + k(\ln M_{it}, \ln K_{it})\alpha_1 + v_{it}$$

$$\ln GVA_{it} = \theta + \beta_k \ln K_{it} + \beta_l \ln L_{it} + k(\ln M_{i(t-1)}, \ln K_{i(t-1)})\alpha_1 + \eta_{it}$$

The choice of instruments for these equations reflects the orthogonality conditions listed above: $\delta_{it1} = (1, \ln K_{it}, \ln L_{it}, k(\ln M_{it}, \ln K_{it}))$,

$$\delta_{it2} = (1, \ln K_{it}, \ln L_{i(t-1)}, k(\ln M_{i(t-1)}, \ln K_{i(t-1)})) \text{ and } Z_{it} = \begin{pmatrix} \delta_{it1} \\ \delta_{it2} \end{pmatrix}$$

Then, for each $t > 1$, the GMM with IV setup applies and the moment conditions are derived from residuals:

$$r_{it}(\theta) = \begin{pmatrix} r_{it1}(\theta) \\ r_{it2}(\theta) \end{pmatrix} = \begin{pmatrix} \ln GVA_{it} - \alpha_0 - \beta_k \ln K_{it} - \beta_l \ln L_{it} - k(\ln M_{it}, \ln K_{it})\alpha_1 \\ \ln GVA_{it} - \theta - \beta_k \ln K_{it} - \beta_l \ln L_{it} - k(\ln M_{i(t-1)}, \ln K_{i(t-1)})\alpha_1 \end{pmatrix}$$

Wooldridge's system estimator builds a matrix of regressors for the system of equation to avoid collinearity. Let X be a matrix of regressors for this system, d be a number of common regressors (e.g. $\alpha_0, \beta_k \ln K_{it}, \ln L_{it}, \ln M_{it}$) and $r1$ and $r2$ be the number of regressors in the first and second equations respectively. Then, the matrix is:

$$X = \begin{pmatrix} X1_1^1 & \dots & X1_1^d & X1_1^{d+1} & \dots & X1_1^{r1} & 0 & 0 & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & 0 & 0 & 0 \\ X1_N^1 & \dots & X1_N^d & X1_N^{d+1} & \dots & X1_N^{r1} & 0 & 0 & 0 \\ X2_1^1 & \dots & X2_1^d & 0 & 0 & 0 & X2_1^{d+1} & \dots & X2_1^{r2} \\ \vdots & \ddots & \vdots & 0 & 0 & 0 & \vdots & \ddots & \vdots \\ X2_N^1 & \dots & X2_N^d & 0 & 0 & 0 & X2_N^{d+1} & \dots & X2_N^{r2} \end{pmatrix}$$

Then, as in Wooldridge (2002), the overidentified linear model is given by $\hat{\beta}^0 = ((X'Z)W^0(Z'X))^{-1}(X'Z)W^0(Z'Y)$, where W^0 is independent weighting matrix. Then, using $\hat{\beta}^0$ to find $W^* = \sigma_{RS}Z'Z$. Thus, the parameters can now be estimated in the second step with:

$$\hat{\beta}^* = ((X'Z)W^*(Z'X))^{-1}(X'Z)W^*(Z'Y)$$

Then, variance-covariance matrix is

$$Var(\hat{\beta}^*) = \frac{1}{N}((X'Z)W^*(Z'X))^{-1}$$

When all variables are estimated, one can come back to the logarithmic TFP form (ω_{it}) and approximate TFP just with:

$$\omega_{it} = \ln GVA_{it} - \beta_k \ln K_{it} - \beta_l \ln L_{it}$$

The following section, 6.3.1.3, will explain how the effects on productivity ω_{it} were measured with the Random Effects Expectation Maximization algorithm.

6.3.1.3 The Random Effects Expectation Maximisation (REEM)

The Classification and Regression Tree approach was defined and its fundamental mechanisms explained in the Methodology Review Chapter (Section 5.3). This section aims to explain mechanisms in REEM trees as these were found to be the most appropriate and feasible machine learning technique that could identify the relationship between previously estimated TFP, ω_{it} , and independent variables that were built throughout the thesis (Chapters 1-3), summarised in the Framework with Hypotheses Chapter as well as cleansed and derived in Sections 6.2.2.4 and 6.2.2.6.

As previously stated in the Methodology Review Chapter (Section 5.3), REEM trees were introduced by Hajjem *et al.* (2011) and Sela and Simonoff (2012) and advanced by Fu and Simonoff (2015). They use longitudinal and cluster unbalanced data and time-varying features. These are the improvements that make the method suitable for this estimation.

As reported by Sela and Simonoff's (2012), there is one major difference between Hajjem *et al.* (2011) and Sela and Simonoff's works. Hajjem *et al.* (2011) dissociate the fixed from the random effects. Fixed effects are modelled with the Classification and Regression Trees (CART) as the standard regression tree, but the random effects are modelled by using a node-invariant linear structure. Whilst, Sela and Simonoff (2012) alternate between two steps. One of the steps is to estimate the regression tree by assuming that estimates of the

random effects are correct. Another step is to estimate the random effects by assuming that the regression tree for the fixed effects is correct. Both authors employ the CART algorithm.

The REEM model is:

$$\omega_{it} = Z_{it}b_i + f(\cdot) + \varepsilon_{it}, \quad i = 1, \dots, I \quad t = 1, \dots, n$$

$$\begin{pmatrix} \varepsilon_{i1} \\ \vdots \\ \varepsilon_{in} \end{pmatrix} \sim N(0, R_i), \quad b_i \sim \text{Normal}(0, D),$$

$$f(\cdot) = f\left(\sum_{j=0}^4 (SBRR_{t-j}), \rho_{it}, a_{it}, r_{it}, s_{it}, PS_{it}, PD_{it}, HHI_{it}, R\&D_{it}, HGF_{it}, FO_{it}, IO_{it}\right)$$

The dependent variable ω_{it} , is the bootstrapped estimate of total factor productivity, as discussed in the previous section (6.3.1.2). For each firm i in period t Z is a matrix of independent variables which may vary or be constant over time and firms and b_i is the vector of random effects. $f(\cdot)$ contains the same variables as Z , but they can differ. These variables are used to estimate the fixed effects via the decision tree. $SBRR$ and four lags are included in the model to capture medium term effects and account for the periodicity of the reliefs. These variables are complemented by the dummy variable ρ to capture the initial³³ effects of receiving any relief or the uplift in relief, irrespective of level as derived in Section 6.2.2.6.5.3.

Additionally, as according to the Framework with Hypotheses Chapter (Section 4.7.1), basic classification variables of firm age (a), the regions and countries (r) of Wales, Scotland, London, North East, North West, Yorkshire and Humberside, East Midlands, West Midlands, East of England, South East and South West were included. Furthermore, the firms were classified into the broad sectors (s) of wholesale, catering, construction, production, property, retail and other services.

In order to account for the effects of industry structure and competition on investment and survival, the model includes indices of regional specialisation via the PS index of Marshall (production) Specialisation and an index for the counter regional Jacob Diversity (PD) defined in Section 4.6.2 and derived in Section 6.2.2.6.3. The industry competition at the national level is controlled via a Herfindahl-Hirschman Index (HHI) defined in Section 4.6.3 and derived in Section 6.2.2.6.2. The Marshallian Specialisation (PS) externalities are captured by calculating the production structure specialisation index, as

³³ Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010.

suggested by Feldman and Audretsch (1999) and Paci and Usai (1999). As defined in Section 4.6.1 and derived in Section 6.2.2.6.1, this exploits the access to firm-level micro data to calculate the specialisation within small two-digit postcode areas, relative to national SIC (2003) two-digit industry output. To better capture this specialisation, extensive ONS data is exploited to use turnover rather than the more usual employment levels. This gives a far more accurate perspective on the concentration and value of the activity. Moreover, it should be a less noisy control for TFP than employment. In the same vein, Section 4.7.3 also suggests controlling for the choice to invest in Research and development with the variable $R\&D$, which comes from the survey element of the ARDx dataset and questions whether a firm intends to invest in such activity within the next two years.

As presented in Section 4.7.4, firms receiving foreign investment are likely to have higher productivity than firms which do not attract foreign investment, after controlling for firm characteristics. There are of course selection effects which bias these findings. Consequently, the dummy variable FO is included. It takes one for firms with a foreign majority owner. In this era of concerns about complex ownership structures and use of complex taxation schemes, variable IO is also included to denote a foreign country registration of the firm's immediate parent firm and this is also the variable ONS used in their calculations. This can be different to FO , which denotes the ultimate country of the owner. HGF controls for high growth firms, HGF is a dummy taking the value of 1 in the years it meets the Eurostat-OECD. (2007) definition, namely average annualised growth in employment greater than 20% per annum, over a three-year period with initial employment not lower than ten. These companies are believed to be performing better than the rest, as discussed in Section 4.7.2.

The error term ε_{it} , is assumed to be uncorrelated with the random effects and independent across observations. R_i is a non-diagonal matrix to account for autocorrelation within firms. The algorithm proceeds by initially setting the random effects to zero and building a decision tree. The random effects are then estimated, given the decision tree and the process iterates until the random effects converge using a restricted maximum likelihood estimator. The decision tree values are then finally updated. Then, a Classification and Regression Trees (CART) algorithm is employed to build the trees.

Sela and Simonoff (2012) explain that if $f(\cdot)$ is a linear function and effects, b_i , are fixed (or correlated with covariates), the model becomes a linear fixed effects model. Likewise, if it is a linear function and effects are uncorrelated, $f(\cdot)$ becomes a linear random effects model.

If the random effects, b_i , were known, a regression tree may be fit to $\omega_{it} - Z_{it} b_i$. On the other hand, if fixed effects, $f(\cdot)$, were known, it may be estimated with a mixed effects linear model with fixed effects. However, both, b_i and $f(\cdot)$, are unknown. As a product, they alternate between estimating the fixed effects, assuming that the estimates of the random effects are correct, and estimating the random effects, assuming that the fixed effects is correct.

Firstly, they adjust the estimated random effects, b_i , to zero. They then iterate through the subsequent steps until the variation in the restricted likelihood function is less than a tolerance value. The first step is to approximate $f(\cdot)$, with a regression tree, based on the target variable, $\omega_{it} - b_i$, and covariates, X_{it} . The second step is to use this tree to produce indicator variables, $l(X_{it} \in g_p)$, where g_p is the p -th group and ranges over all terminal nodes in the tree. The third step is to fit the linear random effects model. The function becomes: $\omega_{it} = b_i + l(X_{it} \in g_p)\mu_p + \varepsilon_{it}$, where μ_p is the expected level of the outcome for group p . \hat{b}_i can be extracted from the estimated model. The fourth step is to substitute the predicted response at each terminal node of the tree with the estimated population level predicted outcome $\hat{\mu}_p$ from the previously fitted linear mixed effects model.

However, later Fu and Simonoff (2016) show that the CART algorithm tends to divide on variables with many more possible split points at the expense of variables with fewer points. They find that a conditional inference tree approach is superior. The core advantage of the conditional inference tree is that it takes into account the distributional properties of the variables. Thus, the results are more robust to the structure of the dataset. This method is used in the estimation. The linear random effects model is estimated using a restricted maximum likelihood (REML) technique. While to estimate regression tree, Fu and Simonoff's (2015) extension of the Sela and Simonoff's (2012) method is used by estimating the regression trees with Hothorn *et al.* (2006). This, according to the analysis of Fu and Simonoff's (2015), should provide more precise estimates.

6.3.1.4 Dynamic Panel Data (DPD) Estimators

An alternative is provided by an array of papers by Harris and Moffat. They argue that if one estimates ω_{it} without other variables that potentially may derive a biased estimation because of an omitted variable problem. They tend to include all variables that may cause changes in productivity and estimate the logarithmic Cobb Douglas productivity estimation with system GMM estimator.

Given that the primary goal of this study is to investigate the effect of SBRR, other variables, which were defined in the previous section (6.3.1.3) are also included. Briefly, *SBRR* refers to the Small Business Rates Relief and its lags for each firm i in period t . The variables in vector X were defined in Section 6.3.1.3. Shortly, ρ captures the initial³⁴ effects of receiving any relief or the uplift in relief, irrespective of level. Other variables are firm age (a), the regions (r) and broad sectors (s), immediate foreign ownership (IO), ultimate foreign ownership (FO), high growth firm dummy (HGF). To at least partly control for the competition, the model includes Marshall Specialisation (PS), Jacob Diversity (PD) and Herfindahl-Hirschman Index (HHI).

Hence, a logarithmic variable, X_{it} , is introduced:

$$X_{it} = \sum_{j=0}^4 (SBRR_{t-j}), \rho_{it}, a_{it}, r_{it}, s_{it}, PS_{it}, PD_{it}, HHI_{it}, R\&D_{it}, HGF_{it}, FO_{it}, IO_{it}$$

Then, the model becomes:

$$\ln GVA_{it} = \beta_L \ln L_{it} + \beta_K \ln K_{it} + \partial_K \ln K_{i(t-1)} + \partial_M \ln M_{i(t-1)} + \partial_L \ln L_{i(t-1)} + \partial_X \ln X_{it} + z_{it}\mu + \xi_{it} + e_{it}$$

To at least partly deal with unobserved heterogeneity, it is common to apply the within (demeaning) transformation, as in one-way fixed effects models, or to take first differences if the second dimension of the panel is a time series, as carried out by Harris and Moffat (2016) and Harris *et al.* (2015). Given the large observed time and relatively small number of firms, the lag feature was exploited within this analysis by converting the productivity function to a dynamic form. In other words, controlling for the lagged dependent variable and estimating the equation with GMM system estimator:

$$\ln GVA_{it} = \beta_{GVA} \ln GVA_{i(t-1)} + \beta_L \ln L_{it} + \partial_L \ln L_{i(t-1)} + \beta_K \ln K_{it} + \partial_K \ln K_{i(t-1)} + \partial_M \ln M_{i(t-1)} + \partial_X \ln X_{it} + z_{it}\mu + \xi_{it} + e_{it}$$

The unique feature of DPD models is their capability of first differencing to remove unobserved heterogeneity. Nickell (1981) shows that the demeaning process creates a correlation between the regressor and error because it subtracts the individual's mean value of the outcome variable and each independent variable from the respective variable. This correlation makes coefficients of the lag dependent variable biased. In other words, the mean of the lagged dependent variable is likely to contain observations of 0 through the period before on y , and the mean error, which is being subtracted from each error term,

³⁴ Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010.

contains contemporaneous values of error. One of the solutions to this may be first differences of the original model.

6.3.1.4.1 Anderson–Hsiao (AH) estimator

However, there is still a correlation between the disturbance process (first-order moving average) and the differenced lagged dependent variable because the disturbance process contains lagged error term. At this point, the Anderson–Hsiao estimator could be used to remove individual fixed effects with instrumental variables estimator by constructing instruments for the lagged dependent variable with the second/third lags. Anderson and Hsiao's (1982) approach is based on a different form of the original equation:

$$\ln GVA_{it} = \beta_{GVA} \ln GVA_{i(t-1)} + \beta_j (J_{it} - J_{i(t-1)}) + \alpha_i + e_{it}$$
 , where J is all independent variables in the model and α_i is individual specific fixed effects. This model in AH's framework becomes:

$$\ln GVA_{it} - \beta_{GVA} \ln GVA_{i(t-1)} = (\ln GVA_{i(t-1)} - \beta_{GVA} \ln GVA_{i(t-2)}) + \beta_j (J_{it} - J_{i(t-1)}) + e_{it} - e_{i(t-1)}$$

This cancels individual effects assumed to correlate with exogenous variable, but the difference of lagged endogenous variable is correlated with the error term ($e_{it} + e_{i(t-1)}$).

AH suggest $(\ln GVA_{i(t-1)} - \beta_{GVA} \ln GVA_{i(t-2)})$ instrumenting with lagged difference $(\ln GVA_{i(t-2)} - \beta_{GVA} \ln GVA_{i(t-3)})$ or level instruments $(\ln GVA_{i(t-2)})$ because these differences should not be correlated with the differenced error term: $E(y_{i,t-2} de_{it}) = 0$ and $E(dy_{i,t-2} de_{it}) = 0$.

Later, Holtz-Eakin *et al.* and Arellano (1989) found level instruments $(\ln GVA_{i(t-2)})$ to be superior because they both had smaller variance and no points of singularities. Furthermore, when level instruments are used, one year less is lost because of lags.

6.3.1.4.2 Arellano–Bond (AB) or Difference Estimator

In empirical work looking at productivity after Wooldridge's (2009) one-step estimation was introduced, Generalised Method of Moments firstly suggested by Holtz-Eakin *et al.* and populated by Arellano and Bond (1991) has become increasingly popular. The main idea behind the estimator is that the instrumental variables approach does not use all available information, so by including more information, more efficient estimates may be found. They separate J_{it} into two parts: $J2_{it}$ and $J3_{it}$, where $J2_{it}$ consists of strictly exogenous regressors and $J3_{it}$ are predetermined regressors (could include lags of $\ln GVA$ as well) and endogenous regressors possibly correlated with the unobserved individual

effect. First differencing, as performed in AH estimator also removes individual effects and its associated omitted variable bias:

$$\ln GVA_{it} = \beta_j(J2_{it} - J2_{i(t-1)}) + \beta_j(J3_{it} - J3_{i(t-1)}) + e_{it} - e_{i(t-1)}$$

In standard 2SLS, so as well as AH estimator, the first observation is lost by applying the twice-lagged level in the instrument matrix:

$$\begin{pmatrix} \ln GVA_{i1} \\ \vdots \\ \ln GVA_{i(t-n)} \end{pmatrix},$$

where n is all lagged periods.

If the twice lagged instrument is included, two observations are lost:

$$\begin{pmatrix} \ln GVA_{i1} & \vdots \\ \ln GVA_{i2} & \ln GVA_{i1} \\ \vdots & \vdots \\ \ln GVA_{i(t-2)} & \ln GVA_{i(t-3)} \end{pmatrix}$$

To reduce the loss of degrees of freedom, AB constructs a set of instruments from the second lag of $\ln GVA$, one instrument pertaining to each time period:

$$\begin{pmatrix} 0 & 0 & \dots & 0 \\ \ln GVA_{i1} & 0 & \dots & 0 \\ 0 & \ln GVA_{i2} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \ln GVA_{i(t-2)} \end{pmatrix}$$

The columns of this instrument matrix are orthogonal to the transformed errors because the resulting moment conditions correspond to an expectation $E(\ln GVA_{i(t-2)}, FDerrors) = 0$.

This solution implies that all available lags can be used as instruments, for endogenous variables twice lagged or higher and for predetermined variables that are not strictly exogenous once lagged variables are also valid because they are only correlated with errors dated t-2 or earlier. Therefore, the instrumental matrix becomes:

$$\begin{pmatrix} 0 & 0 & 0 & 0 & 0 \\ \ln GVA_{i1} & 0 & 0 & 0 & 0 & \dots \\ 0 & \ln GVA_{i2} & 0 & 0 & 0 & \dots \\ 0 & 0 & \ln GVA_{i3} & \ln GVA_{i2} & \ln GVA_{i1} & \dots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \dots \end{pmatrix}$$

6.3.1.4.3 Arellano–Bover and Blundell and Bond (ABBB) or system estimator

Later, Arellano and Bover (1995) and Blundell and Bond (1998) have shown that the lagged levels might be slightly wrong instruments for first differenced variables, particularly if they follow a random walk, so they provide a modification which includes

lagged levels and lagged differences. The chief drawback of the System GMM estimator is the additional restrictions on the initial conditions of the process generating.

6.3.1.4.4 *Instrumental variables in general*

The motivation to use instrumental variables is to isolate “as good as random” variation in the treatment variable, so that selection and unobservable problems could be solved. Revisiting the final equation of the dynamic model:

$$\ln GVA_{it} = \beta_{Gross} \ln GVA_{i(t-1)} + \beta_L \ln L_{it} + \beta_k \ln K_{it} + \partial_K \ln K_{i(t-1)} + \partial_M \ln M_{i(t-1)} + \partial_L \ln L_{i(t-1)} + \partial_X \ln X_{it} + z_{it} \mu + \xi_{it} + e_{it}$$

Given that the capital was measured, it is directly related to investment:

$$\beta_k \ln K_{it} = \beta_1 \ln I_{it} + e_{it}^I \rightarrow \beta_k \ln K_{it} = \beta_1 \ln I_{it} + \beta_2 \ln X2_{it} + e_{it}^I$$

The main concern is that $E(e_{it}^I | \beta_k \ln K_{it}) \neq 0$, so the path diagram of the endogeneity problem is that $\beta_k \ln K_{it}$ affects $\ln GVA_{it}$ but the error term (e_{it}) influences both $\beta_k \ln K_{it}$ and $\ln Gross_{it}$.

The typical instrumental variable approach is to find variables that belong to the second equation but not the first one. Therefore, the following assumptions should be kept: a valid, nontrivial, first stage coefficient (β_2) for observables that belong in the participation equation but not the outcome equation ($\ln X2_{it}$) and a valid exclusion restriction ($E[\beta_2 \ln X2_{it} * e_{it}^I | \ln I_{it}] = 0$)

6.3.1.4.5 *Sensitivity Analysis -Different Transformations, Steps and Ways*

One way, one step system GMM estimator will be compared to the two ways, two steps system GMM estimator and one way, one step difference estimator. As previously discussed at the beginning of this section, some of these are expected to reduce observations and possibly weaker relationships. For instance, the difference GMM approach transforms the data to remove the fixed effects deals to reduce the inherent endogeneity. More specifically, it uses the first difference transformation. This seems a better choice than the within transformation (discussed in Appendix 10.2.2.1), as that transformation is likely to make each observation in the transformed data endogenous for a firm. The one shortcoming of this transformation is that it increases gaps in unbalanced panels. If some values of a variable are not available, then both values around the value will be missing in the transformed data. This motivates an alternative transformation: the forward orthogonal deviations (FOD) transformation, proposed by Arellano and Bover (1995).

6.3.2 Survival Analysis

Up until now, Section 6.3 focused on productivity. It defined the central issues in estimation (Subsection 6.3.1.1) and introduced two ways to estimate factors affecting productivity (6.3.1.2, 6.3.1.3 and 6.3.1.4). The other part of Section 6.3 is devoted to the survival analysis. It was defined and fundamental mechanisms were explained in the Methodology Review Chapter (Section 5.2). The chapter concluded that Cox proportional hazards (CPH) model is the preferred approach to be applied to this study. An advancement in survival analysis made it possible to reduce the amount of limiting assumptions and correct for various estimation flows. It became one of the most frequently applied techniques for the survival analysis because of its semi-parametric nature and theoretical foundations. The first part of this section will focus on implementation and the tests that were employed to test the model.

The Methodology Review Chapter (Section 5.3.1.2) proposed to supplement more standard Cox Regression with survival trees (ST). It also introduced the key concepts of ST. Section 7.3.2 further supplements this by extending the description of the ST for left-truncated and right-censored data which were found to be preferable for this analysis owing to the data structure and their ability to accommodate the longitudinal data.

6.3.2.1 Cox Proportional Hazards (CPH) Model

6.3.2.1.1 Differences between Parametric and Cox Proportional Hazards Models

The exponential parametric model $h(t) = v$ could be specified in a linear logarithmic form. If one takes i as a subscript of observation and x as independent variables, then:

$h_i(t) = e^{\alpha + \sum_{i=1} \beta_i x_i}$, where α is a baseline hazard when all independent variables equal to zero.

Opposing this, the CPH model becomes a semi-parametric model by leaving its baseline hazard $\alpha = h_0(t)$ unspecified:

$$h_i(t) = h_0(t) \times e^{\alpha + \sum_{i=1} \beta_i x_i}$$

Then, to prove that CPH model is a proportional-hazards model (or independent on baseline function), Cox (1972) considers a hazard ratio for two observations different in their independent variables with their corresponding linear predictors:

$$\frac{h_i(t)}{h_{i^*}(t)} = \frac{h_0(t) \times e^{\sum_{i=1} \beta_i x_i}}{h_0(t) \times e^{\sum_{i^*=1} \beta_{i^*} x_{i^*}}} = \frac{e^{\sum_{i=1} \beta_i x_i}}{e^{\sum_{i^*=1} \beta_{i^*} x_{i^*}}} = \text{constant}$$

By using the Cox' method of partial likelihood (1972), estimates may not be as efficient as with maximum likelihood estimation. However, the model is better because it does not randomly select the shape of baseline hazard but estimates it. The use of the exponential function ensures that the hazard is positive.

Proportional hazards models assume that all plants share the same baseline hazard. Unfortunately, this assumption may not be satisfied in an array of occasions. A stratified proportional hazards model should then be used since different groups of plants are allowed to have different baseline hazards, but parameters are the same for all plants. This also helps to avoid the main limitation implied in the proportional hazards assumption, which is that the hazard ratio, that is the ratio of the hazard function to the baseline hazard, is constant over time, which might not be satisfied with the data employed in this thesis.

A test of the proportional hazards assumption is developed by Schoenfeld in 1982. This test of residuals is performed with a package survival in R to ensure that the assumption holds. Variables that do not satisfy this assumption were stratified.

The stratified CPH model was estimated with the matched sample created during the productivity analysis to control for the self-selection into the treatment group. The hazard model takes the following shape:

$$x(t) = \alpha_X X_t + \sum_{i=0}^5 (\alpha_{SBRR\ t-i} SBRR_{t-i}),$$

where $X_{it} = \omega_{it}, \rho_{it}, a_{it}, r_{it}, s_{it}, PS_{it}, PD_{it}, HHI_{it}, R\&D_{it}, HGF_{it}, FO_{it}, IO_{it}$

α 's are the coefficients, *SBRR* refers to the Small Business Rates Relief and its lags for each firm *i* in period *t*. The variables in vector *X* were defined in Section 6.3.1.3. Briefly, ρ captures the initial³⁵ effects of receiving any relief or the uplift in relief, irrespective of level. Other variables are firm productivity (ω_{it}), age (*a*), the regions (*r*) and broad sectors (*s*), immediate foreign ownership (*IO*), ultimate foreign ownership (*FO*), high growth firm dummy (*HGF*). To at least partly control for the competition, the model includes Marshall Specialisation (*PS*), Jacob Diversity (*PD*) and Herfindahl-Hirschman Index (*HHI*).

6.3.2.1.2 Model Diagnostics

Schoenfeld residuals were estimated to see whether proportional hazards assumption holds. The proportional hazards assumption for each covariate is estimated by correlating the corresponding set of scaled Schoenfeld residuals with a suitable transformation of time. The usual time is based on the Kaplan-Meier estimate. Influential

³⁵ Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010.

observations were then investigated to determine whether any of them are very influential and may be incorrectly biasing the model. Finally, an incorrectly specified functional form in the parametric part of the model (nonlinearity) is a problem in Cox Regression as in all generalised linear models. The martingale residuals were plotted against covariates to detect nonlinearity.

6.3.2.2 Survival Trees

The Fu and Simonoff (2017) Survival tree (ST) algorithm advances previous work through its combination of controls for the typical left truncated right censored nature of panel data. Decision trees have traditionally struggled to cope with such structures when there are time variant repressors. The authors argue that this non-parametric approach is preferable to the standard Cox proportional hazards model as the required parametric assumptions are not met or unrealistic.

Unlike the REEM, this algorithm does not control for firm-level intercepts, although clustering on firm is feasible with Huber-white standard errors. This thesis uses the author's LTRCART extension of existing models, which control for left truncation. Given space limitations, see their paper for the full details. The thesis employs the same independent variables as in the REEM algorithm (see Section 7.2.2) with the addition of TFP.

To introduce the tree, it is worth recalling the Poisson regression tree. The following definitions are taken directly from Fu and Simonoff (2017). Assuming that λ is an event rate, t_i is exposure time for observation i , c_i is the observed event count for observation i and $\lambda^* = \frac{\sum c_i}{\sum t_i}$. Then, the within node deviance residual for a Poisson regression tree may be presented as:

$$D = \sum [c_i \ln \left(\frac{c_i}{\lambda^* t_i} \right) - c_i + \lambda^* t_i]$$

The fundamental mechanisms of survival trees, including notations, that were extended by Fu and Simonoff (2016) were discussed in Section 4.3.2.2.2. They show that the full log-likelihood for right censored data (t_i, δ_i, x_i) with $i = 1, 2, \dots, n$ may be expressed as:

$$\ln L = \sum_{i=1}^n [\delta_i \ln \lambda(t_i) - \Lambda(t_i)] = \sum_{i=1}^n \left[\delta_i \ln \lambda(t_i) - \int_0^{t_i} \lambda(\mu) d\mu \right].$$

Let L_i be the left truncation time and R_i be the right-censored time for observation i . Fu and Simonoff (2016) extend the model by replacing $\Lambda(t_i)$ with $\Lambda(R_i) - \Lambda(L_i)$. Now, the

log likelihood for left-truncated and right-censored data $(L_i, R_i, \delta_i, x_i)$, where $i = 1, 2, \dots, n$ is

$$\ln L = \sum_{i=1}^n [\delta_i \ln \lambda(R_i) - \Lambda(R_i) + \Lambda(L_i)] = \sum_{i=1}^n \left[\delta_i \ln \lambda(R_i) - \int_0^{t_i} \lambda(\mu) d\mu \right]$$

The implementation of this method is done in three steps. The cumulative hazards function $\Lambda_0(t)$ is based on all LTRC data. Observations $(L_i, R_i, \delta_i, x_i)$ are counted in the risk set for time t when $L_i \leq t \leq R_i$. On the second stage, exposure time is estimated with $\Lambda_0^*(R_i) - \Lambda_0^*(L_i)$ based on the estimated cumulative function $\Lambda_0^*(t)$. Then, the Poisson regression tree is fitted by assigning estimated $\Lambda_0^*(R_i) - \Lambda_0^*(L_i)$ to t_i and δ_i as the new c_i .

It is worth noting that a different survival object needs to be created. Each row would then represent a time interval, where within each interval all covariates are assumed to have constant values.

Similar variables to those in the Cox Regression (Section 6.3.2.1) were used.

6.3.3 Sensitivity: K-fold & Importance Scores

The thesis employs two standard approaches to test the stability and validity of the REEM and survival trees. Firstly, the k-fold validation method, which compares the predictive capacity of trees to OLS. This first splits the sample into ten random subsamples and then uses each subsample as a validation subset for the estimates coming from the remaining nine subsamples.

More importantly, to test the stability of the results, the thesis employs the random forests algorithm, which does not include the longitudinal aspect of the tree but gives guidance as to which are the most influential variables. The Classification and Regression Tree approach was defined, and fundamental mechanisms were explained in the Methodology Review Chapter (Section 5.3.1.1.2). This section aims to look at random forests as these were found to be the most feasible for sensitivity analysis throughout this thesis. More specifically, this section will extend that by defining the general steps in constructing a general random forest and a conditional inference forest. This will be supplemented by the description of how importance scores are estimated. These scores were estimated throughout the analysis as a sensitivity analysis.

Let a training set be $C = \{C_1, \dots, C_n\}$ with $C_i \equiv (x_i, y_i)$, an independent test case is C_0 and predictor is x_0 , the importance scores can be estimated with several steps. First step is to generate bootstrap resamples, B_1, \dots, B_M by sampling the training set C with replacement. Second step is to develop a regression or classification tree T_m for each

resample B_m , $m = 1, \dots, M$ in the similar manner as was described in the Methodology Review Chapter (section 5.3.1.1.2). At each split, only predictors in a randomly chosen subset of predictors are taken into account. Assuming that p denotes to the total number of predictor variables in C , each tree is grown until all nodes contain observations no more than the maximal terminal node size, which is a pre-specified parameter. Thirdly, for predicting the test case, C_0 , with covariate x_0 , the predicted value of the final RF is obtained by combining the results given by individual trees. If $\widehat{f}_m^*(x_0)$ is the prediction of C_0 by m th tree, the RF prediction for regression:

$$\frac{1}{M} \sum_{m=1}^M \widehat{f}_m^*(x_0)$$

and for classification:

$$\operatorname{argmax}_g \left\{ \sum_{m=1}^M I[\widehat{f}_m^*(x_0) = g] \right\}$$

The interpretation of the results is more difficult as there is no one tree now. However, the RD can estimate importance scores. There is no commonly-known measure of variable importance. The accepted concept is that a predictor variable is important when prediction performance is increased by using the predictor and decreased by not including the variable (Olshen and Brajaratnam, 2010:1644)

6.4 SUMMARY OF EMPIRICAL MODELLING

The Introduction and Background Chapter presented the aim of this thesis, which is to understand whether SBRR has any effects on firms' productivity and survival. This chapter detailed the techniques proposed in the Methodology Review Chapter in order to further show how the second objective was achieved and to make it possible to test the hypotheses. The second objective was *to find appropriate data and analytical technique which could be used to either support or disprove the framework. Simultaneously, to explore other fields for techniques that were not used in policy evaluation before.*

It is also worth recalling the hypotheses derived in the Framework:

- Productivity
 - *H2a: There is no difference in productivity between firms receiving the relief and not in the service sector in the short-term.*

- *H2b: Productivity of manufacturing firms receiving a relief is higher than firms that are not receiving the relief in the short-term.*
 - *H2c: SBRR has no significant impact on productivity in the long term.*
- Survival
 - *H1a: Survival probability of service firms receiving a relief, awarded upon its introduction, is higher than firms that are not receiving the relief in the short-term.*
 - *H1b: There is no difference in survival rates between firms receiving the relief, awarded upon its introduction, and not in the manufacturing sector in the short-term.*
 - *H1c: SBRR has no significant impact on survival rates in the long term.*

In a similar vein to the whole chapter, the summary section is divided into the data and its management (6.4.1) and empirical methodology (6.4.2).

6.4.1 Data

The analysis is based on the U.K. Office of National Statistics (ONS) Annual Respondents Database X (ARDx) first released in July 2016 combined with Business Structure Database (BSD) and Prices Survey Microdata (PSM).

The ARDx combines two existing surveys, the Annual Business Inquiry (1998-2008) and the subsequent Annual Business Survey (2009-14) which firms' representatives are legally required to complete, producing high response rates. It is a census of firms with 250 plus employees and complex stratified sample across size, sector and region of smaller firms. The sample framework is constructed using administrative data on employment and turnover from PAYE and VAT registrations. Importantly, for the purposes of this study, it captures information at both the enterprise and local unit levels.

This data source is combined with the BSD to acquire the annual observations of smaller firms that were not included in the ARDx sample in some years and as such fills in some missing variables. The BSD contains an annual release of a small number of critical variables³⁶ on all UK firms that are VAT registered or employ at least one worker and is complementary to the above business surveys.

³⁶ The variables are; employment, turnover, foreign ownership, and industrial activity based on Standard Industrial Classification (SIC) 92, 2003 or 2007. Year of 'birth' (company start-up date) and 'death' (termination date), as well as postcodes for both enterprises and their local units.

There are nevertheless still many missing observations, particularly on the smaller firms, which would tend to attract SBRR. To ensure a representative sample, the data is cleaned and imputed where appropriate. The imputation is performed either with simplified approaches or predictive mean matching, with the key variables of turnover, employment, region, sector and legal status that had almost no missing data from the ARDx or BSD data sources. The approach is to bootstrap over a thousand samples and average their coefficients and standard errors in order to reduce serial correlation.

The ARDx and BSD do not directly provide controls for input price changes, required for the estimates of TFP. To control for omitted price bias (as defined by Van Beveren, 2010), the PSM is used to deflate values with detailed information on regional and sector level prices rather than deflating using the inherently biased national GDP.

Finally, the large dataset is exploited to recreate the conditions of a social experiment in which firms that receive SBRR are matched to similar firms which did not. This should make the results less model dependent. The large dataset enables the production of good matches by using a wide range of observable characteristics, namely, employment, sector, legal status, deflated turnover, deflated intermediate consumption, deflated GVA, age, size at birth, deflated capital, deflated wage expense, R&D dummy, foreign direct investment dummy. The dependent variable is a dummy, taking a value of one for those firms that received the relief at least twice between 2003-2016 and zero otherwise.

The matching is performed with the Coarsened Exact Matching (CEM) technique. CEM does not use the random pruning applied in Propensity Score Matching, which is shown to increase the level of imbalance (King *et al.*, 2011 and 2016). The broad mechanism behind CEM is to group each variable by recoding so that nearly similar values are assigned the same value (Iacus *et al.*, 2009). The firms were matched one year prior to the SBRR introduction or for youthful firms, their first observable year. This produced a final dataset for the years 2000 to 2015 of 15,042 observations for 1,092 firms. 546 SBRR recipients matched to 546 firms that never received the relief but had similar characteristics.

6.4.2 Empirical Methodology

The modelling draws out some of the nuanced implications SBRR could have on survival and the boundaries on TFP. The method also observes other firm characteristics such as age and clusters by wider regional or sector conditions will influence decisions. These factors are not solely additive but interact such that the path along which any effects

of the universal policy operate on survival or productivity will be difficult to identify a priori.

These considerations led this thesis to adopt the recently developed Random Effects Expectation Maximisation (REEM) decision tree approach of Sela and Simonoff (2012) and subsequently Fu and Simonoff (2015), rather than a parametric multilevel estimator. The Random effects element accounts for the constant differential firm-level factors whilst the decision tree allows the data to discover the complex groupings of firms and their different levels of productivity or survival without imposing a complex parametric structure.

The REEM model is:

$$\omega_{it} = Z_{it}b_i + f(\cdot) + \varepsilon_{it}, \quad i = 1, \dots, I \quad t = 1, \dots, n$$

$$\begin{pmatrix} \varepsilon_{i1} \\ \vdots \\ \varepsilon_{in} \end{pmatrix} \sim N(0, R_i), \quad b_i \sim Normal(0, D),$$

$$f(\cdot) = f\left(\sum_{j=0}^4 (SBRR_{t-j}), \rho_{it}, a_{it}, r_{it}, s_{it}, PS_{it}, PD_{it}, HHI_{it}, R\&D_{it}, HGF_{it}, FO_{it}, IO_{it}\right)$$

The dependent variable ω_{it} , is the bootstrapped estimate of TFP, for each firm i in period t . Z is a matrix of independent variables and b_i is the vector of random effects. $f(\cdot)$ contains the same variables as Z , but they can differ. $SBRR$ refers to the Small Business Rates Relief and its lags, ρ captures the initial³⁷ effects of receiving any relief or the uplift in relief, irrespective of level. Other variables are firm age (a), the regions (r) and broad sectors (s), immediate foreign ownership (IO), ultimate foreign ownership (FO), high growth firm dummy (HGF). To at least partly control for the competition, the model includes indices of regional specialisation via the PS index of Marshall Specialisation and an index for the counter regional Jacob Diversity (JD) as well as Herfindahl-Hirschman Index (HHI) to control for industry competition at the national level. The error term ε_{it} , is assumed to be uncorrelated with the random effects and independent across observations. R_i is a non-diagonal matrix to account for autocorrelation within firms.

³⁷ Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010.

6.4.2.1 Dependent Variable for REEM Trees and Independent for Survival: Total Factor Productivity

The total factor productivity (ω_{it}) dependent variable is not directly observable from production functions and as such needs to be extracted once the weighted sum of inputs have been estimated with controls for simultaneity and selection biases. It is estimated by using Wooldridge's (2009) one-step GMM estimator, which was introduced in Section 6.3.1.2. Wooldridge builds on the influential work of Olley and Pakes (1996) and Levinsohn, and Petrin (2003) and overcomes the identification issues of variable inputs such as labour. This thesis estimates TFP assuming a Cobb Douglas functional form:

$$\omega_{it} = \ln GVA_{it} - \beta_k \ln K_{it} - \beta_l \ln L_{it},$$

where ω_{it} is TFP of the i^{th} firm in period t , $\ln GVA_{it}$ is the firm's logarithmic gross value added in order to simplify the model and eliminate intermediate inputs, K is logarithmic capital and L is logarithmic labour.

6.4.2.2 Dynamic Model

An alternative approach was also employed. The dynamic form of productivity with not only standard variables but all variables related to TFP was estimated with system GMM estimator (notations in Section 6.3.1.4):

$$\ln GVA_{it} = \beta_{Gross} \ln GVA_{i(t-1)} + \beta_L \ln L_{it} + \partial_L \ln L_{i(t-1)} + \beta_k \ln K_{it} + \partial_K \ln K_{i(t-1)} + \partial_M \ln M_{i(t-1)} + \partial_X \ln X_{it} + z_{it} \mu + \xi_{it} + e_{it}$$

6.4.2.3 Survival Analysis

In a similar vein to TFP, the thesis first estimates the hazard of exit using the well-established semi-parametric Stratified Cox Proportionate model:

$$x(t) = \alpha_X X_t + \sum_{i=0}^4 (\alpha_{SBRR_{t-i}} SBRR_{t-i}), \text{ where } \alpha \text{ 's are the coefficients.}$$

$$X_{it} = \omega_{it}, \rho_{it}, a_{it}, r_{it}, s_{it}, PS_{it}, PD_{it}, HHI_{it}, R\&D_{it}, HGF_{it}, FO_{it}, IO_{it}$$

This thesis also employs Fu and Simonoff's (2017) survival trees to account for the left-truncated and right censored data. This technique was chosen because, in a similar way to REEM trees, it partitions the data space into smaller sections where variable interactions are more explicit.

7 RESULTS

This chapter aims to report the results of the thesis. The overall aim of this thesis is to understand whether Small Business Rate Relief (SBRR) has any effects on firms, in particular with regards to their productivity and survival³⁸. This chapter focuses on the matched and imputed data, but other variations of data are presented in Appendix 10.4. The chapter starts with the descriptive statistics of data, which are supplemented by decision trees to draw further insights (Sections 7.1.1.2 and 7.1.2.1). Once data is described, the chapter provides an extensive discussion of results from productivity (Section 7.2) and survival (Section 7.3) analyses. Finally, Section 7.4 combines all findings and discusses them with hypotheses formed in the Framework. The methodology and data sources upon which the results are based were described in the Research Design Chapter.

More specifically, Subsection 7.1 uncovers multiple issues with missing variables. It shows that higher BRs are most likely to be paid by larger firms. However, the smaller the company, the higher dependence on the sector, region and labour productivity is evident. Cleaned and matched data shows that larger firms are more likely to be included in the analysis. As expected, decision trees suggest that SBRR mainly depends on the year. The trees captured that the relief was introduced in 2005 (in the UK) and significantly increased in 2010. Some variables such as sectors and regions are highly related to SBRR as well.

Subsection 7.2 describes the results from TFP estimation. The unbiased REEM tree uncovers specific examples when the relief may affect TFP negatively or positively. It identifies critical variables related to SBRR in splitting this tree. Other factors such as region, rent, sector, HHI and PD indexes and foreign ownership are also found to be influential. The system GMM estimator identifies the positive relationship between the initial³⁹ effects of receiving any relief or the uplift in relief and TFP, but only significant at 90%.

Subsection 7.3 shows the results of survival analysis. CPH also finds firms that were granted the relief during the first year of SBRR existence (or enhancement) to be far more likely to survive. Although survival trees do not identify this relationship, there is a level effect indicating that recipients are slightly more likely to survive.

³⁸ This thesis defines total factor productivity (TFP) is the portion of output not explained by the amount of inputs used in production. Whilst, survival analysis in this setting is a method for analysing the expected duration of time until closure.

³⁹ Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010.

Finally, Subsection 7.4 uses all findings from other sections to discuss the hypotheses. It shows that the relief is likely to be mistargeted. This subsection then expands on the effects of SBRR, separated into three periods similar to those used in forming the hypotheses. It broadly confirms all hypotheses. The wide findings are that property tax reductions are associated with consistently lower productivity and only a very marginal initial improvement in survival.

7.1 DESCRIPTIVE STATISTICS AND ILLUSTRATIONS

Two methods are used to describe the data. Firstly, the usual statistics such as mean, median, standard deviation as well as 25th and 75th percentiles are reported. This is supplemented by decision and classification trees to uncover which firms are more likely to pay lower BR or receive higher SBRR.

7.1.1 ARD_x Data with no Modifications

The first part of this section focuses on the data before any major modifications in Table 7:1 (p. 189). It is worth noting that the data was already merged and limited to one local unit. As discussed in the Research Design Chapter, this made the datasets manageable and analysis could be executed with fewer assumptions and imputations of the critical variables (including BR) because they were not available at the local unit level.

7.1.1.1 Descriptive Statistics

As according to Table 7:1 (p. 189), there were 530,923 unique companies with 6,230,916 observations identified. On average, firms had approximately 14 employees and a turnover of £2,624,310. However, standard deviations and percentiles suggested that multiple outliers were present. For instance, BR expense was reported to be £35,709 on average, but the 75th percentile revealed that most of the businesses were paying £12,863.

The radar chart in Figure 7:1 (p. 188) defines the basic patterns around the not available values (NAs) within data. The administrative data and variables derived from the administrative data (Herfindahl Index, PS, PD, employment and turnover) seem to have little or no missing values. Some variables have a deficient proportion of non-missing values. For instance, the one indicating whether a company died during that period has around 0% of observations filled. It seems reasonable because each company has many observations and only the last one should be identified as death. However, just 0.16% of observations have reported foreign direct investment, which may be reasonable but cannot be included in the analysis owing to there being too few cases with non-missing values.

In the beginning, the exact inputs to productivity process were considered to be used in productivity analysis. However, the coverage was insufficient because some participants were asked only to answer the more extensive survey with those variables. This extensive survey consisted of details on their spending. For instance, just ~0.34% of the whole sample answered the question about water expenditure. Thus, coverage was found to be insufficient for the productivity estimation with the exact inputs.

Missing values (%)

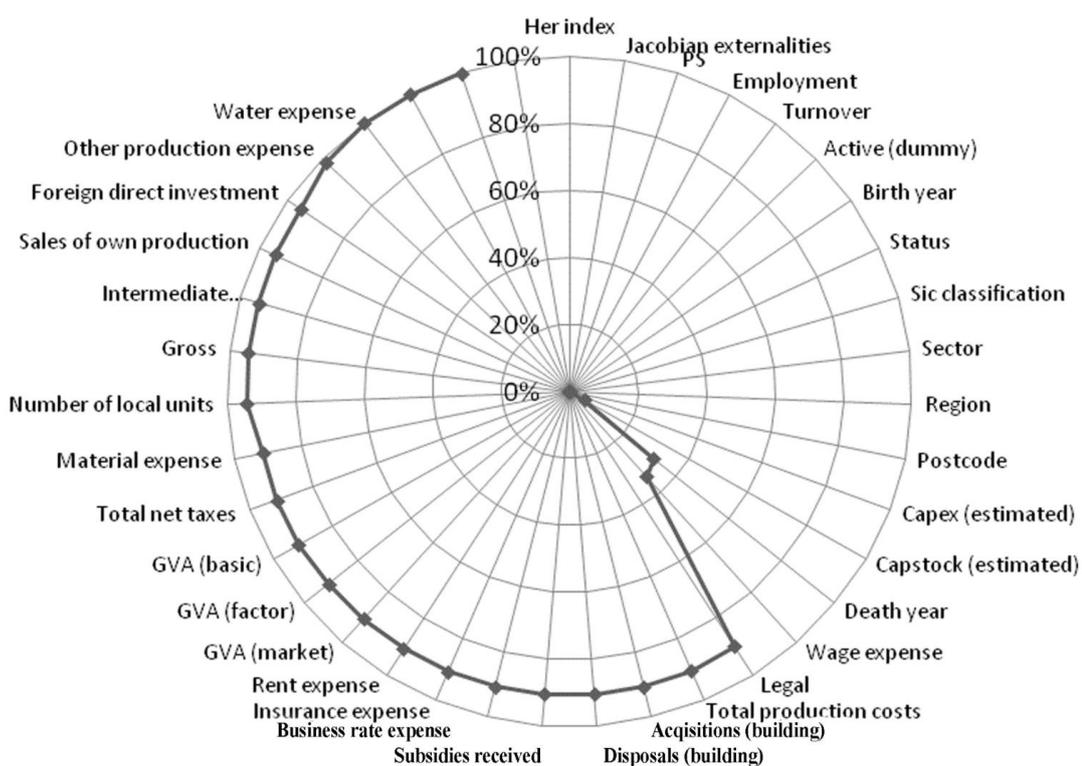


Figure 7:1 Missing values within the data. 0% indicates that variable has no missing values and 100% that all values are missing in that variable.

Variable	N	Mean	SD	Pctl(25)	Median	Pctl(75)
Her index	6230916	0.012	0.03	0.002	0.005	0.014
Jacobian externalities	6230916	0.787	0.074	0.75	0.797	0.838
PS	6229677	1.482	1.794	0.722	1.149	1.725
Employment	6225925	14.154	149.276	1	3	10
Turnover	6225925	2624.307	174971.5	72	187	708
Active (dummy)	6225925	0.894	0.308	1	1	1
Birth year	6225925	1992.859	10.388	1986	1994	2001
Status	6225887	1-60%, 2-22%, 3-14%, 7-4%				
Sector	6230916	See Figure 7:3				
Region	6230916	See Figure 7:3				
Capex	4252279	0.432	28.363	0	0	0.023
Capstock	4114287	1.737	130.291	0.00003	0.001	0.143
Death year	623502	2006.5	3.896	2003	2006	2010
Wage expense	581039	1323.538	11573.76	7	72	555
Total production costs	579151	9851.48	519811.1	22	150	1024
Acquisitions (building)	579151	363.659	8317.989	0	1	29
Disposals (building)	579151	79.534	3548.423	0	0	1
Subsidies received	576130	27.954	2425.88	0	0	0
Business rate expense	574887	35.709	575.047	0	1.771	12.86
Insurance expense	574867	6.714	711.13	0	0	0.08
Rent expense	574404	72.899	2150.55	0.002	0.665	7
GVA (market)	528763	2400.169	135547.1	34	158	915
GVA (factor)	528763	2243.601	134879.1	32	152	887
GVA (basic)	528763	2282.482	134916.8	34	157	909
Total net taxes	356643	221.829	14444.63	0	1	17
Material expense	341127	2.999	443.318	0	0	0
Gross	310188	7047.105	85203.6	63	301	2048
Intermediate consumption	283205	2780.526	30392	0	0	353
Sales of own production	96536	9616.415	56410.41	248	1327	
Foreign direct investment	9024	846.161	8836.406	0	0	1
Other production expense	4393	338.75	7541.275	0	0	0
Water expense	3473	3.601	103.393	0	0	0

Table 7:1 Descriptive statistics of data after minor cleaning; for continues variables, count (N), mean, median, standard deviation (SD), 25th and 75th percentiles are provided.

7.1.1.2 Decision trees - turnover and employment

The lack of targeting was often mentioned as a drawback of SBRR and BRs in general. Thus, the focus of this section is on employment, turnover, sector, region and labour productivity.

Figure 10:4 and Figure 10:5 (Appendix 10.4.1, p. 276-278) broadly illustrate how these variables influenced the amount of BR paid by firms. It shows complex interactions. The node shows that the size was the most important factor out of size, sector, year and labour productivity. Large and medium sized firms (with regards to turnover and employment) were separated from firms with micro and small firms. The larger ones operating in catering, production, retail and property sectors were often related to higher reliefs than firms operating in other sectors.

Much more complex groupings were evident for small and micro firms. Small firms in London were associated with higher BR bills. Also, those with lower labour productivity seemed to receive higher bills than those with higher labour productivity. However, the highest business bills were received by the micro firms in construction and other services sectors based in London. Furthermore, higher labour productivity was related to higher bills.

To supplement this tree, 500 trees were estimated with random forest algorithm with no restrictions, which sorted the importance of the variables in the following order: turnover, sector, employment, region, labour productivity and year. The model suggested that these variables explain ~9% of the variance.

7.1.2 After Imputation and Matching

Once imputed, the overall statistics seemed to consist of lower values. As according to Figure 7:2 (p. 192) all key variables had a lower mean except investment with 1% higher mean than before imputations (£5,130 to £5,220). This increase may relate to the time trend. Investment in the most recent year (2015) was missing. Lower means on average seemed to be reasonable because of the sampling procedure. Smaller firms which possibly had lower values likely to be imputed were not always surveyed. The overall variance (SD) did not deviate much before and after imputation. It was reduced for GVA and rent (by 19% and 10%, respectively) but increased for materials and investment (28% and 1%, respectively). The quantiles further explained that the overall imputed values were not extreme. However, for variables with many missing values, quantile values were far lower after imputation. For instance, 53,724 values were missing for rent. After imputation, the 75th quantile was reduced by 72%. This seemed reasonable since many businesses owned

premises and would therefore not be paying any rent. Thus, more 0s should appear. Maximum and minimum values are not reported because of the disclosure controls, but they are similar before and after the imputation.

546 firms that received SBRR at least twice (with some exceptions as defined in the Research Design Chapter, Section 6.2.2.6.5.3.1) were matched to other 546 firms which had not received the relief, but had similar characteristics on the year before the relief became available. Figure 7:3 compares the distribution before and after matching and imputation with regards to region and sector. 3% of cases (or 1,092 firms) were present in the final matched sample. Scotland had proportionately 5% fewer observations than before matching, London and South East 2% less and South West 1% less. Whilst, Wales (4%) and Yorkshire and Humberside (by 3%) had the largest proportionate increase followed by West Midlands (by 2%) and East Midlands (by 1%). With regards to the sectors, the largest number of firms were matched in the production sector, resulting in a proportionate increase of 29%. There was some increase also in wholesale (5%) and a marginal proportionate increase in construction (1%) sectors. This resulted in substantial decreases in observations in retail (9%) and other services (20%) sectors and a marginal decrease in the property (3%) sector.

Table 7:2 (p. 192) compares the unmatched and uncleaned data with the matched sample after all corrections and imputation. The sample leans towards larger firms with employment and turnover increasing by ~6 times on average. Companies that reported larger investment, GVA and intermediate consumption were more likely to be included in this sample owing to how the surveys were conducted. All larger firms were surveyed, but smaller firms were just sampled, so they might not have at least two observations which were needed both to derive the SBRR variable and estimate the change. It is worth noting that other variables, such as investment and intermediate consumption also had higher values.

Figure 7:2 (p. 192) illustrates how the values were imputed for the most complicated case, GVA. It supports the descriptive statistics. It was evident that the clear majority of the imputed data is around the middle of the range and only relatively several unique values were imputed. These unique values usually had other values that were closely related to the imputed values.

''' Action	Variable	N	Mean	SD
Before	Employment	6,225,925	14.15	149.28
After 1 to 1 matching		15,952	82.92	168.17
After imputation		15,043	81.99	166.07
Before	Turnover	6,225,925	2,624.31	174,971.50
After 1 to 1 matching		15,952	14,767.65	54,046.51
After imputation		15,043	14,539.24	53,594.72
Before	Materials	341,127	3.00	443.32
After 1 to 1 matching		4,673	7,453.21	25,590.58
After imputation		15,047	6,133.42	26,554.34
Before	GVA (basic)	528,763	2,282.48	134,916.80
After 1 to 1 matching		6,268	342,588.30	46,263.02
After imputation		15,047	340,632.60	43,151.42
Before	Investment	4,252,279	0.43	28.36
After 1 to 1 matching		14,025	1.97	12.72
After imputation		15,047	2.11	21.36
Before	Capital	4,114,287	1.74	130.29
After 1 to 1 matching		14,025	10.40	46.25
After imputation		15,047	9.32	126.76

Table 7:2 Key variables before matching and imputation, after matching and after imputation.

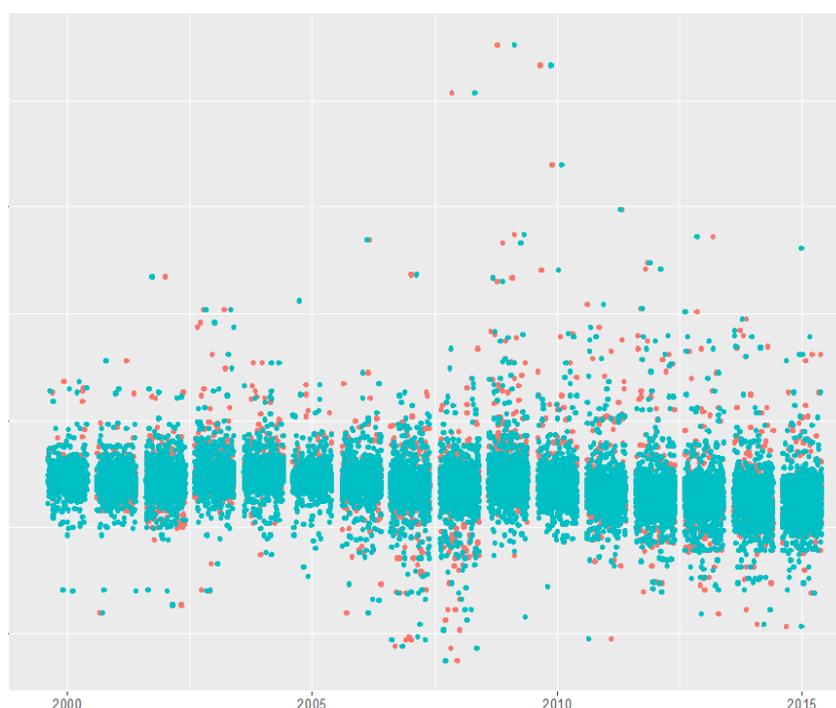


Figure 7:2 GVA real values (green) combined with imputed values (red); The scale had to be removed so that the firms could not be identified.⁴⁰

⁴⁰ Several restrictions were imposed by the data owner. See Section 6.2.1 for more information.

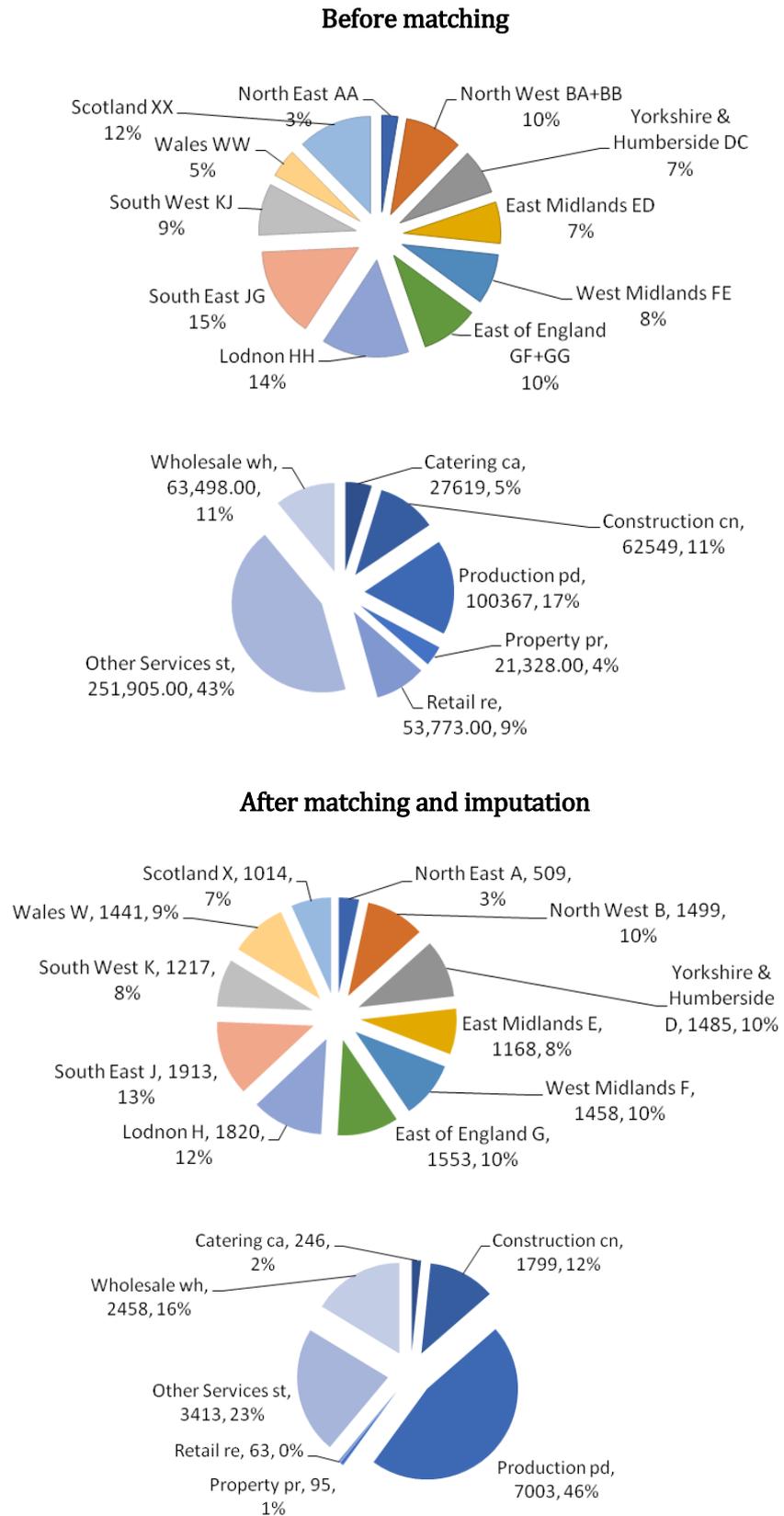


Figure 7:3 Distribution of the data with regards to regions and sectors before (upper graphs) and after matching and imputation (lower graphs), motors trade is excluded from the graphics due to security restrictions, see Research Design Chapter (Section 6.1.3) for more information.

7.1.2.1 Decision trees - SBRR

Figure 10:6 and Figure 10:7 (Appendix 10.4.2, p. 278-279) and an extract of these in Figure 7:4 show a tree with SBRR instead of BRs because matching and cleansing of the data allowed to estimate SBRR. Instead of explaining the amount of the BR paid by the firms, the aim was to predict the amount of SBRR by investigating firms' characteristics. It is worth noting that the matched sample disproportionately boosted the number of firms receiving the relief. Additionally, the illustration was limited to splits on 5% significance and the final node size was limited to a hundred or more cases. These limitations were not imposed during the random forest estimations. To estimate prediction error in random forests, the dataset was split into the train (75% firms) and test (25% firms) parts. The 17% and 36% classification errors were estimated with the train and test datasets, respectively. Also, 35% of R^2 was achieved by random forests. The output of random forests is provided in Appendix 10.4.8.

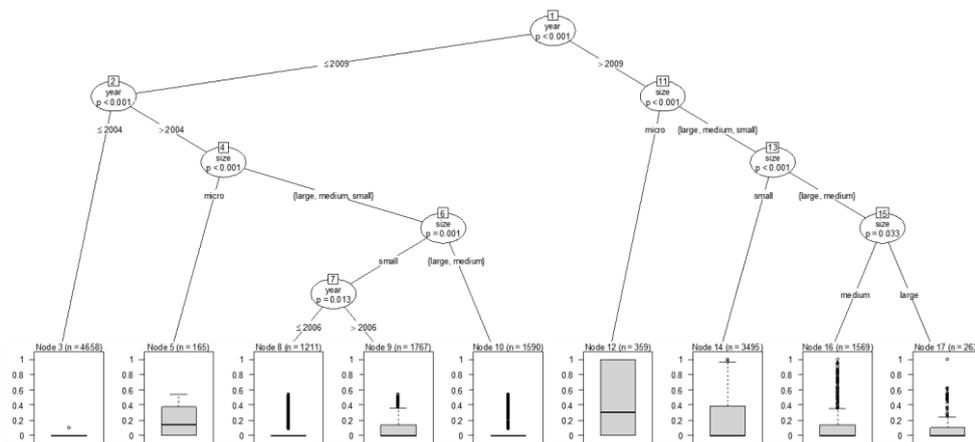


Figure 7:4 Aggregated SBRR tree (n refers to the group's size). Size classification was used according to the EU definition offered in Table 1:1 (Introduction and Background Chapter). Full version with size, year, region and labour productivity variables is available in Appendix 10.4.2.

Unlike in BR case, both random forests and decision trees found year variable to be the most important. Random forests ordered other variables according to their importance: labour productivity, turnover, sectors, regions, employment. Now, sector and region were found to be more influential than employment.

More specifically, the outputs showed the misclassification of SBRR. For instance, the intense mistargeting is evident in Figure 7:4, where not just micro but also medium and large firms were receiving substantial reliefs up to 100% and this misallocation particularly increased after 2009.

With regards to the timescale, the decision tree in Figure 10:7 (p. 279) showed that none of the firms received SBRR during 2000-2004. Between 2005 and 2009, highest relief (~30%) was received by micro (according to turnover) firms in construction, retail and other services sectors in North West, East of England and South West. Further branches on these sectors show that in Yorkshire, East & West Midlands, London and South East large, medium or small firms would be more likely to receive more extensive relief than micro firms (according to employment).

Somehow similar patterns but with higher SBRR were evident for 2010-2015 data. More substantial reliefs were likely to be given to firms with a micro turnover. On average, firms with lower productivity were also likely to receive more substantial reliefs. Also, 109 micro (according to employment) firms in Yorkshire and London in catering, production and retail sectors were receiving lower SBRR than larger firms with exact circumstances. However, micro firms according to both turnover and employment were receiving higher reliefs than other firms, but SBRR seemed to be highly dependent on regions. For instance, micro firms in North East, North West, Yorkshire, East Midlands and London were receiving lower reliefs than other areas.

Regional effects were present, but depended on other variables. This is understandable given different factors such as competition or supply of the premises. Between 2005 and 2010, micro firms operating construction, retail, production, wholesale sectors were receiving 4% relief in London and North East, and Wales and Scotland just 1% on average, while in other regions ~2%. Construction, retail and other service sectors deviated more substantially with an average relief of 33% in North West, East of England and South West, 8% in Wales, Scotland and North East and 26% in other countries (in other just with employees ≤ 10). More recently (2010-2015), micro firms in construction, property and other services in North East, North West, Yorkshire & Humberside, East Midlands and London received 58% SBRR, whilst similar firms in other regions received reliefs of ~36% on average. On the other hand, in catering, production, retail and wholesale sectors micro firms in Scotland, North West, West Midlands, South East and South West reported reliefs of 26%, while similar firms in other regions reported 51% on average.

7.2 TOTAL FACTOR PRODUCTIVITY

This section describes the results from TFP estimation. It starts by providing an extensive discussion on the results from Wooldridge's System GMM estimator (Section 7.2.1) combined with REEM trees (Section 7.2.2) and then in relation to standard econometric techniques equipped to deal with dynamic models (Section 7.2.3). The primary results are supplemented with sensitivity analysis reported in the Appendix 10.4.1. The functional forms and methodology were defined in the Research Design Chapter.

Shortly, system GMM estimator combined with REEM trees identified some relationships between SBRR and TFP. The unbiased REEM tree found cases where SBRR was having mainly negative links to TFP. Other factors such as region, rent, sector, competition indexes (HHI, PD, PS) and foreign ownership were also found to be influential.

7.2.1 Dependent Variable in REEM & Independent in Survival Analyses

Figure 7:5 (p. 197) provides the firm level evolution of estimated TFP during 2005-2015 and links this to the receipt and degree of SBRR. TFP peaked in 2009 and subsequently declined, reflecting the generally negative economic shock. The average estimate of TFP was relatively similar whether firms were in receipt of SBRR or not. The small difference may be explained in part by the tapping nature of the relief, but there is no particular pattern in TFP. However, some differences were evident between SBRR recipients and non-recipients after 2006-2007, 2011 and 2012. These patterns might be related to either introduced or increased SBRR. Non-recipients seemed to outperform recipients before the SBRR introduction (2005) but in the following year, the recipients seemed to outperform non-recipients. Overall, it is clear there is diverse and complex variation around the average levels of productivity even among these carefully matched firms.

The TFP was estimated with Woodridge (2009) method. The matched data with imputation and without provided consistent estimates. As reported in Table 7:3 (p. 198), the coefficients stayed relatively similar after bootstrapping. The imputed dataset with bootstrapping estimated labour and capital coefficients to be 0.018 (SE=0.003) and 0.025 (SE=0.020), respectively. The capital coefficients deviate significantly across the methods. For instance, for the unmatched and unimputed data, estimates deviated significantly with labour and capital coefficients of 0.013 (SE=0.001) and -2.273 (SE=0.226), respectively. The main reason for this may be that the sample size decreases when the data is not imputed, resulting in bias. Also, as described in the Research Design, the capital was approximated. Thus, some estimation errors can be expected.

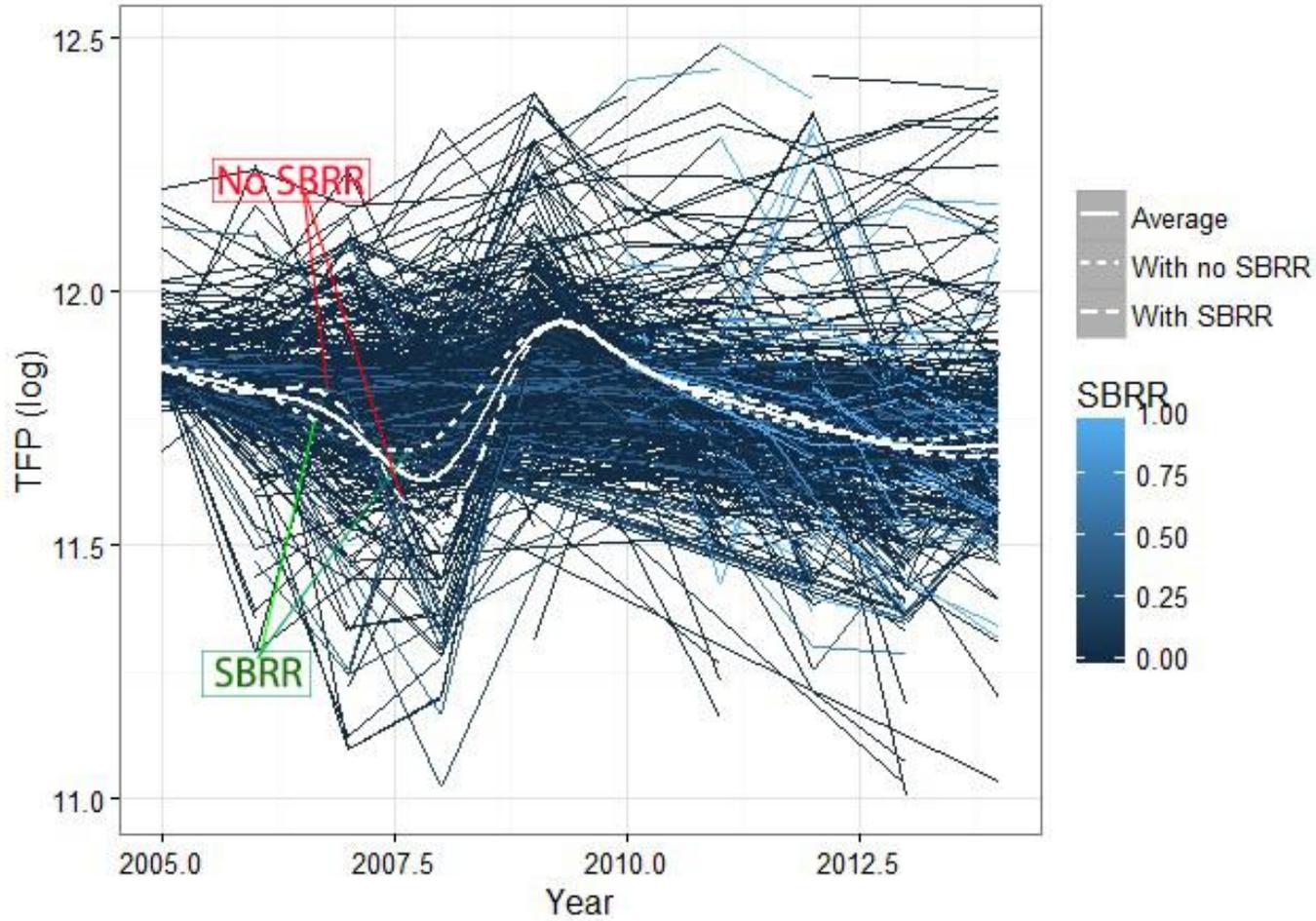


Figure 7:5 The comparison of TFP between SBRR recipients and non-recipients. The white lines correspond to the annual averages of all firms. The white dotted line is the average of SBRR recipients. The white dashed line is the average for non-recipients. The other lines are shaded by the proportionate level of SBRR. Where dark blue is 0% and light blue is 100%.

Method	Labour	Capital	SE(Labour)	SE(Capital)
OP	0.008	0.272	0.003	0.207
LP	0.006	0.286	0.003	0.210
Wooldridge (one sample)	0.008	0.023	0.002	0.022
Wooldridge (bootstrapping)	0.018	0.025	0.003	0.020
Wooldridge (matching, no imputation)	0.033	0.006	0.004	0.020
Wooldridge (no matching, no imputation)	0.013	-2.273	0.004	0.226

Table 7:3 Comparisons of various TFP estimates with different approaches and different data.

7.2.2 Unbiased REEM trees

The estimated TFP with Wooldridge (2009) method reported in the previous subsection was used as a dependent variable in unbiased REEM trees. The following paragraphs describe the key relationships in Figure 10:8 (Appendix 10.4.9, p. 289) with its simplified extracts in Figure 7:6 - Figure 7:9 and with particular emphasis on the firms for which SBRR was causing changes in TFP according to the unbiased REEM trees. The algorithm splits these cases into 45 groups. The root was consistently split on the SBRR's second lag. The aggregate results imply that those 2,540 records of the firms that received the relief after two years had 6% lower productivity than other firms.

The focus is on the most influential branches, with the greatest numbers of firms in the final nodes. In Figure 10:8 (Appendix 10.4.9, p. 289), the root first splits on a two year lag of SBRR. The 2,540 observations for firms receiving lagged SBRR had 6% lower TFP than the other observations of firms not receiving SBRR.

The branch for firms in receipt of SBRR (lagged by two years) is followed in Figure 7:6. The following split is on the level of competition and region. In the South and East of England, Wales and Scotland, a split for 1,222 observations is on the five-year lagged SBRR at 38% relief. Observations for firms receiving less relief having ~5% higher TFP. However, TFP for all observations in these regions is over 4% lower than for firms in other regions. In fact, in the other regions, we also see the next significant node is the five-year SBRR lag, this time at 40%. The pattern of TFP is the same, with lower TFP for the 248 observations from firms receiving more relief than the 981 observations with less or no relief. The conclusion from this branch is that irrespective of region and sector (excluding catering in some regions) there is a negative relationship with two year and five year lagged SBRR and firm TFP. This aligns with the Framework which suggested firms receiving SBRR would be less likely to invest and may increase mark-ups.

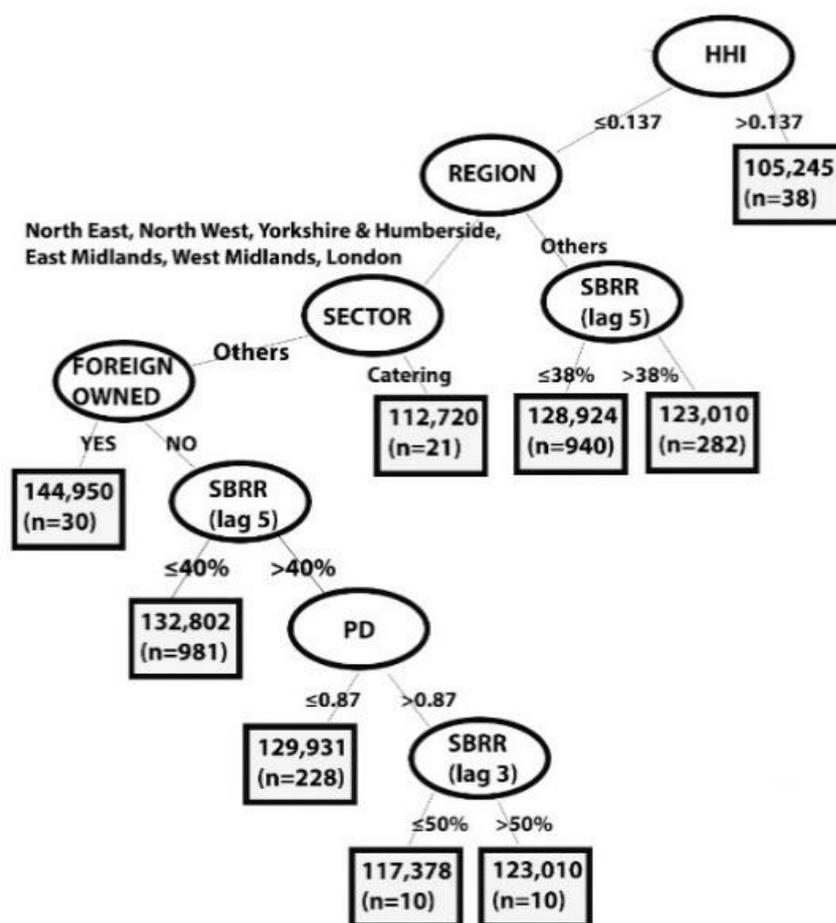


Figure 7:6 Extract of the tree for firms that received the relief two years prior. The full tree is available in Appendix 10.4.1 (p. 276). The outcome value refers to the estimated TFP as reported in Figure 7:5 (p. 197).

Figure 7:7 follows the observations for firms which did not receive two year lagged SBRR and were based in London. The specific characteristics of London firms made them different to observations in other regions. London firms were not significantly affected by SBRR but by other variables. The firms that were operating in catering, construction, production, property, retail and wholesale were dependent on R&D. Those 669 observations related to firms that were not planning to invest on R&D had 5% higher R&D. For those that were planning to invest in R&D, their TFP was dependent on PS. Firms with $PS > -0.47$ had 15% higher productivity.

The other split refers to those firms which were operating in other sectors had 10% higher TFP than other firms. The following splits for those firms operating in other sectors show the importance of foreign ownership, where this component is associated to 24% higher productivity, particularly among those firms competing in more competitive industries ($HHI > 0.03$). UK owned firms younger than 18 years seem to also depend on the competition with $PS > -0.38$ being linked to 12% higher TFP. Those older than 18 years old tend to have higher TFP than younger firms.

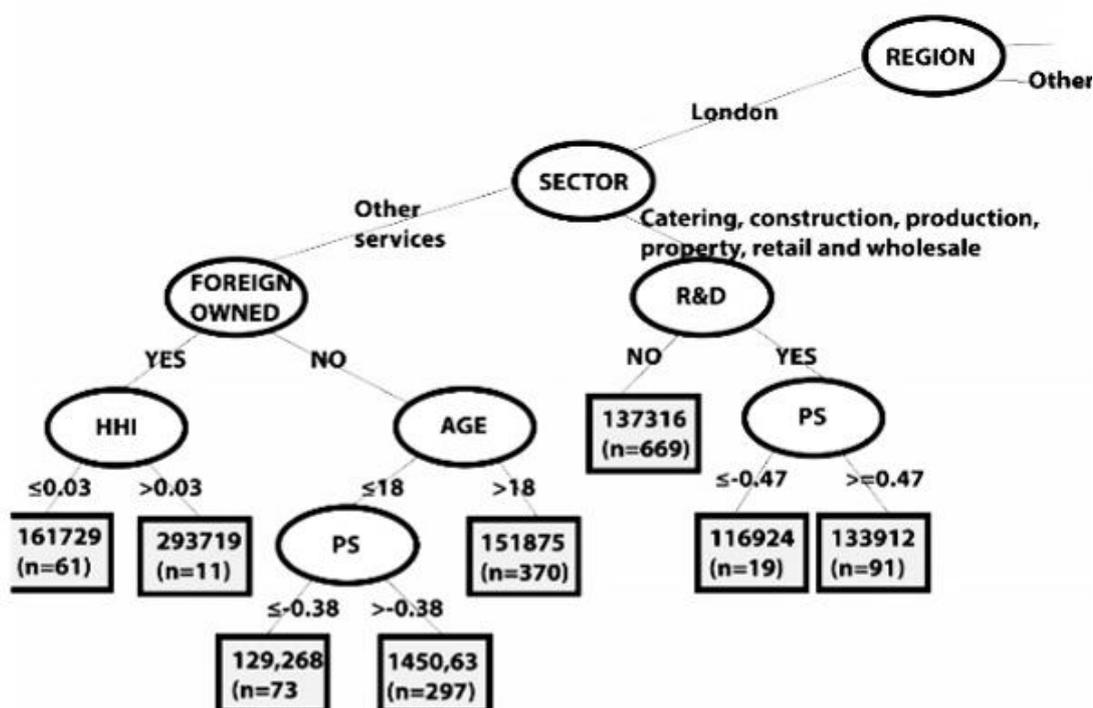


Figure 7:7 Extract of the tree for firms that did not receive any SBRR lagged two years ago and were operating in London. The full tree is available in Appendix 10.4.1 (p. 276). The outcome value refers to the estimated TFP as reported in Figure 7:5 (p. 197).

Figure 7:8 turns towards the right of the full tree (Appendix 10.4.1, p. 276) and describes instances where firms had SBRR lagged by two greater than 0 and were operating in other regions than London and older than 32 years. 1,738 regional firms older than 32 years had 5% lower TFP than younger regional firms. The unbiased REEM tree did not split on BSRR for those firms. However, they depend on other variables. Foreign-owned firms were positively related to diversification with $PD > 0.79$ had 45% higher TFP than other foreign firms operating in less diversified regions ($PD \leq 0.79$). The tree then separates old firms (> 38 years) and shows that those experiencing higher employment growth were likely to have lower TFP than those which cannot be regarded as high growth firms depending on the region. Those not older than 38 years, tended to depend on sector and region representing various mixes. The property, wholesale and other services sectors had 7% lower TFP in North West and Scotland, while catering, construction, production and retail sectors in North East, South East and Wales underperformed other regions by $\sim 6\%$.

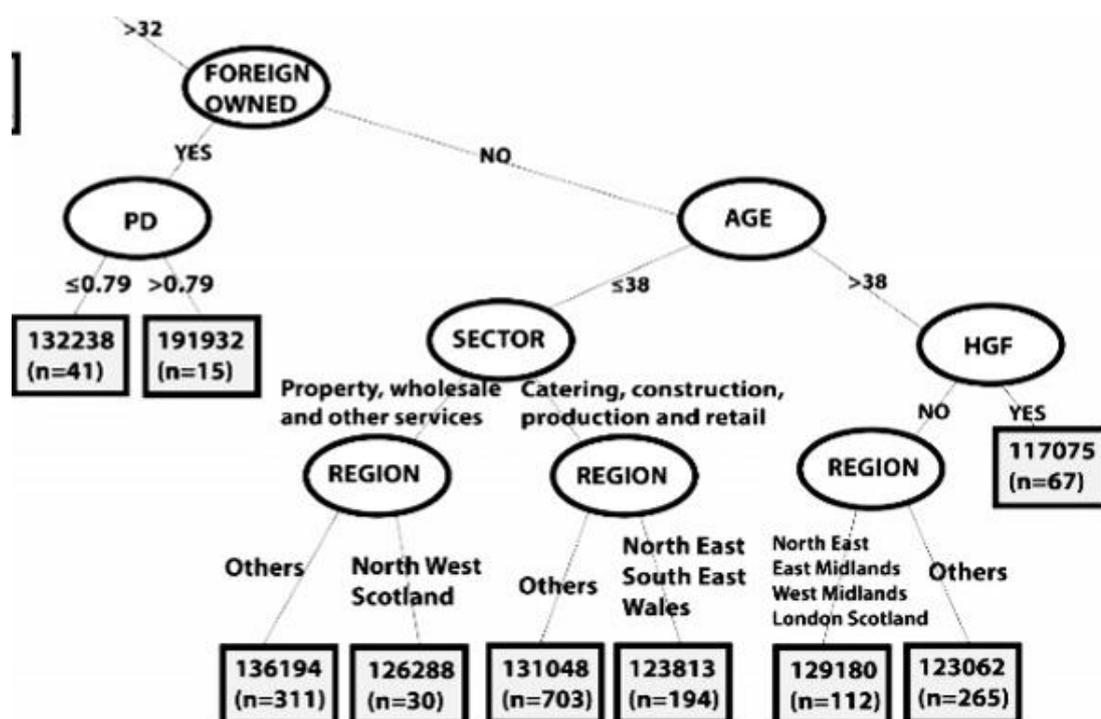


Figure 7:8 Extract of the tree for firms that did not receive SBRR two years ago and were operating in other regions than London and older than 32 years. The full tree is available in Appendix 10.4.1 (p. 276). The outcome value refers to the estimated TFP as reported in Figure 7:5 (p. 197).

The estimation was performed on 13,951 observations of 1091 firms. To test the validity, k-fold assurance method was employed. As shown in Table 7:4, the REEM model performed ~3% better and provided lower standard errors than OLS. This method was supplemented with both dynamic system-GMM estimator and random forests.

	Mean	Min	Max	SD
REEM (2)	0.331532	0.306428	0.361278	0.000218
OLS (1)	0.347494	0.307494	0.404882	0.000652
(2)/(1)	0.954067	0.996534	0.892304	0.334366

Table 7:4 The K-fold validation. REEM predictions compared to OLS.

To test the estimates, effects to TFP were also estimated with random forest (RF) algorithm. Table 7:5 shows estimated importance scores for the REEM tree. Without controls for correlation between observations, Jacobian externalities, HHI and region variables became the most influential. Whilst, current SBRR and SBRR lagged by two were 8th and 9th on the list. The results were broadly consistent with the REEM tree.

Variables	Productivity
PD	282669470.2
HHI	224507266.6
Region	141526539.9
Age	127377111.5
Sector	122741434.3
R&D	89087896.4
High growth firm (HGF) dummy	75200671.6
SBRR	44403483.8
SBRR lagged by 2	39536232.9
PS	28489371.1
Immediate foreign ownership	16754358.7
Ultimate foreign ownership	16754358.7
SBRR lagged by 3	10722731
SBRR lagged by 5	8099703.5
SBRR lagged	6526279
SBRR lagged by 4	512537.5
SBRR (first enhanced/ first introduced)	-340104.4

Table 7:5 Random forest importance scores – productivity

7.2.3 Dynamic Model

The long-run coefficients obtained from an estimation of the dynamic productivity equation using CEM to control for self-selection into the treatment group and with bootstrapping through 1000 samples are displayed in Table 7:6 (p. 205) and compared with other models in Appendices (Table 7:8, p. 281 and Table 10:2, p. 282). These results are useful in establishing a baseline set of estimates that allow comparison with the estimates obtained with not imputed data and no matching.

Various lags of SBRR were included in the equation. However, the only variable indicating whether SBRR was the first recipient of enhanced/introduced relief was significant at 90%. This implies that those receiving the relief had approximately 12% higher TFP. Other variables were insignificant but showed the direction towards which the SBRR might influence some of the firms. All variables but SBRR lagged by three years were related to slightly higher productivity (0.04%-3%). However, even the cumulative sum totalling to 0.031 (excluding the first recipient of enhanced/introduced relief) did not indicate any substantial influence.

The estimates of the coefficients on lagged employment and capital were statistically significant at the 99% level and lagged investment at 95% level, meaning that holding all other variables constant, a 10% increase in employment would result in .04% decrease in GVA. However, 10% increase in capital and lagged investment would result in 39% and 8% increase in GVA.

The coefficient on the Herfindahl Index was negative and statistically significant at the 95%, indicating that 100% increase in the index would result in 12% lower TFP than the initial value. Herfindahl Index is a measure of the size of firms in relation to their industry, indicating the amount of the concentration. It should also be noted that the HHI does not take account of either potential or international competition and is dependent on the definition of the industry (Okada, 2005). Thus, the result may suggest that higher market concentration (e.g. monopoly) would result in lower TFP. In addition to that, age was significant implying that those firms that were older were less likely to be productive. In fact, with each year, the productivity seems to be lessened by approximately 2%. Other variables were insignificant. PD, PS, HGF dummy seemed to contribute to TFP positively while R&D dummy had an adverse effect.

Variable name	Estimate	SE	Z	Pr(> z)	
Intercept	0.0223	0.028	0.791	0.43	
GVA (defl & 1st lag)	0.0295	0.031	0.956	0.34	
Employment (log)	0.0277	0.033	0.834	0.40	
Employment (log & 1st lag)	-0.0043	0.002	-2.396	0.02	***
SBRR (log)	0.0010	0.001	0.776	0.44	
SBRR (log & 1st lag)	0.0004	0.001	0.482	0.63	
SBRR (log & 2nd lag)	0.0006	0.001	0.600	0.55	
SBRR (log & 3rd lag)	-0.0015	0.001	-1.461	0.14	
SBRR (log & 4th lag)	0.0305	0.046	0.670	0.50	
Capital (defl & log)	0.3859	0.135	2.857	0.00	***
Capital (defl, log & 1st lag)	-0.1119	0.074	-1.517	0.13	
Investment (defl, log & 1st lag)	0.0788	0.038	2.098	0.04	**
SBRR (first introduced & first enhanced)	0.1166	0.068	1.702	0.09	*
HGF dummy	0.0045	0.009	0.484	0.63	
R&D dummy	-0.0116	0.035	-0.332	0.74	
PD (log)	0.0036	0.010	0.369	0.71	
PS (log)	0.0443	0.028	1.600	0.11	
Age (log)	-0.0220	0.011	-2.041	0.04	**
HHI (log)	-0.1174	0.055	-2.141	0.03	**
Materials (defl & log)	0.3915	0.344	1.137	0.26	

Table 7:6 The coefficients obtained from the estimation of the dynamic productivity equation using CEM to control for self-selection into the treatment group bootstrapped through 1000 samples.

7.2.3.1 Dynamic Model Diagnostics and Sensitivity Analysis

One of the imputed samples was used to assure that the overall model passed the standard tests. The variables indicating rent, sector and region did not have sufficient amount of different values within observations. Thus, they had to be excluded from this model. To allow for measurement error, instruments were lagged by two to eight periods. This proved to be a sufficient number of lags to avoid rejection of the null of valid instruments in the Sargan test at 5% level. Both hypotheses of autocorrelation were successfully rejected with p-values of 0.3 and 0.5. The model also passed Wald test for coefficients and time dummies with chisq of 240.81 (df=21, p= \sim 0) and 201.44 (df=11, p= \sim 0) indicating that it fits better with coefficients and time dummies than without.

The sensitivity analysis with various data is reported in Appendix 10.4.4 (Table 10:1, p. 281 and Table 10:2, p. 282). The long-run coefficients obtained from an estimation of the dynamic equation using no mechanism to control for selection into the treatment group are displayed in the two last columns. These results were used for comparison with the estimates obtained using CEM. To allow for measurement error, instruments were also

lagged two to eight times. As reported in Appendix 10.4.4 (Table 10:2, p. 282), it also passed all standard tests. The Sargan test was rejected at the 10% level. The second-order autocorrelation was rejected with -1.62 ($p=.10$). The model passed Wald test for coefficients and time dummies with chisq of 409.13 ($\text{df}=19$, $p\sim 0$) and 142.85 ($\text{df}=11$, $p\sim 0$).

Due to the increased number of NAs, R&D dummy and HGF dummy had to be excluded. The model now had highly significant (at 99%) lagged dependent variable. Holding all other variables constant, a 10 % change in lagged GVA resulted in 0.9% higher GVA. It is likely that this lagged variable captured some of the employment and capital effects. Employment was insignificant. Current capital seemed to be positively related to GVA, but lagged capital showed a negative relationship.

Standard errors were now significantly increased and slightly different relationships were identified. Current SBRR was significant at the 99% indicating that holding other variables constant, 10% increase in SBRR would increase TFP by .04% (previously reduced by .03% and standard error was increased by 12%). In this model SBRR (first introduced or enhanced) was significant and showed a negative relationship. It seemed that firms that were first-time SBRR recipients of introduced or enhanced SBRR reduced their TFP by 3.1%. This model separated these two effects because of fewer periods. It seems that this model also separated those firms that were granted SBRR according to their characteristics, which is why the same relationship was not identified after matching. The model had higher standard errors.

Although HHI became insignificant, PD was significant. Holding other variables constant, 10% increase in PD would decrease TFP by .2%. Additionally, English firms had 8.7% higher TFP than Welsh and Scottish firms.

Other types of GMM estimators were also reported in Appendix 10.4.4 (Table 10:1, p. 281 and Table 10:2, p. 282). The relationships were weaker and standard errors higher. This was particularly evident once the difference in difference transformation was employed, resulting in the loss of ~53% observations. It was the only model that failed to reject Sargan's test even with eight lags and found only one variable to be significant. The overall fit of the first model seemed to be the best.

7.3 SURVIVAL ANALYSIS

This subsection describes the results of survival analysis. To achieve this aim, it starts by providing extensive discussion on the results from Stratified Cox Proportionate Hazard Model (CPH) (Section 7.3.1). It then turns to survival trees (Section 7.3.1).

CPH consistently with Dynamic Estimator (Section 7.2.3), found a variable capturing the initial⁴¹ effects of receiving any relief, or the uplift in relief, very influential. Firms that were granted the relief during the first year of SBRR existence (or enhancement) were found to be far more likely to survive. No other variables related to SBRR were found to be highly significant. However, there was some indication that industry concentration plays a part in survival. Furthermore, a small number of firms operating in the property and retail sectors were less likely to close. Also, the North West and East of England were less negatively associated with closure.

On the other hand, survival trees did not identify any relationship between firms that were granted the relief during the first year of SBRR existence (or enhancement) and survival. However, there was a small level effect indicating that recipients were slightly more likely to survive and were less fragile than other firms. Also, variables such as foreign ownership, rent and competition indexes seemed to highly influence survival.

7.3.1 Stratified Cox Proportionate Hazard Model

The long-run coefficients obtained from an estimation of the survival equation using CEM to control for self-selection into the treatment group with imputation are displayed in Table 7:7 and compared to other models in Appendix 10.4.5 (p. 283). The model was estimated with 14,926 observations (some removed due to being missing), 242 deaths and 504 relocations.

One of the imputed samples was used to assure that the overall model passed the standard tests. The proportional hazards test revealed that sector and region classifications and age did not satisfy the proportional hazards assumption requiring covariates to multiplicatively shift the baseline hazard by the same amount through time. The model was therefore stratified on region and sector. Furthermore, a different classification of age was introduced. It took a value of 1 if it was the first operational year for that firm, a value of 2 if it was in between second and fifth operational year and a value of 3 if it was older than five years. It then passed the standard hazard assumption test with chi-square of 46.28

⁴¹ Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010.

($p=.12$). The model was clustered on company ID (entref) to control for correlation between observations.

All models then passed all standard statistical tests as reported in Table 10:4 (Appendix 10.4.5). The main model had low explanatory power with R^2 of 0.3% (max=9%) and a concordance score of 61%(+/-10%). It is worth noting that economic conditions, particularly during the recession, were not directly controlled for but rather indirectly by employing matching. This resulted in relatively low R^2 . Yet, it passed all standard tests. The likelihood-ratio, Wald and score chi-square statistics are asymptotically equivalent tests of the omnibus null hypothesis that all of the β s are 0. In this instance, the test statistics were in close agreement, and the omnibus null hypothesis was soundly rejected: likelihood ratio was 39.22 (df=17, $p<0.01$), Wald test = 961.7 (df=17, $p<0.01$), Log-rank test = 44.62 (df=17, $p<0.01$) and robustness test with 31.62 ($p=0.02$).

In line with the dynamic productivity estimation, the only highly significant variable directly related to SBRR was ρ capturing the initial⁴² effects of receiving any relief or the uplift in relief. Both outcomes of the variable had a p-value of $<0.01\%$, with hazard ratios of -14.86 and -14.49, respectively. Thus, holding other covariates constant, if a firm was granted the relief during the first year of SBRR existence, its hazard ratio ($e^{-14.86} = \sim 0$) indicates that it has a high probability of survival. Likewise, if a firm was the first to receive the enhanced relief, it has ($e^{-14.49} = \sim 0$) much lower risk of death than others. Also, current SBRR was significant at 90% confidence level. Current SBRR was associated with 70% lower probability of closure.

After accounting for other variables, there were no statistically significant associations between various SBRR lagged values and closure. This was not to say that these risk factors were not associated with all-cause mortality; their lack of significance is likely due to confounding (interrelationships among the risk factors considered). For the statistically significant risk factors, the 95% confidence intervals for the hazard ratios did not include 1 (the null value). In contrast, the 95% confidence intervals for various SBRR lagged values included the null value. They only indicate a trend towards significance. For instance, a weak positive effect on survival might exist from current SBRR and SBRR lagged by four to five periods. Some negative relationship may exist between SBRR and survival for other periods.

Consistently, SBRR (first introduced) is significant and highly linked to the low probability of closure throughout all models with different imputation and matching

⁴² Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010.

reported in Table 10:3 (Appendix 10.4.5, p. 283). All models, except the one using non-matched and non-imputed data, have SBRR (first enhanced) also significantly related to TFP. Instead, it finds current SBRR to be negatively related to closure with a hazard ratio of -0.9 ($p=0.03$).

There were two significant variables not directly related to SBRR in the main model reported in Table 7:7. Firms with non-UK immediate ownership were almost three times more likely to close. The relationship was consistent across models reported in Table 10:3 (Appendix 10.4.5, p. 283).

Furthermore, those that planned to invest in R&D in the following two years were 32% less likely to close than those that did not plan to invest in R&D. The relationship became weaker after matching probably because of the decreased sample size, but was evident before matching and after matching and imputation as showed in Table 10:3 (Appendix 10.4.5, p. 283).

	Estimate	SE	SE (r)	Z	Pr(> z)
TFP	0.000002	0.000003	0.000003	0.50	0.62
SBRR	-1.12	0.56	0.67	-1.66	0.10*
**SBBR (1st lag)	0.47	0.55	0.58	0.82	0.41
SBRR (2nd lag)	0.002357	0.53	0.54	0.004383	1.00
SBRR (3rd lag)	0.42	0.52	0.54	0.79	0.43
SBRR (4th lag)	0.22	0.52	0.56	0.40	0.69
SBRR (5th lag)	-0.54	0.54	0.57	-0.95	0.34
Age dummy -2	0.13	1.10	1.10	0.12	0.90
Age dummy- 3	0.51	1.05	1.06	0.48	0.63
PD	0.39	1.17	1.02	0.38	0.71
PS	0.16	0.19	0.19	0.82	0.41
HHI	0.001358	1.84	1.67	0.00	1.00
Im. Foreign Ownership	1.02	0.25	0.24	4.30	0.00***
R&D	-0.39	0.17	0.17	-2.33	0.02**
HGF	-0.21	0.15	0.15	-1.44	0.15
SBRR (first introduced)	-14.86	6617.27	1.12	-13.23	0.00***
SBRR (first enhanced)	-14.49	2051.14	0.88	-16.44	0.00***

Table 7:7 Cox model with matched imputed data bootstrapped through 1000 samples. Tests and sample size are reported in Appendix (Table 10:2, p. 282).

7.3.2 Survival trees

The survival trees estimated using CEM to control for self-selection into the treatment group and with automated imputation are displayed in Figure 7:10 and Appendix (Section 10.4.10 p. 291). The model was estimated with 15,047 observations and 242 deaths. Another tree with controls for size instead of estimated TFP is presented in Figure 10:9 (Appendix 10.4.5.1.1, p. 285).

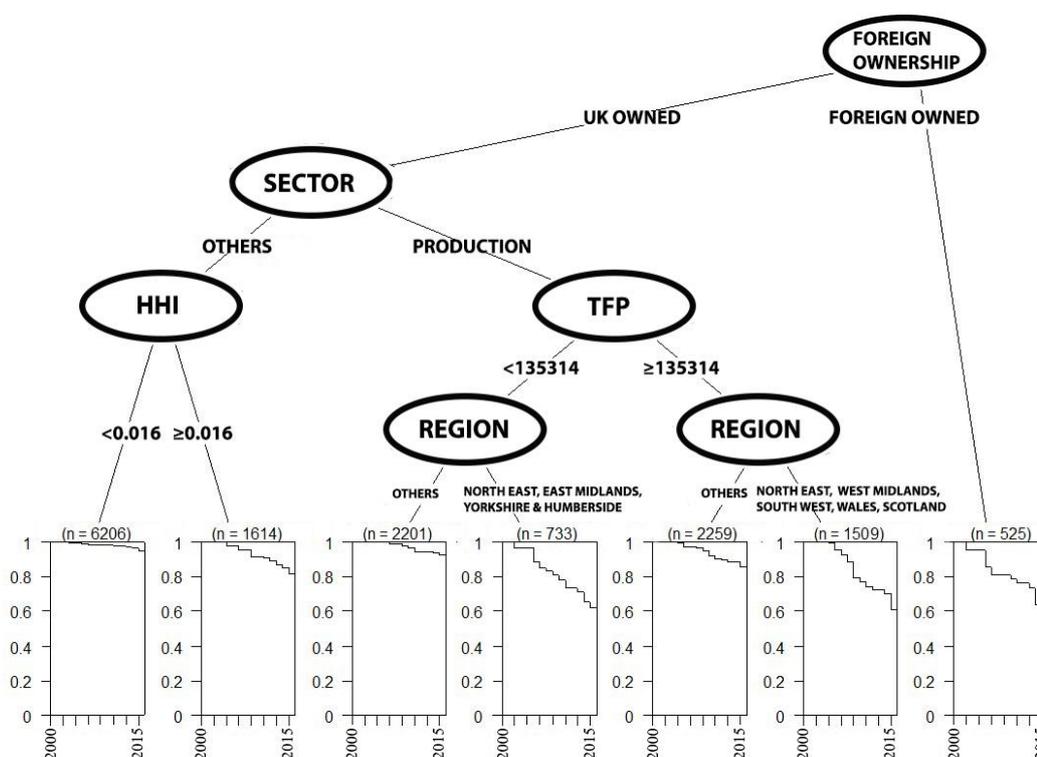


Figure 7:10 The main survival tree.

In Figure 7:10, the survival tree captures the importance of foreign ownership to survival. All observations are below the first node, which divides firms with UK and non-UK immediate foreign ownership. For the small number of observations with non-UK immediate foreign ownership, the probability of survival is lower on average.

However, the vast majority of observations refer to UK owned firms. The tree then divides UK firms into sectors. All sectors except production are then split on HHI, where small companies operating in sectors which are less concentrated towards several major players tend to outperform others.

Firms in the production sector highly depend on the estimated TFP and region where they are located. The graph for those with annual TFP at just under 135,314 operating in North East, East Midlands, Yorkshire and Humberside shows a steep decline in survival for firms above this threshold. Similarly, those with TFP of at least 135,314 in

North East, West Midlands, South West, Wales and Scotland seem to experience some of the lowest rates of survival.

There is no relationship with SBRR as found in the CPH model. The inconsistency is around the initial effects of the reliefs. This clearly dissipates quickly and the tree focuses across the entire period, alternatively the effect is captured by the variables. Thus, Figure 7:11 was estimated to illustrate level effects in the predicted likelihood of closure. Without controlling for other variables, SBRR recipients were slightly less likely to close. In particular, firms receiving the initial⁴³ relief or the uplift in relief seem to outperform others slightly. The Cox Regression identified that those firms which received the relief would benefit from it at that year. However, survival trees were considering the overall impact and excluded it from the output.

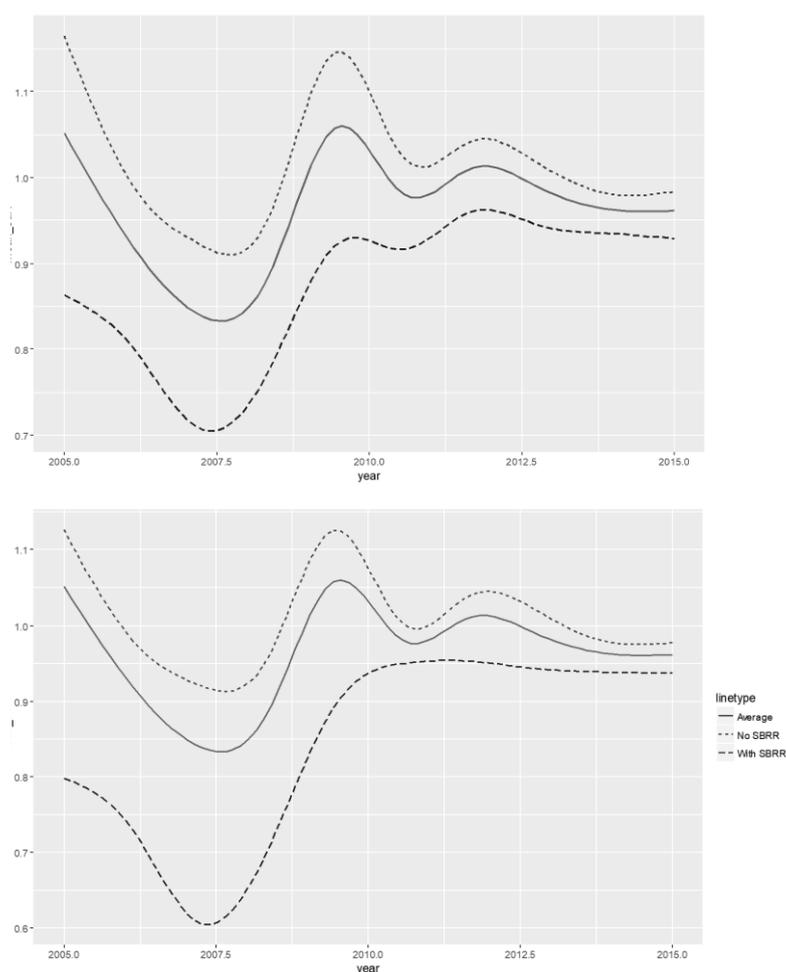


Figure 7:11 Average survival probabilities over time estimated with survival trees. The graph on the bottom refers to current SBRR recipients vs non-recipients, whilst the upper graph is for SBRR (first/enhanced) recipients.

⁴³ Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010.

7.3.3 Random Forests

For the survival analysis, random forest (RF) algorithm provided somewhat different results to those estimated by the survival trees. The prediction error was estimated to be 18% with full data 30% and 25% with test sample. Table 7:8 suggests that the key variables identified by the RF are still immediate foreign ownership and TFP. However, now the RF algorithm suggests that current SBRR and age are also important.

Given this inconsistency, a further comparison of survival probabilities of current SBRR-recipients with non-recipients was prepared. The survival graphs in Figure 8:13 were estimated with random forests to compare the previously estimated probabilities to the current ones. It provided very similar relationships to the previous estimation. SBRR recipients were more likely to survive than firms not receiving the relief. However, it seems evident that firms with no SBRR had slightly more diverse but relatively similar survival probabilities on average to those that received SBRR.

Variables	Survival
TFP	0.0072
SBRR	0.0034
Immediate foreign ownership	0.0032
Age	0.0029
SBRR lagged by 3	0.0017
R&D	0.0016
SBRR lagged by 2	0.0015
SBRR lagged by 4	0.0014
Sector	0.0013
PS	0.0013
SBRR lagged	0.0012
PD	0.0012
High growth firm (HGF) dummy	0.0009
SBRR lagged by 5	0.0001
SBRR (first enhanced/ first introduced)	0
Ultimate foreign ownership	0
Region	-0.0003
HHI	-0.0003

Table 7:8 Radom forests - estimated variable importance with matched data with automated imputation

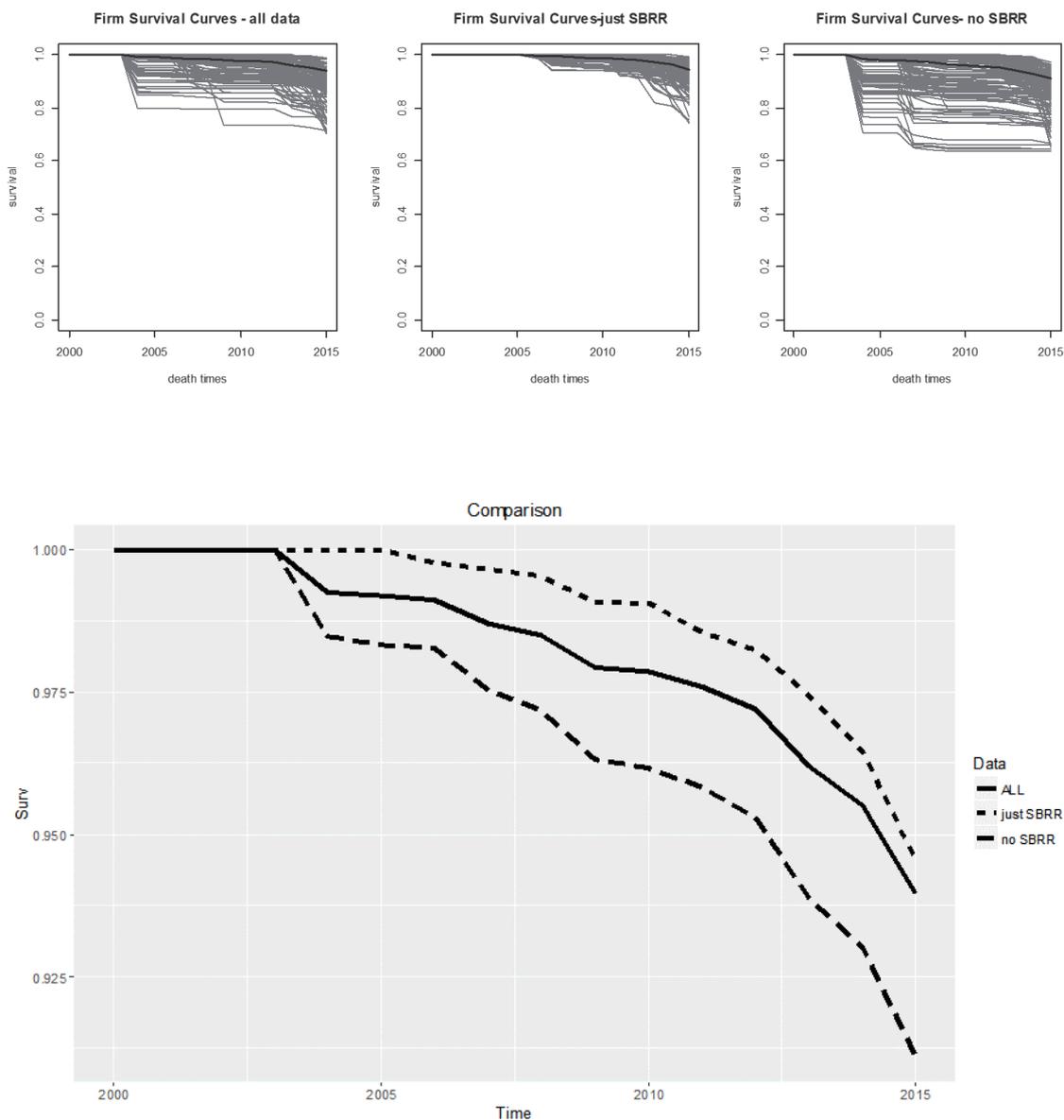


Figure 7:12 Survival curves estimated with Random Forests; In the upper graph, the grey lines show how curves deviate across 500 trees, whilst the black lines show average survival curves. In the bottom graph the averages are presented together.

7.3.4 Comparison of Survival Estimators

The Cox Regression found SBRR (first introduced and enhanced) dummy highly significant. Further visualisations with other methods indicated some relatively marginal initial SBRR effects on survival. SBRR recipients seemed to have marginally higher chances of survival. Figure 7:13 shows how different methods estimated survival curves. The LTRC probabilities were converted to be comparable to Kaplan-Meier curves. The overall probabilities were somehow consistent. The LTRCART trees seemed to capture recession while others did not because they were based on Kaplan-Meier curves.

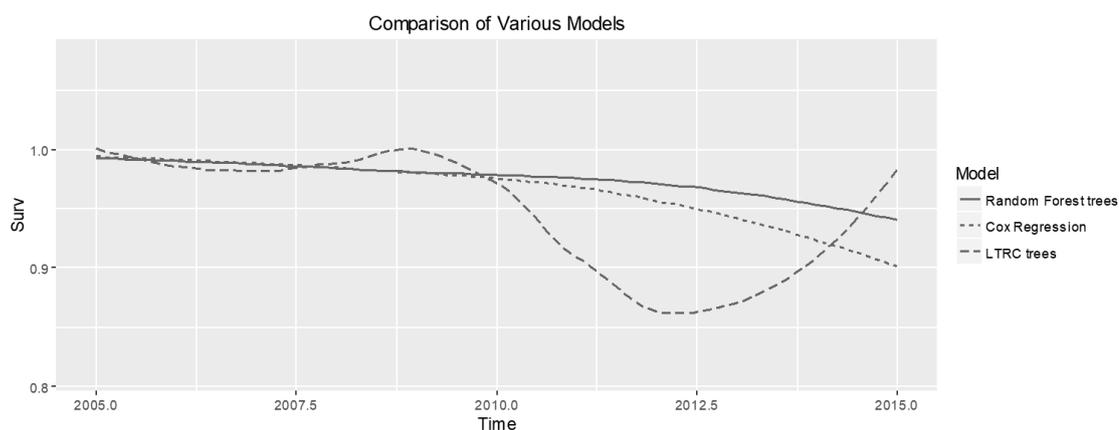


Figure 7:13 Comparison of survival curves estimated by the three methods.
Source: author's calculations.

7.4 DISCUSSION OF THE RESULTS

The overall aim of this thesis is to understand whether Small Business Rate Relief has any effects on firms, in particular with regards to their productivity and survival. To achieve this aim, the following objectives were formed:

To create a theoretical framework which suggests whether SBRR may influence productivity and survival. The framework should be based on the existing theories of tax incidence and the UK business environment.

To find appropriate data and analytical technique which could be used to either support or disprove the framework. Simultaneously, to explore other fields for techniques that were not used in policy evaluation before.

To acquire the knowledge through the theoretical framework and empirical evidence of the extent to which SBRR may influence productivity and survival.

Theory and Empirical Reviews achieved the first objective by extending Duranton's framework and forming the key hypotheses which are presented below. The Methodology Review and Research Design Chapters found and described the datasets (ARDx, BSD, PMS) and techniques (system GMM, Wooldridge's GMM and unbiased REEM trees for productivity and Cox Regression and LTRCART trees for survival) applied within the analysis. This section focuses on the third objective. It discusses the empirical findings of the thesis by using both results from the analysis and theoretical insights from the Literature Review. The theoretical framework shaped the following hypotheses on productivity:

- *H2a: TFP of firms receiving a relief, awarded upon its introduction or enhancement, is lower than of firms that are not receiving the relief in the short term;*
- *H2b: TFP of firms receiving SBRR is lower than of firms that are not receiving the relief in the medium term;*
- *H2c: SBRR has little or no significant impact on productivity in the long term;*

and survival:

- *H1a: survival probability of firms receiving a relief, awarded upon its either introduction or enhancement, is higher than of firms that are not receiving the relief in the short term;*
- *H1b: survival probability of firms receiving SBRR is lower than of firms that are not receiving the relief in the medium term;*
- *H1c: SBRR has no significant impact on survival rates in the long term.*

This section starts by unfolding the basic description of firms receiving the relief to identify whether the right firms were actually rewarded the relief. This first part shows that, in fact, those SBRR recipients were mistargeted. The chapter then expands on the effects of SBRR, separated into three periods similar to those used in forming the hypotheses.

7.4.1 Firm Characteristics

This thesis started by discussing the primary aims expressed in policy reports. These were related to the support during the recession, economic growth and general support for "genuinely" small firms. However, in the official policy papers, no objectives were identified. From the reports and speeches of politicians, intended recipients seemed to be micro firms.

Given this lack of definition for both expected and intended recipients, the Theory Review (Section 2.2) further investigated possible reasons the government might consider supporting small firms. These were mainly related to the equity, market failure and externalities introduced by BRs. The following paragraphs present the results, explaining why SBRR in its current form cannot be justified solely by these criteria.

Firstly, this thesis argues that the rating system needs to take into account ability to pay and must also be able to respond to circumstances, such as the broader economic environment. BRs may well be a substantial expense for some businesses (Peck *et al.*, 2014). However, this relief is unlikely to reduce the bills for those in need and, simultaneously, to address the ability-to-pay principle or support firms with the potential to grow because it does not target those firms directly. The policy, which is solely based on the premises the firm is occupying, was found to be too simplistic to verify any extent of the ability to pay.

This is predominantly evident in the decision trees (Section 7.1 and figures in Appendices 10.4.1 and 10.4.2), where on several occasions larger firms were entitled to more substantial reliefs than smaller firms. For instance, the decision trees with the broader data (in Section 7.1.1.2 and Appendix 10.4.1) indicated that the government did not necessarily support micro firms. According to the EU definition, micro firms are those with less than 11 employees, reporting turnover of less or equal to £2 mln⁴⁴. However, the decision trees showed that on multiple occasions BR bills do not correspond to the groupings by size. For instance, according to the detailed tree reported in Appendix 10.4.1 (Figure 10:5, p. 277), the firms that were employing under 50 individuals with turnover from £2 to £10 million, particularly in construction, motor trade and wholesale sectors often paid far lower bills than those with nearly exact circumstances but turnover under £2 million. Furthermore, decision trees on SBRR as a dependent variable uncovered even more frequent and substantial cases. Figure 7:4 (Section 7.1.2.1, p. 194) highlighted that not only micro but also medium and large firms were receiving substantial reliefs of up to 100%.

Furthermore, it is ambiguous whether recipients were actually in need of public funds. Instead of supporting firms that ask for help, the relief only introduced externalities in the already complex market. One indication of increasing complexity comes from the lack of SBRR dependence on the region. Regional effects in the decision trees (Appendix 10.4.1 and 10.4.2) were highly dependent on other variables but they did not seem to be related to the supply of land or historic property prices. It is challenging to find any reasons why

⁴⁴ See Introduction and Background Chapter (Section 1.1) for the exact definition.

the central government may intentionally provide more support for some firms in more affluent parts of the country. Although Southern micro firms were often seen as performing better than firms in other parts of the UK, SBRR did not follow the similar distribution. In fact, as illustrated in Appendix 10.4.2, before 2010, South West and East of England experienced higher reliefs than other regions, while firms based in Wales and Scotland were receiving lowest reliefs. However, after 2010 Wales received the highest reliefs and SBRR recipients in North West and West Midlands the lowest reliefs. This is contrary to the UK commercial property prices⁴⁵.

The distortion introduced by the SBRR is even more evident when the sector variable is also included in the equation. The detailed decision trees reported in Appendix 10.4.2 showed that micro firms between 2010 and 2015 experienced some complex SBRR distribution between sectors and regions. In property, construction and other service sectors, SBRR was 22% lower in North East and West, Yorkshire & Humberside and East Midlands than in other regions. On the other hand, firms that were operating in wholesale, retail, catering and production sectors and were situated in the North West, East and West Midlands, South East and West and Scotland received 25% lower reliefs than those based in North East, Yorkshire & Humberside, East of England and Wales. The distribution between sectors and regions does not suggest any reasonable indication that firms in genuine need of support received the relief owing to little or no relationship between either property values or overall performance of areas being identified in the data.

Thus, the government supported not just micro firms but also larger ones. With its simplified definition only weakly corresponding to expected rents⁴⁶, it failed to accommodate the ability-to-pay principle, and by doing so to reduce market failure. Instead of removing externalities, the government introduced further distortions by encouraging businesses to reside in the premises with lower rateable values. By doing so, instead of strengthening the progressive taxation, the government supported some businesses almost irrespectively to their fundamental characteristics. It might not equate well with fairness around firms that deserve or need support.

This new evidence on mistargeting is an important contribution given that the few existing studies of SBRR (Regeneris Consulting, 2015; Piedad Consulting, 2014; Peck *et al.*, 2014) isolated only intended recipients, which were usually small firms, and did not look for other businesses that were not supposed to be supported by the policy. Furthermore,

⁴⁵ As according to the HM Land Registry: Price Paid Data: <https://www.gov.uk/government/collections/price-paid-data> (Accessed 18.07.2018).

⁴⁶ See Introduction and Background Chapter (Section 1.1) for the exact definition.

even when only smaller firms were considered, Peck *et al.* (2014) found that for some SBRR was not useful and called for better targeting. The degree of mistargeting is far higher than Peck *et al.* (2014) uncovered as this thesis showed that some larger businesses were also entitled to SBRR. Furthermore, given that the data excluded all businesses that had more than one local unit, even more substantial mistargeting should be expected.

As a result, this thesis suggests that relief of this nature should adhere to the clear principles set out in the broader consultation on the non-domestic rate review that has an aim with timescales and most importantly targeted – for example, at specific sectors, ability to pay or economic growth in order to achieve higher efficiency of government spending. This better targeting could help to support high growing firms (e.g. defined in Section 4.7.2, p. 92) or in temporary hardship situations. The need for reliefs should be regularly evaluated, including assessments of whether they are achieving their desired purpose and impact.

An even more simplistic definition, depending on the characteristics of a firm, might substantially reduce mistargeting. To define the intended recipients, the relief might be based on the fundamental characteristics of intended recipients such as turnover or employment. Thus, building on to the definition derived in the Introduction and Background Chapter, a micro firm would have to employ less than 11 people, have a turnover of less or equal to £2 million and receive 100% relief post-2010 (and 50% pre-2010). If one considered solely descriptive statistics of the data in this study, this criterion could be a good starting point in the SBRR reform, which may potentially reduce capitalisation effects discussed in various terms because it would be linked to the business, not just the premises. On the other hand, any changes should be well thought out since increasing tax costs associated with employment may result in rising unemployment or alternative business models.

7.4.2 Short Term (H1a and H2a)

This chapter previously uncovered that the relief was not dependent on business characteristics. This section discusses any changes with regards to total factor productivity and survival within the group of those mistargeted recipients in the short term. Simultaneously, it confirms the H1a and H2a hypotheses, which indicate that TFP (survival probability) of firms receiving a relief, awarded upon either its introduction or enhancement, is likely to be lower (higher) than firms that are not receiving the relief in *the short term*.

In line with the Framework, the initial recipients of higher SBRR were significantly related to the higher survival in that year. Cox Regression in Section 7.3.1 (p. 207), showed that holding other covariates constant, those firms that received the initial⁴⁷ relief or the uplift in relief, had an extremely high probability of survival. However, it is important to state that the LTRCART trees did not capture this relationship directly but the graph in Figure 7:11 (p. 211) indicated a marginal effect owing to different reporting. The trees report on the overall importance throughout the years, while the Cox Regression reports on the impact in a particular year when the dummy variable takes the value of one. The random forest algorithm (Figure 7:12, p. 213) also found current SBRR to be influential.

The primary reason for the very high probability of survival of those firms may be increased cash flow which is yet to be acquired by the landlord with increased rents. The business owner is the most likely to experience any measurable returns in this term. Thus, the increased cash flow would help underperforming firms to sustain their business. This supports Peck's *et al.* (2014) qualitative study where some business owners found SBRR exceptionally helpful and even claimed that they would have to close their firms if they did not receive the SBRR.

The dynamic model in Section 7.2.3 provided some indication that first introduced (enhanced) SBRR may be related to some improvements in TFP. However, this was inconsistent across models (Appendix 10.4.4). In fact, both methods showed that SBRR did not have a significant positive effect on TFP in the longer terms. However, the tree in Section 7.2.2 showed many instances where firm's SBRR was associated to lower TFP. The results from this TFP estimator directed to two-sided effects. One might claim that the supported firms might be more likely to have lower TFP than their competitors because they were initially occupying premises with a lower value. However, this is unlikely since the data was included from 2000 and matching was applied to control for the prior observable characteristics to assess whether it is related to the introduced SBRR or not.

Thus, effects on both survival and productivity are according to the Framework, which indicated that firms which start receiving the relief were less likely to relocate or close than non-recipients, but more likely to either sublet their premises, decrease employment or reduce their investment in TFP. The latter case was captured in the analysis with the reduction in TFP and might be regarded as one of the unintended consequences that, according to Hilber (2017), is likely to offset the positive incentive effects of certain policy measures. Simultaneously, SBRR recipients received more cash flow, resulting in a

⁴⁷ Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010.

higher probability of survival. Thus, the relief possibly discouraged firms from investing in their productivity and provided them with an incentive to stay in the current premises in the short term.

Thus, further than assisting, in a small way, existing businesses which may still be struggling, this intervention does not contribute to improving the economy. Those micro firms that did not receive the relief were probably less likely to survive as a result of the increase in competition or inability to reduce costs to the level achieved by recipients. Building on the previous argument, in the broader market, with regards to the key indicators such as turnover and employment, smaller firms may be recipients and non-recipients at the same time in the same areas. The positive effect on survival by recipients would mean that some non-recipients were disadvantaged by the relief because their immediate competitors could reduce their prices owing to either already introduced or enhanced relief. Consistently lower TFP in the main tree (Appendix 10.4.3, p. 280) indicates that those recipients would be more discouraged to invest in their TFP than non-recipients. Thus, as according to the theory with the standard neoclassical assumptions on competitive markets, the supported, less efficient, firms took a share of possibly more efficient but not supported businesses. The resulting market is where consumers still pay the same price but the taxpayer's money is used for the relief, so the taxpayer pays more for the goods. This is also supported by the general trends in the business deaths across the UK which were presented in the Introduction and Background Chapter.

7.4.3 Medium Term (H1b and H2b)

In the short term, further than providing marginal support for existing businesses, which may still be struggling, SBRR did not contribute to improving the economy. Although it seems challenging to separate the short and long terms because many factors may influence how quickly SBRR is capitalised into rents, this thesis defines the medium term as a term in between short (low or no capitalisation) and long (full capitalisation) terms as discussed in the Framework with Hypotheses Chapter (Section 4.6). The speed and extent of capitalisation are likely to depend on the competition within the region and industry. This section focuses on H1b and H2b hypotheses. TFP and survival probability of firms receiving SBRR are more likely to be lower than those of firms not receiving the relief in *the medium term*.

The theoretical framework suggested that the majority of firms that received SBRR would experience harmful distortions such as increased rents that would be likely to cause relocations or closures in the medium term. Although variables related to SBRR in survival analysis were insignificant, the effects were adverse. This indicates that SBRR might not

always have a medium-term effect. However, if it does, the effect is more likely to be more harmful than positive. Moreover, Wooldridge's TFP estimator illustrated with Figure 7:5 (p. 197) showed that in the medium term, the general trend is towards the decrease in TFP caused by the SBRR as well as the dynamic TFP estimator found lagged SBRRs by three years (Table 7:6, p. 205) to be negatively related to GVA but insignificant.

It seems that the more companies that exist in the same industry and region, the higher competition for their premises would be expected. Those premises in competitive regions would be popular. Business owners would be likely to increase rents once the SBRR becomes available. However, in less competitive areas or/and sectors, recipients would be likely to continue receiving the reliefs because these would not be captured into higher rents. This explains why dynamic TFP estimator and Cox Regression could not identify significant uniform results for variables related to SBRR.

The speed and extent of these effects were likely to be dependent on the competition within the region and industry. The analysis identified several variables related to competition to be influential on how the company performs in all models. For instance, once the focus is on the LTCARD tree (reported in Section 7.3.2), two of the most influential variables found were HHI and regions. It captured competition effects nationwide with the HHI and within regions with region variable. Likewise, dynamic TFP estimator (reported in Section 7.2.3) and random forests (Table 7:5, p. 203) found competition indexes and regions to be the most influential.

The data indicates that those variables might include effects on how firms also behave once SBRR is granted for the premises in the medium term. The examples from unbiased REEM trees reiterate the same ideas that SBRR was negatively related to SBRR. For instance, Figure 7:9 (p. 202) refers to 6,088 observations from regional firms younger than 32 years which were operating in sectors other than catering, which were not awarded any relief two years prior and were situated in less diversified areas ($PD \leq 0.825$). The once lagged SBRR refers to the short-term effect. It separated those which were awarded higher than 70% SBRR a year prior. Those not awarded the relief of at least 70% were further divided according to region. North East, North West, Yorkshire and Humberside, East Midlands, South West, Wales and Scotland were grouped together and further separated according to the competition across industries. Only those with low concentration towards major players across sectors ($HHI \leq 0.008$) were split according to the relief lagged by two years. This implies that those which did not receive the relief two years ago, but did three years ago and were operating in some of the least concentrated

industries were 7% less productive than those that were not awarded the relief but had similar circumstances. The effect was not identified even for slightly more concentrated industries ($\text{HHI} > 0.008$), once again showing that the relief in competitive industries or regions was capitalised promptly with no added benefits to property owners.

To supplement these findings, it is worth recalling Hilber's (2017) reasoning on local supply constraints for commercial properties. He argued that they should depend on the degree of substitutability of locations, relocation costs and the preference of business owners. These seem to be important factors but they are difficult to measure especially with data from accounts. The data shows that competition between sectors and regions also influences the capitalisation process.

Furthermore, this thesis identified two effects that might be explained by the economic theory. One of them is continued distortion similar to that previously described in the short term. In the medium term, some firms would still pay initial rents and experience similar benefits of increased cash flow as in the short term. Thus, the positive effect on survival by recipients would mean that some non-recipients were disadvantaged by the relief because their immediate competitors could reduce their prices due to either introduced or enhanced relief. On the other hand, in more competitive sectors and/or areas, an adverse effect is likely to be experienced by the recipients owing to potential overcapitalisation of SBRR into property prices. The recipients would be hit by the increased rents which may push them to bankruptcy or relocation.

Duranton's *et al.* (2011) study possibly misidentified these medium-term effects to the long-term effects because of their shorter term of study. The opposite effect of SBRR than Duranton's *et al.* (2011) as the tax liability would be reduced instead of increasing tax burden as it was in the Duranton's *et al.* (2011) study. They found that higher taxes damage employment but cause more entrants at the same time. They argued that in their business environment (pre-1990s), higher taxes would influence more businesses to relocate or exit and, thus, ease the entry of other firms. This would cause new entrants to come into the market. Similarly, this thesis found that SBRR supported some firms in the short and medium terms as well as that supported firms had lower incentive to invest in their TFP than other firms. Duranton's *et al.* (2011) study was limited to the shorter period and was likely to have employment figures recorded only twice across that period. Therefore, it seems sensible that they captured the medium-term effects instead of the long-term effects as they were defined in our framework.

7.4.4 Long Term (H1c and H2c)

In the Framework (p. 79), it was reasonable to assume a perfectly competitive market with small moving costs in the long term results in no benefit of SBRR because firms would be changing locations, with demand of properties increasing until an equilibrium where SBRR is fully capitalised into rents. As a result of these assumptions, the hypotheses were directed towards little or no effects of SBRR on both survival and TFP in *the long term*.

The overall results support the hypotheses and confirm the perfectly competitive market. In Stratified Cox Proportionate Regression and dynamic TFP estimation, the further lags of SBRR were insignificant. The former presented some positive effects on survival and the latter suggested that the lagged SBRR might be likely to reduce TFP in the long term.

However, some adverse effect might be evident in firms that were not endorsed to invest in their processes to become more competitive in the previous periods. Some firms may be underperforming with regards to TFP as a result of SBRR. The tree identified three instances in Section 7.2.3 (p. 204), where higher SBRR lagged five times would consistently be linked with lower TFP. This variable was affecting more than one-third of all observations.

The findings are in line with the previous studies on capitalisation. In the Empirical Review, this thesis did not identify any studies related to both UK BRs and either TFP or survival, so only the findings on capitalisation can be broadly compared. The results support a wider message on capitalisation from such previous studies as Bond *et al.* (1996 and 2013) and Mehdi (2003), who identified full capitalisation in the long term. The relief has no significant positive effect in the longer term but may not be fully offset by the rents in the short term.

8 CONCLUSIONS

This chapter highlights how the aims of the thesis were achieved and how this thesis contributed to the existing empirical and theoretical knowledge. It gathered literature to build a theoretical model and employed sensitive datasets to increase our understanding of Small Business Rates Relief (SBRR) and its effects on firms, in particular with regards to their productivity and survival. These resulted in policy recommendations. Simultaneously, the thesis supplemented standard econometric techniques with advanced approaches from Computer Science that had previously not been employed in policy evaluation. This thesis defines total factor productivity (TFP) as the portion of output not explained by the amount of inputs used in production, whilst survival analysis in this setting is a method for analysing the expected duration of time until closure.

This chapter is divided into five sections and follows a similar flow to the thesis. Section 8.1 is devoted to the theoretical contribution to knowledge made in this thesis, showing how SBRR may cause firms to change once SBRR is either introduced or enhanced in the short, medium and long terms. Section 8.2 then describes the contribution to knowledge regarding methodology in the field. The restricted, but extensive datasets were used with not only some of the most advanced approaches in Econometrics, but also suitable techniques from Computer Science. The complex empirical findings presented in this thesis broadly confirmed the Framework, making a further contribution to empirical knowledge of commercial property reliefs discussed in Section 8.3. The chapter concludes with policy implications coming from the theoretical and empirical findings in Section 8.4 and avenues for future research in Section 8.5.

8.1 CONTRIBUTION TO THEORY

This thesis started by gathering theoretical and empirical literature on the tax incidence, capitalisation, property taxation and governmental intervention. This literature was then developed into a model to introduce a new understanding of the effect of SBRR. This was mainly achieved by updating the existing Duranton's *et al.* (2011) framework according to the newly discovered evidence from the literature.

The survey of the studies on SBRR identified few theoretical contributions directly linked to relief for firms occupying premises with lower rateable value. Thus, the thesis started with broader mechanisms on property taxation. The established literature on tax incidence and capitalisation to property prices directed the research to three views; old,

new and benefit. Out of these, most applicable to the current UK environment was the new view building on the general equilibrium mechanisms, implying, at least partial, capitalisation. This means that some part of the SBRR is likely to be handed to property owners through increased rents. This view was slightly more suitable for the more centralised UK environment.

The assumptions in these models were often slightly unsuitable for the UK environment as the vast majority of theories were shaped by US scholars. A further survey of the literature (Chapters 2 and 3) and insights into differences across countries (Chapter 1, Section 1.3) suggested that theories originating from abroad may not necessarily apply to the UK environment owing to differing tax systems, property markets and culture.

Thus, the thesis focused on developments from the three theoretical studies from the UK (Sections 2.1.2-2.1.5 in the Theory Review Chapter). Fraser (1984) was one of the first scholars providing a complete view of property economics in the UK. His theory provided an indication of how business rates are likely to change rents and ownership in short, medium and long terms. This thesis adopted those terms. Fraser's ideas were further extended by Duranton's *et al.* (2011) who quantified various scenarios with the aim of predicting possible effects by looking at either a negative or positive shock in demand. Both Fraser and Duranton *et al.* theories were made for the pre-1990s UK with decentralised taxation, meaning that their assumptions may not necessarily be valid for the post-1990s UK.

In addition, with a slightly similar perspective to that of the new view, Hilber (2017) suggested possible unintended consequences from property taxes. These were related to the distortions from the preferential taxation to some firms disadvantaging others. He also argued that there is no uniform capitalisation across the location, implying that SBRR may be beneficial for some areas but harmful for others,

As a result, the framework proposed in this thesis, adopted Fraser's short, medium and long terms and inspired by Duranton *et al.*, mimicked either a negative or positive shock in demand with different scenarios depending on the relief. Furthermore, in line with Hilber's theoretical argument on no uniform capitalisation, the framework controlled for capitalisation by employing indexes on the competition.

Furthermore, all empirical articles related to the non-domestic property taxation in the UK were reviewed systematically in the Empirical Review [Chapter](#). The empirical literature confirmed the importance of property tax incidence, implying that small businesses may not necessarily be receiving SBRR, especially in the shorter terms. The

previous literature on business rates mainly focused on capitalisation or qualitative cross-sectional policy evaluation and had only discussed employment. No studies have been found that investigate how non-domestic property taxation reliefs relate to either survival or productivity. From this limited existing literature, it was evident that at least some amount of capitalisation should be expected.

The gathered theoretical knowledge, supplemented by a systematic literature review of the business rates, resulted in the novel theoretical framework. It is novel because it reshaped the most sophisticated UK non-domestic property taxation framework to include SBRR and productivity and redefined assumptions for the framework to fit the post-1990s environment. Furthermore, the framework removed some of the unrealistic assumptions, such as uniform capitalisation. This theoretical framework suggested that capitalisation is likely to be different across properties, proposing to control for this with three competition indices. Firstly, overall market concentration suggesting whether monopolies are predominant in the industry was estimated with Herfindahl-Hirschman Index, market concentration in a particular region with Marshallian and local market diversification with Jacobian externalities. The proposed indexes accounted for the competition for similar premises, regionally and nationally and the extent of SBRR capitalisation into rents.

The modelling showed that exits are positively related to higher rents, and taxes are negatively related to reliefs. Some small firms may then survive a given negative shock, irrespective of productivity. If a firm survives a negative demand shock, it will reduce the used output from installed capacity, leading to lower productivity. The higher the fixed level of rent and taxes, the greater this decline as these costs absorb a greater proportion of turnover, increasing the salience of the tax, but reliefs would ameliorate the effect.

Once the positive shocks are considered, the reliefs may become an impediment to productivity gains, within existing supply constraints. In the decision between maintaining or increasing capacity at the current premises, the positive shock would need to be sufficient to cover the increased tax and loss of reliefs after revision of higher rateable values. Instead of enabling firms to overcome putative growth frictions, they could be less likely to invest, relative to the counterfactual of no reliefs. This would be in line with Duranton *et al.* (2011). Reliefs would also impede the decisions to relocate, relative to no relief, as the positive demand shock would need to be greater to induce firms receiving reliefs to change location and feasibly improve productivity.

In general, the static argument supporting the reliefs is that the higher relative cost of property taxes for small firms in their fixed costs (repeated in H.M. Treasury, 2016) disproportionately reduces profits and ability to invest. Givord *et al.* (2013) argue that small firms tend to be more financially constrained than larger firms and might be more responsive to tax incentives. However, Holtz-Eakin (2000) challenges this narrative, arguing studies that suggest finance restrictions limit small firms have not shown too few or the wrong firms are funded. The conclusions from this basic modelling show that the story is rather more nuanced than the arguments supporting the reliefs. Firms may be better placed to survive negative shocks, but they are also more likely to be less productive, with higher investment thresholds. Capitalisation will also reduce the putative negative effects of the property tax, but this could vary by the degree and type of competition for commercial space. That said, the statutory incidence on occupiers makes this a highly salient tax irrespective of economic incidence.

8.2 CONTRIBUTION TO METHOD

The theoretical modelling drew out some of the nuanced implications SBRR may have on survival and investment boundaries. It showed that the effects are likely to vary across businesses owing to the differences in SBRR capitalisation in rents. Firm characteristics are not solely additive, but interact such that the path along which any effects of the universal policy operate on survival or productivity is difficult to identify a priori.

These considerations, supplemented by a review of methodologies in the Methodology Review Chapter, led to the adoption of two recently developed decision tree algorithms (Section 8.2.1) supplemented by more standard estimators (Section 8.2.2). The contribution to the methodology also comes from using three sensitive rich data sources (Section 8.2.3).

8.2.1 Trees Not Used Previously in Policy Evaluation

The thesis borrowed some of the most recent methodologies from Computer Science and applied them with more common approaches. Although the thesis estimated total TFP by employing relatively standard Wooldridge (2009) one-step estimator, the novelty is its use of the estimated TFP as a dependent variable in the REEM and independent in ST and Cox Regression to illustrate how SBRR affected TFP and survival. The trees were chosen because they are more capable of identifying changing relationships across regions, sectors and other variables that were likely to have multiple interactions

with each other and be non-linear. The standard analysis and its assumptions were too sensitive for this analysis. The traditional empirical analyses would assume a constant relationship between these independent variables and productivity because they are based on point estimates that lead to a single value of a statistic. Furthermore, the REEM trees were chosen instead of other machine learning approaches like random forests because they can account for a longitudinal aspect of the data. ST algorithm was capable of accommodating left-truncated and right-censored longitudinal data.

8.2.2 Extensions to the Standard Approaches

The thesis employed two relatively standard approaches to estimate TFP. The first was Wooldridge's one step estimator, which provided a dependent variable to account for the effects of SBRR with REEM trees. The results were supplemented by TFP estimated with the dynamic estimator. Likewise, the Stratified Cox Regression was used to estimate survival. An innovative aspect within these two approaches is different matching and deflators.

To estimate the effects of SBRR, the thesis recreated the conditions of a social experiment by employing Coarsened Exact Matching (CEM) instead of more typically applied Propensity Score Matching (PSM). CEM does not use random pruning applied in PSM which was proven to increase the level of imbalance (King *et al.*, 2011 and 2016). This is likely to boost effects, but the matching controls for the impact of other observed and unobserved variables makes data less model dependent, biased and inefficient.

Furthermore, the majority of studies have used industry deflators to estimate firm-level prices. To control for omitted price bias (as defined by Van Beveren, 2010), instead of deflating with a GDP estimator as usual in the field, PSM was used to estimate the exact values for the specific firm's prices.

8.2.3 Large Sensitive Datasets

Moreover, the unique feature of this research project is its use of data sources that are extensive, but rarely employed because of security restrictions regarding access. None of the empirical studies discussed in the Empirical Review Chapter employed such extensive datasets. All coding and data analysis was performed in the Secured Lab managed by the UK Data Service. The analysis was based on the Office of National Statistics (ONS) Annual Respondents Database X (ARDx) first released in July 2016 combined with Business Structure Database (BSD) and Prices Survey Microdata (PSM). ARDx was combined with BSD to acquire annual observations of firms not included in the scope of ARDx in some years. This helped to estimate the competition indexes and fill missing observations in

ARDx. The BSD was an appropriate dataset to fill those gaps as it covers almost the entire UK business population. These datasets resulted in a sample of 1,092 firms over 17 years.

8.3 CONTRIBUTION TO EMPIRICAL EVIDENCE

The Results Chapter (Section 7.4) showed that the effects on both, survival and productivity, broadly follow the Framework. In the short term, firms which start receiving SBRR were less likely to relocate or close than non-recipients, but more likely to either sublet their premises, decrease employment or reduce their investment in TFP. The latter scenario was captured in the analysis with the reduction in TFP and might be regarded as one of the unintended consequences that, according to Hilber (2017), is likely to offset the favourable incentive effects of such policy measures as SBRR. Simultaneously, SBRR recipients received more cash flow, resulting in a higher probability of survival. The relief possibly discouraged firms from investing in their productivity as they were able to sustain the competitive advantage without investment and provided them with an incentive to stay in their current premises in the short term.

Thus, further than short term assistance of existing businesses which may still be struggling, this intervention does not contribute to improving the economy. In the short-term results, the recipients were less likely to invest in their TFP than non-recipients. Thus, as according to the theory with the standard neoclassical assumptions on competitive markets, the supported but possibly less efficient firms may take a share of possibly more efficient, but unsupported businesses. The resulting market (as shown in the Theory Review, Section 2.2.1.3) is where consumers still pay the same price, but the taxpayer's money is used for the relief, so the taxpayer pays more for the goods.

This effect might be even higher because SBRR is given to some firms with large turnover and/or employment. The thesis found that with regard to employment and turnover, medium and large sized firms were sometimes entitled to receive the relief. This new evidence on mistargeting is an important contribution, given that the few existing studies of SBRR (e.g. Peck *et al.*, 2014) isolated only intended recipients, (usually small firms), and failed to consider other businesses that were not supposed to be supported by the policy. Furthermore, even when only the smaller firms were considered, Peck *et al.* (2014) found that for some firms, SBRR was not useful and called for better targeting. The degree of mistargeting is much higher than Peck *et al.* (2014) discovered because, as this thesis showed, some larger businesses were also entitled to SBRR. Furthermore, given that

the data excluded all businesses that had more than one local unit, even more substantial mistargeting should be expected.

In the medium term, some firms would still pay initial rents and experience similar benefits of increased cash flow as in the short term. Thus, the positive effect on survival by recipients would mean that some non-recipients were hurt by the relief because their immediate competitors could reduce their prices due to either introduced or enhanced relief. On the other hand, in more competitive areas, the adverse effect is likely to be experienced by the recipients because of the possible overcapitalisation of SBRR into property prices. The recipients would be hit by the increased rents which may either push them to reduced investment in TFP, close or relocate.

Duranton's *et al.* (2011) study possibly misidentified these medium to long-term effects. The opposite effect should be present in this study because SBRR, as the tax liability, would be reduced instead of increasing the tax burden as highlighted in Duranton's *et al.* (2011) study. They found higher taxes hurt employment, but also relate to more entrants. They argued that in their business environment (pre-1990s), higher taxes would influence more businesses to relocate or exit and, thus, ease the entry of other firms. This would cause new entrants to come into the market. Similarly, this thesis found that SBRR supported some firms in the short and medium terms, as well as that supported firms had less of an incentive to invest in their TFP than other firms. Duranton's *et al.* (2011) study was limited to the shorter period and was likely to have employment figures recorded only twice across that period. Therefore, they were likely to capture the medium-term effects instead of the long-term effects.

However, the findings are in line with the other UK studies on capitalisation and tax breaks. This thesis did not identify any studies related to both UK business rates and either TFP or survival, but the results support the broader message on capitalisation from such previous studies as Bond *et al.* (1996 and 2013), who identified full capitalisation in the long term implying that taxation is offset by the inverse rent adjustments in the long term. In a similar vein, it supports other studies (e.g. Wyld *et al.*, 2010) showing that there is little evidence of a change in survivorship as a consequence of the introduction of tax breaks.

8.4 POLICY IMPLICATIONS

The thesis found that the substantial reductions in tax revenue totalling up to £9 billion over five years in England alone⁴⁸ results in only very marginal benefits in survival and no benefits to productivity. In fact, this study found that observations for firms with higher levels of lagged SBRR were consistently associated with lower levels of total factor productivity.

The Introduction and Background Chapter (Section 1.4.3, p. 27) started with the narrative underlying the policy of reductions (HM Treasury 2016b, 2017). This thesis could not find any support for those arguments. Results show that property tax reductions are unlikely to enable small firms to lead local growth through a reduction in financial constraints which were believed to disproportionately limit their ability to invest and innovate, relative to larger firms. This feeds off the wider narrative. For instance, the Chief Executive of Tesco (BBC, June 2018), the largest supermarket chain in the UK, linked closures of high-street shops to BR. In July 2018 The Financial Times reported naïve research with the title 'How UK Business Rates Shake-up is Deepening High Street Gloom' (Bounds, 2018). These comments echo the influential position of the Federation of Small Businesses that the tax is an expensive, unfair burden, discouraging growth and investment (FSB website, no date). Contrary to this narrative, this thesis does not find any indication that the relief may enhance productivity, support more productive firms or extend the life time of firms, especially in the longer term.

These findings are reported just as the UK government is gradually returning BR revenue to local control in England via devolution of powers or greater revenue retention. As approached in the Introduction and Background Chapter (Section 1.4.3, p. 27), powers have already been devolved to Scottish and Welsh national governments. These recent reductions are framed, on one side, by high profile concerns about ever-tighter funding for local authorities which will become increasingly dependent on local property taxes. On the other side, the strong perception from firms paying BR, i.e. commercial property taxes levied on business occupiers, is that the tax is an antiquated burden on entrepreneurial spirits. The pressures from firms have seen central governments incrementally move away from BR as a flat tax with the introduction of ever-deeper SBRR.

⁴⁸ The most recent extension to reductions from April 2017 and 2018 will further reduce tax revenue across England by £9 billion over five years and remove 600,000 firms from liability (HM Treasury, 2017).

However, it is worth noting that the thesis looked only at productivity and survival. Some may argue that SBRR may exist for the sake of enabling people to pursue independence, creativity, a family tradition or even an opportunity to adopt new ideas in the hope of founding the next growth firms. Others may suggest that there is a concentration of difficulty to employ people in these firms. These might be the real intentions and they might be legitimate, but only if business owners received the relief. Although the thesis did not model these explicitly, the results suggest that the relief is likely to be capitalised into rents, especially in the longer term, meaning that intended recipients would not receive any benefit.

Thus, the thesis reasons that there is little justification for the relief and its enhancement was likely to be more based on political rhetoric than evidence. This thesis supports Bergstrom (2000), who states that policy-makers may be focused too heavily on maximising political objectives rather than economic efficiency. This is because removing policies like SBRR might be very unpopular amongst voters. Although some politicians may know that SBRR is not benefiting small firms but rather property owners as the Northern Ireland Centre for Economic Policy uncovered in 2014. They are unlikely to act against these policies because of negative perceptions.

However, the government is investing in projects such as Making Tax Digital (2019) which should help to improve the relief by enabling the government to account for the key characteristics of businesses operating in particular premises and, thus, to reduce capitalisation. This is important because a relief of this nature should adhere to the clear principles set out in the broader consultation on the non-domestic rate review that has the stated aim with timescales. The relief should be targeted – for example, at specific sectors, ability to pay or economic growth. The need for reliefs should be more regularly evaluated, including assessments of whether they are achieving their desired purpose and impact.

Whilst region also plays a consistent defining role in grouping observations, this thesis finds interesting evidence from its use of competition indexes. This suggests nuanced and targeted policy on understanding accounting for local drivers and constraints could be more fruitful than the current generic firm-based policy. Regional differences consistently play a role in explaining TFP. There was no simple, consistent regional pattern, except for London, which has no relationship with SBRR. This region has a higher weighted average TFP, although only a small number of extreme firms cause this difference; most observations are in-line with the rest of the country. More interestingly, for approximately

one quarter of observations⁴⁹ greater Jacobian Diversity explains firm's higher productivity. The mainstream logic underlying the SBRR focuses on firm-level constraints and sees tax reductions as solutions, whereas the Jacobian argument is that urban areas facilitate innovation through their institutional organisation and attraction of economic actors (i.e. innovation) and as such is spatially orientated rather than firm orientated (Florida *et al.* 2017). The findings support this latter case, but not for all areas and as such this thesis would argue research and policy focused on diverse location factors rather than generic subsidies would prove to be a more fruitful means of targeting rate relief.

Conversely, the current market, with multiple support incentives, may only increase the churn of businesses, which is already higher in the UK than the average across OECD countries (as reported in the Introduction and Background Chapter, Section 1.2). This thesis highlights the need to look for alternatives. It broadly supports the dynamic capabilities theory (introduced in the Theory Review Chapter, Section 2.2.2.3) implying that the government should directly help firms to enhance their dynamic capabilities, for example, by supporting broadband or infrastructure projects instead of providing extra cashflow with SBRR which might be quickly capitalised into rents. Even if not capitalised, this direct capital through the relief can help to overcome liquidity constraints, but not increase dynamic capabilities because building and land are generic and not a source of dynamic capabilities. However, it may be a resource that businesses command - so dynamic capability may lead businesses to use their space better by enhancing productivity, for instance. Programmes such as innovation grant schemes may be more beneficial in this case, dependent upon how effectively businesses are using these incentives. In fact, even public subsidies to R&D were not found to trigger additional firm-financed spending greater than the subsidy itself (Dimos and Pugh, 2016). More specifically, in the context of micro firms, the primary focus probably should be on the decision maker, so a business owner. Thus, incentives to undergo management training would be an appropriate way to enhance dynamic capabilities within a small firm. Theoretically this may help small businesses to compete in national or even international markets.

8.5 LIMITATIONS AND AVENUES FOR FUTURE RESEARCH

This study was limited by several assumptions mainly imposed due to its use of secondary data. Ideally, another study with extensive primary data observing firms after

⁴⁹ This figure principally comes from combining end nodes for firms which are in the branch for observations of firms younger than 32 in Appendix 10.4.3 (p. 290). For more detail, see the Results Chapter (Section 7.2.2, p. 208).

further reforms in 2018, could be conducted. The primary study would not have limitations imposed in this thesis. It would not have to be limited by available variables and would not require imputation. It could then also include firms that have more than one local unit. Removing these limitations imposed due to the usage of secondary data could directly estimate capitalisation and impact on both, TFP and survival. This thesis supplemented the main models with other outputs in Appendices 10.4.4-10.4.6 which provided broadly consistent results. However, a further study with primary data could provide greater credibility and directly control for the effects discussed in Section 4.7.

More importantly, further research should directly quantify capitalisation because policy makers and firms seem unable to fully comprehend how capitalisation of the SBRR occurs. This makes challenging and changing policy difficult, and as such requires the support of considered research. If the research finds overwhelming capitalisation, governments would have the opportunity to raise awareness of this and reduce the salience of the tax and consequential political pressure by aligning the economic and statutory incidence of BR on property owners and removing the reliefs. If research finds this not to be the case and the least productive firms are simply absorbing the gains rather than innovating, again there would be a clear-cut case for removal of the reliefs. Both of these outcomes lead to the revocation of the policy, but without an evidence base, any policy change could prove to be politically complicated.

The theoretical evidence is also lacking. This thesis uncovered extensive theoretical arguments on property taxation and reliefs, but mainly focused on the US. The empirical evidence related to UK non-domestic taxation is relatively limited. To supplement the evidence from this study, a further study, possibly qualitative or even ethnographic, looking at several different firms over the change in the business rates between 2018 and 2021, could provide fruitful results and could potentially replicate Peck's *et al.* (2014) study to understand the perspective of the business owner a bit better. It could answer such questions as how the relief is experienced by business leaders and staff, what happens to the relief, and how landlords and property agents behave. A case study with ethnographic aspects could possibly be employed. Sensitive issues for management such as an increase in taxes, organisational difficulties, and accounting could be investigated with a personal touch. Flexible and opportunistic data collection methods could be employed to account for the extent of capitalisation. For instance, the phenomenon could be explored with the case study approach. but by collecting and writing up the project including for the existence of the researcher. This would support authors such as Richardson (1990:10) who states that the researchers "weigh and sift experiences, make choices regarding what is significant,

what is trivial, what to include, what to exclude ... we [researchers] craft narrative, we write lives.”

Additionally, methodological development should be further continued. Firstly, the thesis invites more interdisciplinary research projects. adopting approaches from different fields and applying them to policy evaluation. This would result in capturing more diverse interactions across variables and, thus, estimating more precise effects. This thesis employed pioneering trees to estimate the effects on TFP, which were measured with the control function approach. Future research may provide the whole mechanism that estimates TFP and draws trees in one step. Furthermore, the development of algorithms such as random forests, but including the longitudinal aspects of the data is required to facilitate the more complex understanding.

8.6 SUMMARY OF CONTRIBUTIONS

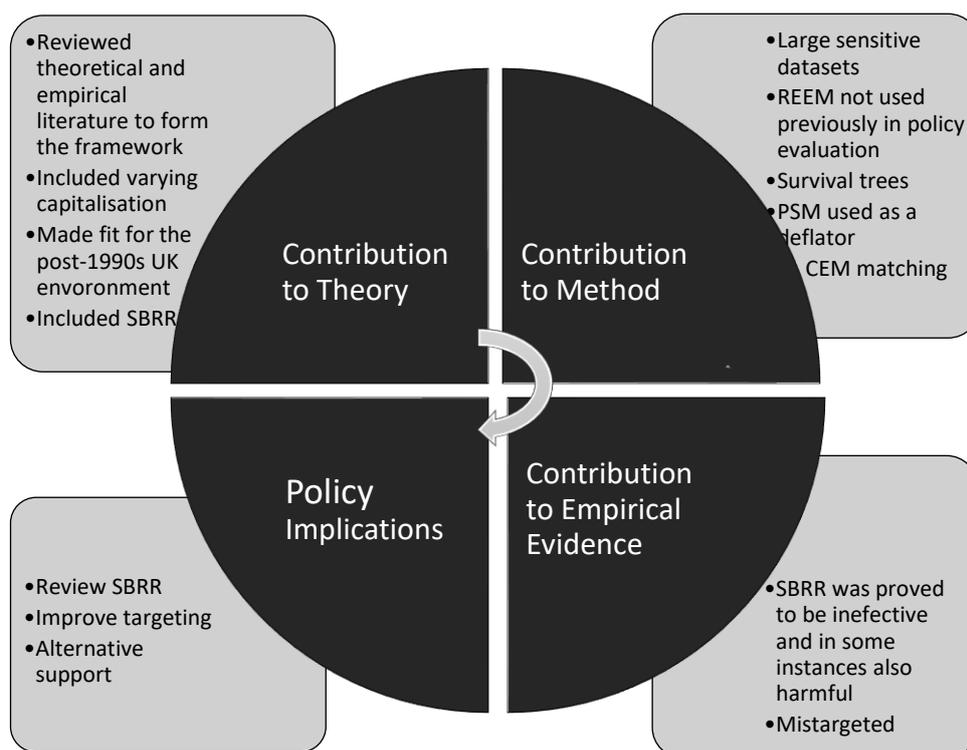


Figure 8:1 Overview of contribution to the knowledge of the thesis.

The key contributions of this thesis are summarised in Figure 8:1. The thesis reviewed fundamental literature on property taxation to form a theoretical framework, which includes varying capitalisation, is fit for the post-1990s UK environment and models effects of SBRR. To test those effects, the thesis employed large sensitive datasets. It used

this data not only with improved⁵⁰ standard econometric techniques, but also advanced approaches from Computer Science that were not previously employed in policy evaluation. This resulted in a contribution to empirical evidence and policy implications. The thesis did not find any evidence that SBRR is effective. Thus, together with other recommendations it invited to review SBRR and look for alternatives.

⁵⁰ Improved by CEM matching and more precise deflators.

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10 APPENDICES

10.1 APPENDICES TO INTRODUCTION

10.1.1 BR Bill

The BR bill as presented and explained by the Aberdeenshire Council (<https://www.aberdeenshire.gov.uk/business/business-rates/your-bill/>, 2018).

Aberdeenshire
COUNCIL  Finance

1 CUSTOMER

2 125 SYCAMORE ROW
FRASERBURGH
AB43 9AF

3 Date of Issue: 07-AUG-2007

4 Reference No: 110217X - 2000 **5**

6 Financial Year: 2000

7 Contact Tel No: 01345 519622



Business Rates Bill

8 The reason this bill has been issued is: Change to Liable Responsibility

The Breakdown of what you must pay is as follows:

	From	To	£
9 Charge for Period	10 25-AUG-2000	31-MAR-2001	600.03
Small business Relief 10%	25-AUG-2000	21-SEP-2000	-8.44
Small business Relief-20%	22-SEP-2000	31-DEC-2000	-35.88
Transitional relief			-25.00
11 Payments received as at date of issue			- 327.03
12 Transfers at Date of Issue			-144.82
13 Balance due			£ 119.86

14 INSTALMENTS TO BE PAID BY: CASH/CHEQUE

15 You should pay the above balance as follows:

ONE INSTALMENT DUE ON 31/08/2000 **16** 1 X 119.86

17 For Information Only

	£
Rateable Value	17000.00
Rate poundage	0.448
Adjusted Rate Poundage	
Annual charge	2450.00

18 This charge relates to

24, MARKETHILL ROAD
TURRIFF
AB53 4PD

Property No: 11863

No	Description
1.	The person(s) or company liable for payment of the bill
2.	Contact address – where the business rates bill will be issued
3.	Date, the business rates bill was issued
4.	Your business rates reference number - to help us deal with your query quickly, always quote this number when you contact us
5. & 6.	This is the financial year that your bill relates to
7.	Phoning us – if you have any questions about your bill, please phone this number
8.	The reason the business rates bill has been issued; for example, annual bill, duplicate bill, exemption, relief
9.	Charges for your bill and any reductions that have been awarded to your account
10.	This is the period the charges on this bill relates to
11.	Payments that have been made to this account up to the date the bill was issued
12.	Payments that have been transferred from other reference numbers or other financial years
13.	This shows the outstanding balance payable for this bill
14.	This is the current payment method of your bill
15.	Payment instalment dates
16.	This is the instalment value to be paid by each instalment date
17.	Please note this is the annual charge for this property based on the rateable value and rate poundage
18.	This is the subjects that the Business Rates bill relates to

10.1.2 Regions and Sectors

ONS also provides births and deaths by sector. Figure 10:1 (p. 265) offers a description of the data for 2010 and 2015. It seems evident that sectors deviate a lot. Manufacturing sector seems to deviate less than service sector. The most extreme case is business administration and support service sector which experienced many deaths (22.6%) in 2010 but also experienced the most births (20.4) in 2015. The only industries that did not have more deaths than births in 2010 were health, education, and information & communication industries.

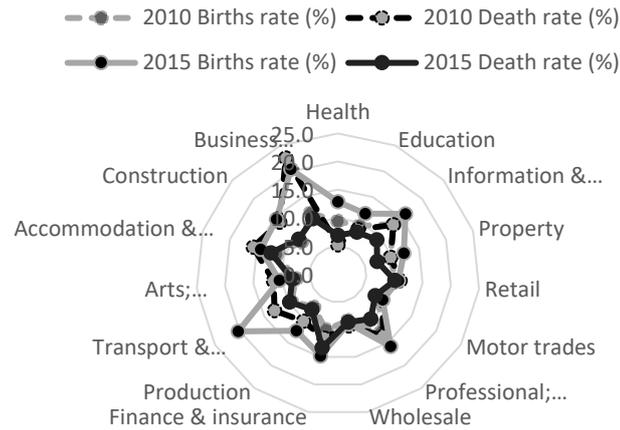


Figure 10:1 Business birth and death rates by sector, UK, 2015. Source: ONS (2010,2015).

On the other hand, Figure 10:2 (p. 265) shows that birth and death rates do not deviate much between regions. The two extreme cases are London and Northern Ireland. The former has the highest business birth rate at 18.6% and 13.1% and death rate at 10.5% and 15% in 2015 and 2010, respectively, while Northern Ireland had the least deaths and births in both years. Figure 10:2 further confirms that firms recovered after the post-recession period and the amount of births significantly exceeds deaths in all regions in 2015.

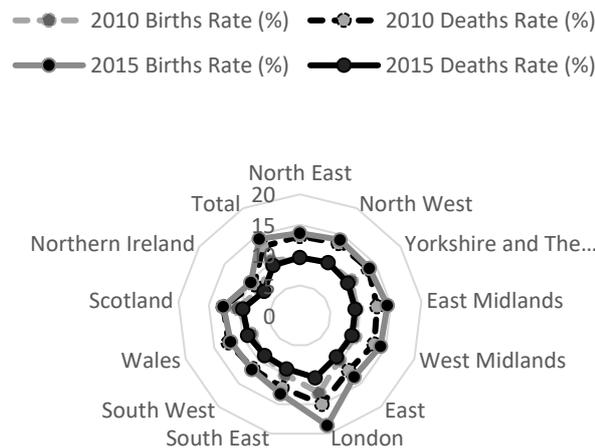


Figure 10:2 Business birth and death rates by region, UK, 2015. Source: ONS (2010,2015).

10.1.3 Other reliefs

The descriptions of other reliefs are adopted from the UK government website (<https://www.gov.uk/apply-for-business-rate-relief>).

10.1.3.1 Charitable Relief

Properties that are occupied by charities and mostly used for charitable purposes can claim a reduction of 80% in business rates, same as community amateur sports clubs. Billing authorities have the discretion to increase this to 100%.

10.1.3.2 Empty Buildings Relief

In general, empty commercial buildings are not taxed for three months.

10.1.3.3 Transitional Relief

Transitional relief limits how much BR bill can change each year as a result of revaluation. It is automatically applied by the local authorities in England.

10.1.3.4 Rural Rate Relief

Properties which are occupied by businesses in a rural area with a population below 3,000. 100% SBRR is also applied to the only village shop or post office, with RV of up to £8,500 and the only public house or petrol station, with RV of up to £12,500. Local councils in Wales can also give relief to other rural retail businesses of up to 100% (for properties with RV under £16,500). Rural Rate Relief takes precedence over Small Business Rate Relief, so it is possible for a property to attract a 50% mandatory discount under the former, in place of a 100% mandatory discount under the latter.

10.1.3.5 Discretionary (Hardship) Relief

Section 69 of the Localism Act 2011 provides a power for billing authorities in England and Wales to reduce the business rates of any local ratepayer. The Government has not issued guidance in respect of how this power might be used, though councils must ensure that the reliefs they allow do not transgress state aid rules.

10.1.3.6 Exempted Buildings

Agricultural land and buildings, including fish farms, buildings used for training or welfare of disabled people, buildings registered for public religious worship or church halls are exempt from business rates.

10.1.3.7 Relief for Pubs

Pubs in England with RV of less than £100,000 will receive £1,000 off their business rates bill. The relief will be applied from 1 April 2017 to 31 March 2018.

10.2 APPENDICES TO THEORY REVIEW

10.2.1 Fundamental Concepts Related to Business Rates

Figure 10:3 shows differences between progressive, proportional and regressive tax rate. A *progressive tax rate* would increase proportionately to the taxpayer's income. Probably the most widely discussed is *the ability to pay principle*, which is a progressive taxation principle that maintains that taxes should be levied according to a taxpayer's ability to pay. The opposite is a regressive tax, which would be decreasing proportionately to the taxpayer's income. A proportionate tax is in between regressive and progressive. A proportionate tax rate should be constant.

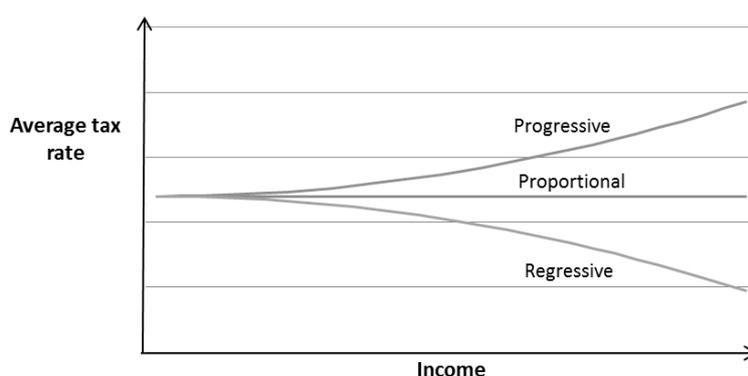


Figure 10:3 Progressive, proportional and regressive tax rate.

Horizontal equity is a theory claiming that individuals with similar income and assets should be taxed equally regardless of the tax system in place.

Administrative costs are indirect costs that an organisation incurs not directly tied to a particular function such as manufacturing, production or sales.

Land. Early economists such as Marshall (1890) treat land as a separate factor of production. Arguably, this changes once economy shifts from the agriculture to the service sector. Thus, these are reviewed very briefly. Mills (1972) summarises early urban land models, which includes Wingo's (1961) analysis around urban transport costs and rents and Alonso's (1964) general theory of land rent. The latter also considers commercial leases (for a more extensive summary see Mills, 1972). The first British study focusing on land is by Evans (1972 and 1973) who explains residential location decisions. All these models assume perfect competition and are based on Thunen's theory, which relies on many unrealistic assumptions such as homogeneity of producers and consumers (for the more extensive list, see Launhardt, 1983).

Perfect competition and efficiency. Evans (1995) summarises early literature on property market efficiency and perfect competition. He concludes that in the short-term property markets are not efficient, but in the long-term, they should be 90% efficient. Many models including Fraser's rental surplus model assume market perfection. On the other hand, other models may consider market being not perfect but either weak, semi-strong or strong (as introduced by Fama in 1970). This is a common trade of a market efficiency hypothesis (for an extensive review, see Brown, 1991:62-138).

Law of diminishing returns. This principle reasons that once one combines fixed factor (land) with other variable factors (e.g. buildings, crops), increments in output eventually decrease. Fraser (1984) illustrates this with an example of farmland and crops. He assumes that a fixed factor is a land and a variable element is a seed. The total output would increase with each seed. However, marginal product (a result of the use of each extra unit of seed) would be rising in the beginning but decreasing once the peak is reached. Then, Fraser, in hand with neoclassical economics, attempts to identify the optimal amount of land and capital (see Fraser, 1984:186-195). He focuses on the two main factors causing rent to be paid, profit potential and competition.

10.2.2 Econometric Techniques

10.2.2.1 Fixed Effects Estimator

To understand the empirical papers, the central estimation techniques are introduced in the following paragraphs. The introduction follows Mandaka and Lahiri's (2010) chapter 15. They provide an extensive discussion on econometrics for panel data analytics.

They start by defining *fixed effects estimator*, which is given by:

$$y_{it} = \alpha_i + \beta'x_{it} + u_{it} \quad \begin{matrix} i = 1, 2, \dots, N \\ t = 1, 2, \dots, T \end{matrix}$$

where y_{it} is the output and x_{it} is the vector of inputs for the i_{th} farm in the t_{th} period. α_i captures farm-specific inputs (e.g., managerial skills) and is assumed to be constant over time.

For the simplicity, it is assumed that $u_{it} \sim \text{IN}(0, \sigma^2)$ and there is just one explanatory variable. If group means are $\bar{x}_i = \frac{1}{T} \sum_t x_{it}$, $\bar{y}_i = \frac{1}{T} \sum_t y_{it}$, then within-group sums of squares and sums of products are

$$\begin{aligned} W_{xxi} &= \sum_t (x_{it} - \bar{x}_i)^2 \\ W_{xyi} &= \sum_t (x_{it} - \bar{x}_i)(y_{it} - \bar{y}_i) \\ W_{yyi} &= \sum_t (y_{it} - \bar{y}_i)^2 \end{aligned}$$

Let $W_{xx} = \sum_i W_{xxi}$ with W_{xy} and W_{yy} defined similarly.

The estimates of the parameters α_i and β are obtained by minimising $Q = \sum_{i,t} (y_{it} - \hat{\alpha}_i - \hat{\beta}x_{it})^2$ with respect to α_i and β .

We get

$$\begin{aligned} \frac{\partial Q}{\partial \hat{\alpha}_i} = 0 &\Rightarrow \sum_t (y_{it} - \hat{\alpha}_i - \hat{\beta}x_{it}) = 0 \\ \text{or } \hat{\alpha}_i &= \bar{y}_i - \hat{\beta}\bar{x}_i \\ \frac{\partial Q}{\partial \hat{\beta}} = 0 &\Rightarrow \sum_{i,t} x_{it} (y_{it} - \hat{\alpha}_i - \hat{\beta}x_{it}) = 0 \end{aligned}$$

Substituting the expression for $\hat{\alpha}_i$ in the second equation and simplifying we get

$$\hat{\beta} = W_{xy} / W_{xx}$$

The residual sum of squares is $W_{yy} - W_{xy}^2 / W_{xx}$. In the case of several explanatory variables, W_{xx} is a matrix and $\hat{\beta}$ and W_{xy} are vectors.

We get *within-group* estimator of β and α .

$$\begin{aligned} \hat{\alpha}_i &= \bar{y}_i - \hat{\beta}'\bar{x}_i \\ \hat{\beta} &= W_{xx}^{-1} W_{xy} \end{aligned}$$

10.2.2.2 Random Effects Estimator

If α_i 's are treated as random variables rather than fixed constants, then we should turn to the *random effects model*.

For simplicity, just one explanatory variable is used and it is further assumed that

$$\begin{aligned}\alpha_i &\sim \text{IID} (0, \sigma_\alpha^2) \\ u_{it} &\sim \text{IID} (0, \sigma_u^2)\end{aligned}$$

and that α_i and u_{it} are independent.

Since α_i are random, the errors now are $v_{it} = \alpha_i + u_{it}$. The presence of α_i produces a correlation among the errors of the same cross-section unit. The errors from the different cross-section units are independent. Thus we have:

$$\begin{aligned}\text{cov}(v_{it}, v_{is}) &= \sigma_u^2 + \sigma_\alpha^2 \quad \text{for } t = s \\ &= \sigma_\alpha^2 \quad \text{for } t \neq s \\ \text{cov}(v_{it}, v_{js}) &= 0 \quad \text{for all } t, s \text{ if } i \neq j\end{aligned}$$

Due to the correlation of errors, generalised least squares (GLS) estimator should be used to get efficient estimates. For simplicity, Maddala's (1971) simplified GLS is defined:

$$\hat{\beta}_{\text{GLS}} = \frac{W_{xy} + \theta B_{xy}}{W_{xx} + \theta B_{xx}} \quad \theta = \frac{\sigma_u^2}{\sigma_u^2 + T \sigma_\alpha^2},$$

where W refers to within-group, and B refers to between-group data, and

$$\begin{aligned}B_{xx} &= T_{xx} - W_{xx} \\ B_{xy} &= T_{xy} - W_{xy} \\ B_{yy} &= T_{yy} - W_{yy}\end{aligned}$$

where T refers to total (and W refers to within) sums of squares and sums of products defined earlier.

Note that $\hat{\beta}_{\text{OLS}} = T_{xy}/T_{xx}$ and $\hat{\beta}_{\text{LSDV}} = W_{xy}/W_{xx}$. Thus the OLS and LSDV estimators are special cases of the GLS estimator with $\theta = 1$ and $\theta = 0$, respectively.

Many studies have been published discussing which method is more appropriate for the estimators (Wallace and Hussain, 1969; Maddala and Mount, 1973; Mundlak, 1978). The most common way to access whether fixed or random effect estimator should be used

is Hausman test. The typical tests for serial correlation of u_{it} are either Durbin-Watson or Berenblut-Webb test.

10.2.2.3 Hausman Test

The Hausman test is often applied to tests for fixed versus random effects models. The Mundlak argument says that α_i are correlated with x_{it} but in a particular way. We can test the hypothesis

$$H_0 : \alpha_i \text{ are not correlated with } x_{it}$$

$$H_1 : \alpha_i \text{ are correlated with } x_{it}$$

Under H_0 , the GLS estimator is consistent and efficient. On the other hand, the within-group estimator $\hat{\beta}_w$ is consistent whether the null hypothesis is valid or not since all time-invariant effects are subtracted out. Thus, we can construct $q = \hat{\beta}_w - \hat{\beta}_{GLS}$ and $V(q) = V(\hat{\beta}_w) - V(\hat{\beta}_{GLS})$. Hence we use $m = \hat{q}'[\hat{V}(\hat{q})]^{-1}\hat{q}$ as a χ^2 -statistic with d.f. k where k is the dimensionality of β . Hausman (1977) also shows that this test can be more conveniently implemented by augmenting the λ -transformed GLS regression with $(x_{it} - \bar{x}_i)$,

$$\text{i.e., } y_{it} - \lambda \bar{y}_i = \alpha(1 - \lambda) + \beta'(x_{it} - \lambda \bar{x}_i) + \gamma'(x_{it} - \bar{x}_i) + v_{it}$$

and testing the statistical significance of γ corresponding to these additional demeaned variables.

10.2.2.4 Dynamic Panel Estimator

Note that $\alpha_i \sim \text{IN}(0, \sigma_\alpha^2)$ and $u_i \sim \text{IN}(0, \sigma_u^2)$ and α_i and u_{it} are independent.

Dynamic panel models are usually divided into two categories. The serial correlation model
$$\begin{aligned} y_{it} &= \beta x_{it} + \alpha_i + w_{it} \\ w_{it} &= \rho w_{i,t-1} + u_{it} \quad |\rho| < 1 \end{aligned}$$
 and state dependence model

$$y_{it} = \beta x_{it} + \gamma y_{i,t-1} + \alpha_i + u_{it}.$$

There are a few problems introduced by the inclusion of a lagged dependent variable in the model. Since y_{it} is a function of α_i , it immediately follows that $y_{i,t-1}$ is also a function of α . As a result, $y_{i,t-1} y_{i,t-1}$ is correlated with the error term. This makes the

OLS estimator biased and inconsistent even if the u_{it} are not serially correlated. For the fixed effects (FE) estimator, the within transformation wipes out α_i , but $y_{i,t-1} - \bar{y}_{i,t-1}$

where $\bar{y}_{i,t-1} = (1/(T-1)) \sum_{t=2}^T y_{i,t-1}$ $\bar{y}_{i,-1} = \sum_{t=2}^T \frac{y_{i,t-1}}{T-1}$ will still be correlated with $(u_{it} - \bar{u}_{i,-1})$ even if u_{it} is not serially correlated. The within estimator is biased and inconsistent.

The random effects GLS estimator is also biased in a dynamic panel data model because $(y_{i,t-1} - \lambda \bar{y}_{i,-1})$ correlates with $(u_{it} - \lambda \bar{u}_{i,-1})$. Anderson and Hsiao (1981) suggest first differencing the model to get rid of the α_i :

$$y_{it} - y_{i,t-1} = \beta(x_{it} - x_{i,t-1}) + \gamma(y_{i,t-1} - y_{i,t-2}) + (u_{it} - u_{i,t-1})$$

Then, using $\Delta y_{i,t-2} = y_{i,t-2} - y_{i,t-3}$ or $y_{i,t-2}$ as an instrument for $\Delta y_{i,t-1} = y_{i,t-1} - y_{i,t-2}$ $\Delta y_{i,t-1} = (y_{i,t-1} - y_{i,t-2})$. These instruments will not be correlated with $\Delta u_{it} = u_{it} - u_{i,t-1}$ $\Delta u_{it} = (u_{it} - u_{i,t-1})$, as long as the u_{it} themselves are not serially correlated. This *instrumental variable* (IV) estimation method does not make use of all the available moments conditions (instruments) and does not take into account the differenced structure on the residual disturbance Δu_{it} . In simple dynamic error components models, the estimator that uses differences $\Delta y_{i,t-2}$ rather than levels $y_{i,t-2}$ for instruments has a singularity problem and substantial variance over a significant range of parameter values. In contrast, the estimator that uses instruments in levels, i.e. $y_{i,t-2}$, has no singularities and much smaller variance.

Arellano and Bond (1991) proposed a *generalised method of moments* (GMM) procedure that is more efficient than the Anderson and Hsiao (1982) estimator. Rather than using only the instrument $y_{i,t-2}$ for all t , Arellano and Bond (1991) suggest using increasingly more number of lagged instruments as t approaches T . Thus, at $t=T$, the procedure uses $[y_2, y_3, \dots, y_{T-2}]$ as the instruments set. These and the successive models like Arellano–Bover and Blundell and Bond (ABBB) will be discussed in detail in the Research Design Chapter.

10.3 APPENDICES TO METHODOLOGY REVIEW

10.3.1 Productivity Functions

10.3.1.1 (Marginal) Labour Productivity

The output depends on which form of productivity function is assumed. There are several forms of production functions in standard economic theory. The more recent textbooks by Besanko *et al.* (2013) and Nicholson and Snyder (2011) have separated them into two: single input and multiple input functions. The most common examples of single input productivity are labour productivity (LP) and marginal labour productivity (MLP). The former is the average output per unit of labour. The latter is the rate at which total output changes as the firm changes its quantity of labour. These methods are being continuously used even in the recent studies (Vandenbergh *et al.*, 2013; Chatzimichael and Tzouvelekas, 2014; Nishida *et al.*, 2014) because of their simplicity:

$$LP = \frac{Y_{it}}{L_{it}}$$

$$MLP = \frac{\Delta Y}{\Delta L}, \quad MKP = \frac{\Delta Y}{\Delta K}$$

However, the simplicity comes with inherent limitations such as the lack of technological knowledge included in the analysis, unlike in the TFP.

Another important concept in productivity functions is the marginal rate of technological substitution of labour for capital (MRTS) which measures the rate at which labour can be substituted for capital while holding output constant along an isoquant. As described by Nicholson and Snyder (2011:299-300), the marginal rate of technical substitution of labour for capital is equal to the ratio of the marginal product of labour (MPL) to the marginal product of capital (MPK):

$$MRTS = \frac{MLP}{MKP}$$

10.3.1.2 Multiple inputs

In the clear majority of studies, multiple inputs were used to estimate productivity. Once two or more inputs are introduced, substitution and output effects could influence the form of the production function. An extensive discussion of these is presented in section 2.1.1.1.2 (p. 37). Shortly, the effect of a decrease in the price of capital on the amount of capital demanded where output, Y , would remain unchanged. This induces the firm to shift its input mix towards the capital, and away from labour. The elasticity of substitution

measures the proportionate change in capital/labour relative to the proportionate change in the MRTS along an isoquant:

$$ES = \frac{\% \Delta \left(\frac{\text{capital}}{\text{labour}} \right)}{\% \Delta (MLP/MKP)}$$

10.3.1.3 Linear form

$ES = \infty$. This form exhibits constant returns to scale for any $t > 1$:

$$Y_{it}(L, K) = \beta_L L + \beta_K K \rightarrow Y_{it}(tL, tK) = \beta_L tL + \beta_K tK = tY_{it}(L, K)$$

Therefore, all isoquants are parallel straight lines with slope $-\beta_L/\beta_K$. Because the MRTS is constant along any straightline isoquant, the denominator in the definition of ES is equal to 0 and hence ES is infinite. The obvious drawback of this productivity function is that labour and capital could be used as perfect substitutes, which is by no means reasonable.

10.3.1.4 Fixed proportions form

$ES=0$. Capital and labour must always be used in a fixed ratio. Because k/l is a constant, it is easy to see from the definition of the elasticity of substitution that σ must equal 0. The mathematical form of this function is:

$$Y_{it}(L, K) = \min(\beta_L L, \beta_K K) \rightarrow Y_{it}(tL, tK) = t * \min(\beta_L L, \beta_K K) = t * Y_{it}(L, K),$$

$a, b > 0,$

where the operator *min* means that q is given by the smaller of the two values in parentheses.

Again, increasing or decreasing returns can be easily incorporated into the functions by using a nonlinear transformation of this functional form for any $t > 1$.

This production function could be beneficial in some circumstances. For instance, factories with machines requiring a certain number of people to run them, but any excess labour is superfluous. However, in the vast majority of cases, it is not valid.

10.3.1.5 Constant elasticity of substitution (CES).

Arrow *et al.* (1961) introduced a function that that incorporates all of the three previous cases and allows SE to take on other values. For $p \leq 1, p \neq 0$ and $\gamma > 0$, this function is: $Y_{it}(L, K) = (K^p + L^p)^{\gamma/p}$

The inclusion of γ/p does allow to permit introduction of returns to scale. It could exhibit either increasing ($\gamma > 1$) or diminishing ($\gamma < 1$) returns. The direct application of the definition of SE to this function provides (see Besanko *et al.*, 2013):

$$SE = \frac{1}{1-p} \rightarrow p = \frac{SE-1}{SE}$$

This offers a way to estimate other p values: linear ($p = 1$), fixed-proportions ($p = -\infty$) and Cobb Douglas ($p=0$). That is why by assuming constant returns and $p = 0$, the CES function takes Cobb-Douglas form. The many-input CES function would take the following form:

$$Y = [\sum \beta_i x_i^p]^{1/p}, p \leq 1$$

Similarly, the function has either constant (for $\gamma = 1$) or increasing (for $\gamma > 1$) returns to scale. $p \leq 1$ that is why function exhibits diminishing marginal productivities for each input. Elasticity of substitution stays unchanged.

Furthermore, nested functions that use a CES aggregator to contract a composite for related variables that have different rates of substitution has been used. For instance, assuming that two variables (x_1 and x_2) are closely related. They can be expressed with CES function framework and then included in Cobb Douglas function:

$$x_4 = [\gamma x_1^p + (1 - \gamma)x_2^p]^{1/p} \rightarrow y = x_3^{\beta_3} x_4^{\beta_4}$$

10.3.1.6 Stochastic frontier analysis with Cobb-Douglas productivity function

Aigner *et al.* (1977) and Meeusen and Broeck (1977) have started gathering ideas around the stochastic production frontier models. The production frontier model with random component $\exp(v_i)$, which is a stochastic component that describes random shocks affecting the production process, can be written as:

$$Y_{it} = f(x_i, \beta) TE_i \exp(v_i)$$

,where y is output, x is a vector of inputs used, $f(\cdot)$ is a production frontier, β is a vector of technology parameters and TE denotes the technical efficiency and is also a stochastic variable, with a specific distribution function, common to all producers.

Assuming that TE is also a stochastic variable, so $TE = \exp(-u)$ and that $f(\cdot)$ takes the log-linear Cobb-Douglas form, the model can be written as:

$$\ln Y = \beta_0 + \sum_{i=1}^n \beta_i \ln x_i + v_i - u_i$$

10.4.2 Decision Trees with SBRR as a Dependent Variable

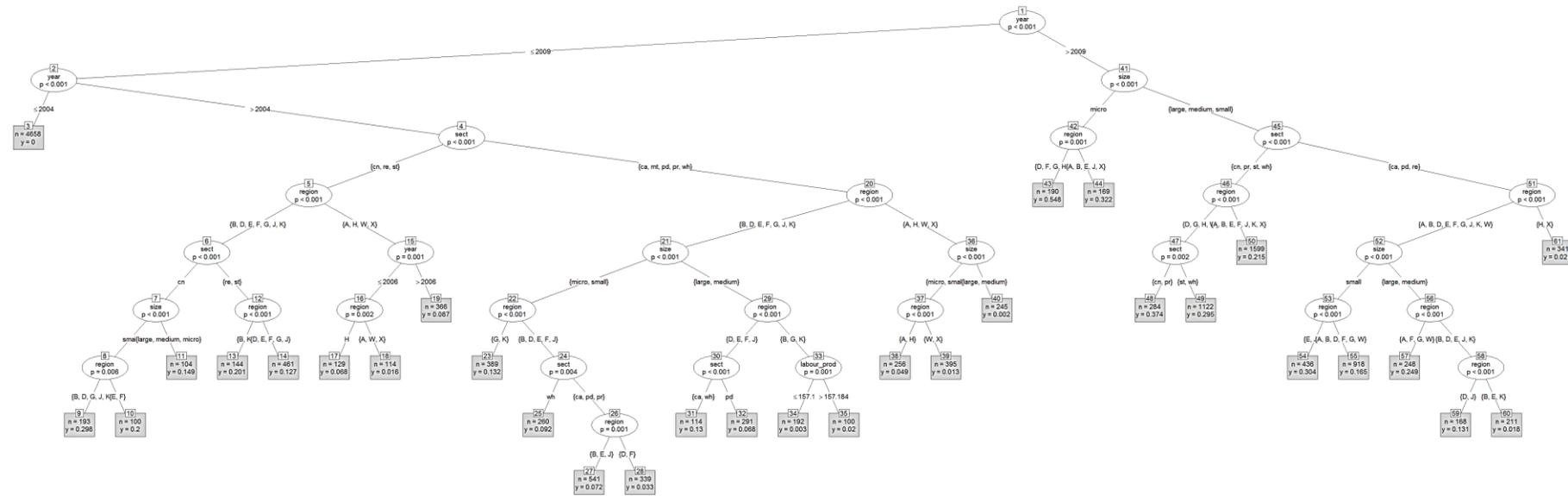


Figure 10:6 Decision tree indicating how SBRR can be predicted with employment, turnover, sector, region and labour productivity. Region and sector annotations are present in Figure 7:3 (p. 193).

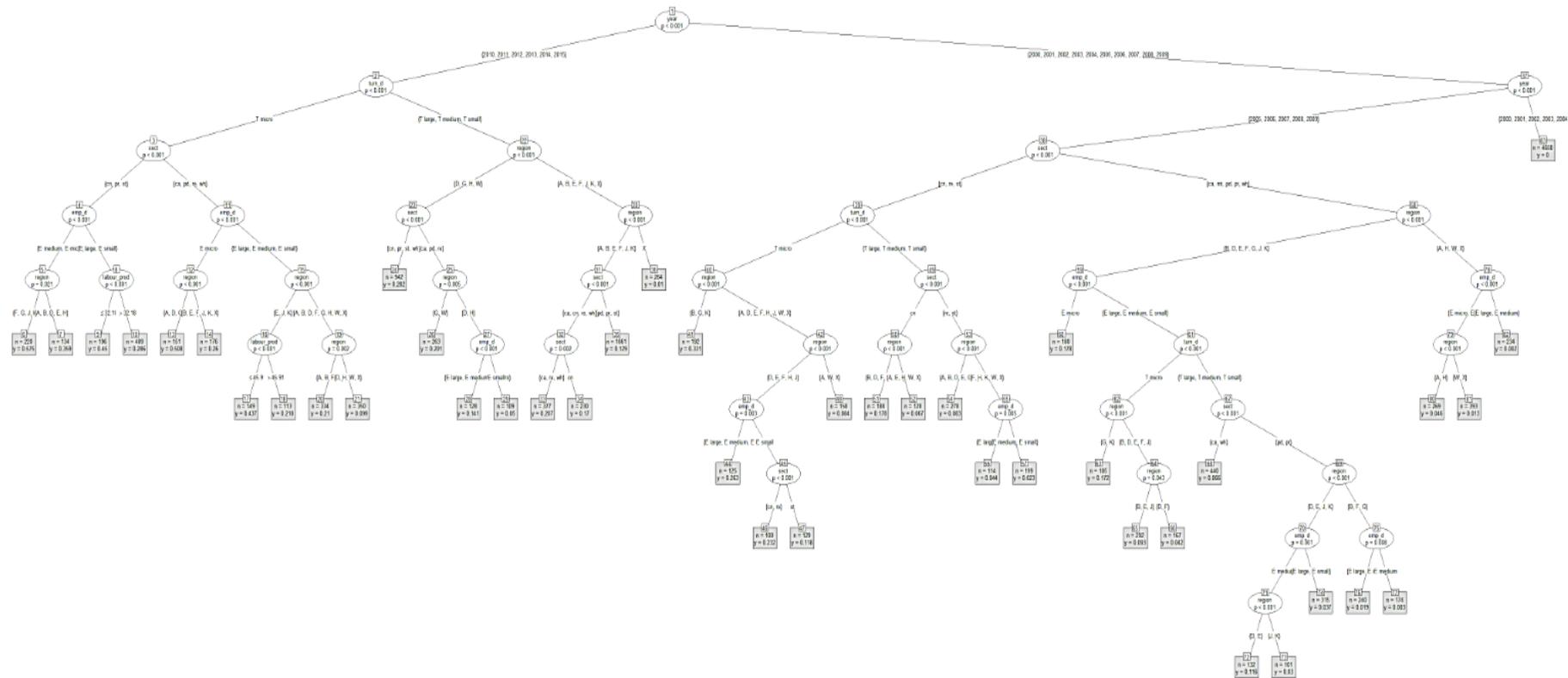


Figure 10:7 An extension of Figure 10:6 (p. 278) but by separating turnover (*T* in the graph) and employment (*E* in the graph). Region and sector annotations are present in Figure 7:3 (p. 193).

10.4.3 Main REEM Tree

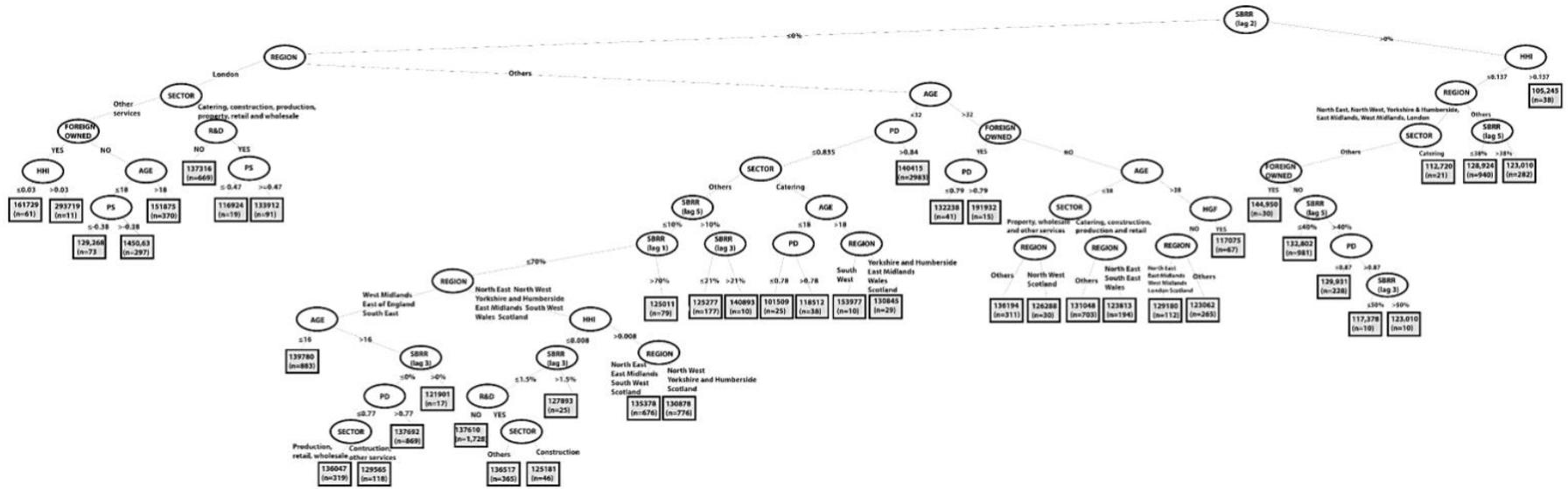


Figure 10:8 Unbiased REEM Tree indicating how other factors might influence TFP.

10.4.4 Sensitivity Analysis (Dynamic TFP)

Variable name	Matched and imputed data (one sample)												Unmatched and unimputed		
	Twoways, onestep			Oneway, one step			Twoways, two steps			Twoways, onestep			Twoways, one step		
	Estimate	SE	P	Estimate	SE	p	Estimate	SE	P	Estimate	SE	Pr(> z)	Estimate	SE	P
V2	0.236	0.158	0.13	0.500	0.252	0.05	0.239	0.158	0.13	-0.197	0.052	<0.01	0.593	0.059	0.00
GVA (defl & 1st lag)	0.020	0.025	0.41	0.001	0.041	0.99	0.015	0.021	0.47	-0.027	0.029	0.35	0.093	0.022	0.00
Employment (log)	-0.006	0.020	0.75	-0.155	0.100	0.12	-0.013	0.019	0.51	-0.020	0.021	0.34	-0.006	0.015	0.68
Employment (log & 1st lag)	0.003	0.001	0.01	-0.004	0.003	0.22	0.002	0.001	0.10	-0.006	0.006	0.36	0.001	0.002	0.44
SBRR (log)	-0.003	0.001	0.01	-0.001	0.001	0.34	-0.002	0.001	0.07	0.008	0.009	0.35	0.004	0.001	0.00
SBRR (log & 1st lag)	-0.001	0.000	0.08	-0.001	0.001	0.04	-0.001	0.000	0.12	0.001	0.001	0.59	0.000	0.002	0.80
SBRR (log & 2nd lag)	0.000	0.001	0.76	-0.002	0.001	0.17	0.000	0.000	0.87	0.001	0.001	0.54	0.000	0.002	0.81
SBRR (log & 3rd lag)	-0.001	0.001	0.21	-0.003	0.002	0.10	-0.001	0.001	0.20	0.000	0.001	0.60	0.003	0.002	0.05
SBRR (log & 4th lag)	0.307	0.015	0.05	0.256	0.322	0.43	0.151	0.154	0.33	-0.248	0.241	0.30	-1.296	0.780	0.10
Capital (defl & log)	-0.059	0.136	0.66	0.870	0.466	0.06	0.079	0.161	0.62	0.309	0.277	0.26	2.332	0.797	0.00
Capital (defl, log & 1st lag)	-0.027	0.012	0.03	0.129	0.180	0.47	-0.026	0.012	0.02	-0.054	0.055	0.32	-0.982	0.582	0.09
Investment (defl, log & 1st lag)	-0.092	0.030	0.00	0.015	0.038	0.69	-0.051	0.023	0.02	0.199	0.210	0.34	0.025	0.031	0.41
SBRR_F dummy	0.018	0.020	0.38	0.236	0.135	0.08	0.024	0.021	0.25	-0.007	0.007	0.30	-0.031	0.009	0.00
HGF dummy	-0.001	0.008	0.93	0.005	0.015	0.72	-0.002	0.005	0.66	Insufficient			Insufficient		
R&D dummy	-0.004	0.009	0.67	0.030	0.024	0.22	0.000	0.008	0.97	0.094	0.091	0.30	Insufficient		
Endland dummy	-0.002	0.027	0.94	-0.014	0.061	0.82	-0.015	0.036	0.68	0.038	0.019	0.04	0.087	0.036	0.02
PD (log)	0.023	0.015	0.12	0.033	0.025	0.18	0.017	0.010	0.11	0.004	0.008	0.58	-0.020	0.008	0.01
PS (log)	0.012	0.011	0.28	0.123	0.071	0.08	0.013	0.013	0.29	-0.060	0.063	0.34	-0.009	0.008	0.25
Age (log)	0.002	0.004	0.64	-0.016	0.011	0.12	0.000	0.003	0.91	-0.015	0.012	0.20	0.001	0.003	0.70
Her Index (log)	-0.055	0.027	0.04	-0.086	0.051	0.09	-0.035	0.022	0.10	0.252	0.235	0.28	0.000	0.008	0.97
Materials (defl & log)	0.000	0.000	0.10	0.003	0.003	0.37	-0.003	0.006	0.63	0.000	0.000	0.16	0.000	0.000	0.27

Table 10:1 Sensitivity analysis (Dynamic TFP) - various specifications of model; number of observations used and various tests are reported in Table 10:2 (p. 282);

	Matched and imputed data				Unmatched and unimputed
	Two ways, onestep	One way, one step	Two ways, two steps	Two ways, one step but diff in diff transformation	Two ways, one step
Lags used	2 to 8	2 to 8	2 to 5	2 to 8	2 to 8
Sample	n = 1091, T = 2-16, N = 15040	n = 1091, T = 2-16, N = 15040	n = 1091, T = 2-16, N = 15040	n = 1091, T = 2-16, N = 15040	n = 7786, T = 1-15, N = 32267
Number of Observations	19841	19841	19841	9380	7885
Sargan test	chisq(621) = 667.6319 (p-value = 0.1)	chisq(670) = 691.0494 (p-value = 0.28)	chisq(432) = 414.1932 (p-value = 0.72)	chisq(421) = 653.2655 (p-value = 0.01)	chisq(406) = 442.3601 (p-value = 0.1)
Autocorrelation test (1)	-0.99 p=0.32	-1.05 p=0.3	-0.62 p=0.53	-1.13 p=0.26	-5.75 p=<0.01
Autocorrelation test (2)	0.73 p=0.47	0.9 p=0.37	0.36 p=0.72	-1.03 p=0.3	-1.63 p=0.1
Wald test	chisq(21) = 240.8072 (p = < 0.01)	chisq(21) = 3390634 (p= < 0.01)	chisq(21) = 134.4476 (p = < 0.01)	chisq(20) = 445.7199 (p-value = < 0.01)	chisq(19) = 409.1293 (p-value = < 0.01)
Wald test (time dummies)	chisq(11) = 201.4404 (p= < 0.01)		chisq(11) = 157.5674 (p-value = < 0.01)	chisq(11) = 198.8505 (p-value = < 0.01)	chisq(10) = 142.845 (p-value = < 0.01)

Table 10:2 Sensitivity analysis (Dynamic TFP) - characteristics and tests of models.

10.4.5 Sensitivity Analysis (Cox Regression)

Variable	One sample			Matching, no imputation			No Matching, no imputation		
	Estimate	SE (r)	Pr(> z)	Estimate	SE (r)	Pr(> z)	Estimate	SE (r)	Pr(> z)
TFP	0.00001	0	0.08*	0	0	0.35	0	0	0.21
SBRR	-1.055	0.649	0.1*	-1.012	0.952	0.29	-0.895	0.418	0.03**
SBRR (1st lag)	0.398	0.551	0.47	-0.407	1.197	0.73	0.076	0.457	0.87
SBRR (2nd lag)	-0.049	0.531	0.93	0.665	1.22	0.59	0.172	0.488	0.72
SBRR (3rd lag)	0.428	0.522	0.41	0.071	1.462	0.96	0.223	0.517	0.67
SBRR (4th lag)	0.284	0.549	0.61	-3.574	4.145	0.39	-1.734	1.156	0.13
SBRR (5th lag)	-0.57	0.566	0.31	3.75	3.607	0.3	-1.254	1.529	0.41
Age dummy -2	0.157	1.114	0.89	0.046	0.883	0.96	1.865	0.725	0.01***
Age dummy -3	0.56	1.076	0.6*	-0.278	0.797	0.73	1.757	0.719	0.01***
PD	0.336	1.015	0.74	1.689	1.691	0.32	0.322	0.58	0.58
PS	0.139	0.193	0.47	0.511	0.336	0.13	0.035	0.091	0.7
HHI	-0.146	1.669	0.93	-1.232	2.367	0.6	-1.692	1.079	0.12
Im. Foreign Ownership	0.977	0.24	0***	1.168	0.413	0***	0.505	0.111	0***
R&D	-0.391	0.17	0.02**	-0.423	0.285	0.14	-0.196	0.08	0.01***
HGF	-0.15	0.145	0.3	-0.397	0.248	0.11	-0.066	0.079	0.4
SBRR (first introduced)	-14.891	1.108	0***	-15.593	1.219	0***	-13.744	0.258	0***
SBRR (first enhanced)	-14.525	0.86	0***	-15.822	1.206	0***	0.103	0.545	0.85

Table 10:3 Sensitivity analysis (Cox Regression), tests and the sample size is reported in Table 10:4 (p. 284).

	One sample	Matching, no imputation	No Matching, no imputation
Concordance	0.605 (SE=0.099)	0.685 (SE=0.166)	0.576 (SE=0.049)
	0.003	0.005	0.002
R square	(max=0.092)	(max=0.063)	(max=0.167)
Likelihood ratio test	39.22 (df=17, p=0.002)	29.53 (df=17, p=0.030)	79.25 (df=17, p<0.001)
Wald test	961.7 (df=17, p=0)	843.5 (df=17, p=0)	4109 (df=17, p=0)
Score (logrank) test	44.62 (df=17, p<0.001)	32.08 (df=17, p=0.01)	68.78 (df=17, p<0.001)
Robust	31.62 (p=0.02)	25.34 (p=0.087)	88.05 (p<0.001)
Sample	14926	5917	39294

Table 10:4 Sensitivity analysis (Cox Regression) - characteristics and tests of models

10.4.5.1.1 *Influential Observations and Nonlinearity*

To find the most influential observations, the index plots were made. Comparing the magnitudes of the largest dfbeta values to the regression coefficients suggested that none of the observations is influential individually, even though some of the dfbeta values were more extreme compared to the others. The graphs were not reported because of the disclosure controls.

Nonlinearity—that is, an incorrectly specified functional form in the parametric part of the model—is a potential problem in Cox Regression as it is in linear and generalised linear models. The martingale residuals were plotted against covariates to detect nonlinearity. The graphs were not reported because of the disclosure controls.

10.4.6 Sensitivity Analysis (Survival Tree)

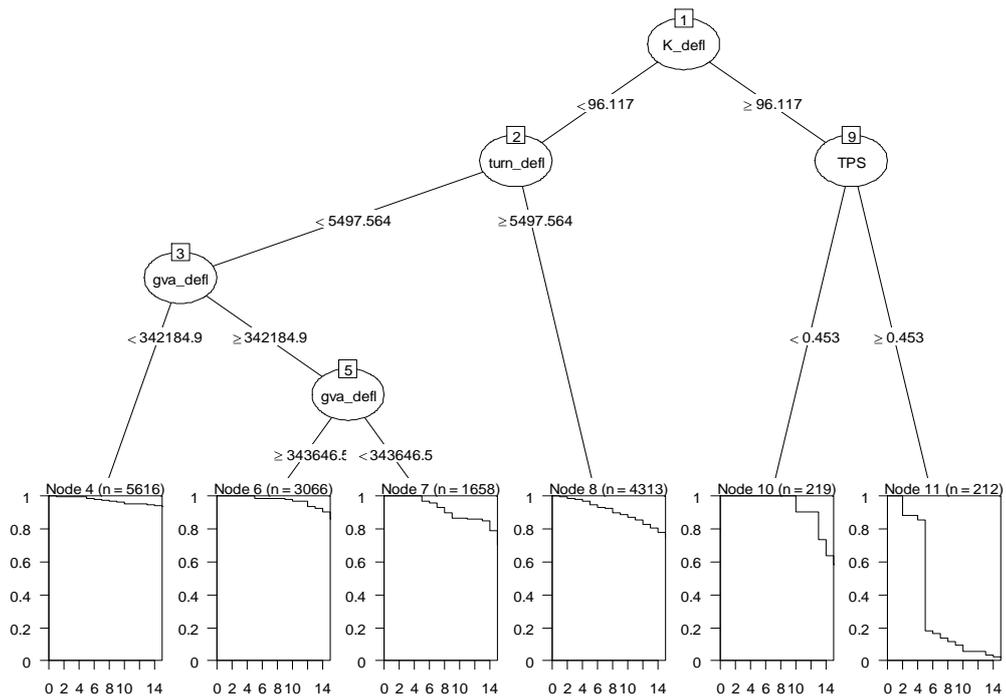


Figure 10:9 Survival tree with turnover ($turn_defl$), capital (K_defl), employment and GVA (gva_defl) included instead of the estimated TFP as it was done in the main tree available in Figure 7:10 (p. 210).

10.4.7 Decision Tree from Section 7.1.2.1 (p. 194)

- 1) year == {2010, 2011, 2012, 2013, 2014, 2015}; criterion = 1, statistic = 2081.797
- 2) turn_d == {T micro}; criterion = 1, statistic = 194.633
- 3) sect == {cn, pr, st}; criterion = 1, statistic = 96.075
- 4) emp_d == {E medium, E micro}; criterion = 1, statistic = 43.843
- 5) region == {F, G, J, K, W, X}; criterion = 0.979, statistic = 26.179
- 6)* weights = 220
- 5) region == {A, B, D, E, H}
- 7)* weights = 134
- 4) emp_d == {E large, E small}
- 8) labour_prod <= 32.18035; criterion = 1, statistic = 16.367
- 9)* weights = 196
- 8) labour_prod > 32.18035
- 10)* weights = 489
- 3) sect == {ca, pd, re, wh}
- 11) emp_d == {E micro}; criterion = 1, statistic = 62.56
- 12) region == {A, D, G, H, W}; criterion = 1, statistic = 37.284
- 13)* weights = 151
- 12) region == {B, E, F, J, K, X}
- 14)* weights = 176
- 11) emp_d == {E large, E medium, E small}
- 15) region == {E, J, K}; criterion = 1, statistic = 92.4
- 16) labour_prod <= 45.91013; criterion = 0.999, statistic = 14.175
- 17)* weights = 149
- 16) labour_prod > 45.91013
- 18)* weights = 113
- 15) region == {A, B, D, F, G, H, W, X}
- 19) region == {A, B, F, G}; criterion = 0.998, statistic = 27.642
- 20)* weights = 334
- 19) region == {D, H, W, X}
- 21)* weights = 350
- 2) turn_d == {T large, T medium, T small}
- 22) region == {D, G, H, W}; criterion = 1, statistic = 120.316
- 23) sect == {cn, pr, st, wh}; criterion = 1, statistic = 39.726
- 24)* weights = 942
- 23) sect == {ca, pd, re}
- 25) region == {G, W}; criterion = 0.995, statistic = 16.469
- 26)* weights = 263
- 25) region == {D, H}
- 27) emp_d == {E large, E medium, E micro}; criterion = 0.999, statistic = 20.253
- 28)* weights = 128
- 27) emp_d == {E small}
- 29)* weights = 109
- 22) region == {A, B, E, F, J, K, X}
- 30) region == {A, B, E, F, J, K}; criterion = 1, statistic = 52.043
- 31) sect == {ca, cn, re, wh}; criterion = 1, statistic = 41.206

- 32) sect == {ca, re, wh}; criterion = 0.998, statistic = 18.246
- 33)* weights = 377
- 32) sect == {cn}
- 34)* weights = 230
- 31) sect == {pd, pr, st}
- 35)* weights = 1061
- 30) region == {X}
- 36)* weights = 264
- 1) year == {2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009}
- 37) year == {2005, 2006, 2007, 2008, 2009}; criterion = 1, statistic = 1147.848
- 38) sect == {cn, re, st}; criterion = 1, statistic = 348.716
- 39) turn_d == {T micro}; criterion = 1, statistic = 200.481
- 40) region == {B, G, K}; criterion = 1, statistic = 125.961
- 41)* weights = 192
- 40) region == {A, D, E, F, H, J, W, X}
- 42) region == {D, E, F, H, J}; criterion = 1, statistic = 42.325
- 43) emp_d == {E large, E medium, E micro}; criterion = 0.997, statistic = 17.779
- 44)* weights = 125
- 43) emp_d == {E small}
- 45) sect == {cn, re}; criterion = 1, statistic = 19.303
- 46)* weights = 100
- 45) sect == {st}
- 47)* weights = 129
- 42) region == {A, W, X}
- 48)* weights = 158
- 39) turn_d == {T large, T medium, T small}
- 49) sect == {cn}; criterion = 1, statistic = 55.491
- 50) region == {B, D, F, G, J, K}; criterion = 1, statistic = 41.329
- 51)* weights = 188
- 50) region == {A, E, H, W, X}
- 52)* weights = 128
- 49) sect == {re, st}
- 53) region == {A, B, D, E, G, J}; criterion = 0.999, statistic = 34.807
- 54)* weights = 278
- 53) region == {F, H, K, W, X}
- 55) emp_d == {E large, E micro}; criterion = 0.995, statistic = 16.715
- 56)* weights = 114
- 55) emp_d == {E medium, E small}
- 57)* weights = 199
- 38) sect == {ca, mt, pd, pr, wh}
- 58) region == {B, D, E, F, G, J, K}; criterion = 1, statistic = 140.955
- 59) emp_d == {E micro}; criterion = 1, statistic = 111.128
- 60)* weights = 180
- 59) emp_d == {E large, E medium, E small}
- 61) turn_d == {T micro}; criterion = 1, statistic = 71.079
- 62) region == {G, K}; criterion = 1, statistic = 80.87

```

63)* weights = 185
62) region == {B, D, E, F, J}
64) region == {B, E, J}; criterion = 0.957, statistic = 14.022
65)* weights = 292
64) region == {D, F}
66)* weights = 167
61) turn_d == {T large, T medium, T small}
67) sect == {ca, wh}; criterion = 1, statistic = 48.073
68)* weights = 440
67) sect == {pd, pr}
69) region == {D, E, J, K}; criterion = 1, statistic = 41.233
70) emp_d == {E medium}; criterion = 0.999, statistic = 16.741
71) region == {D, E}; criterion = 1, statistic = 23.321
72)* weights = 132
71) region == {J, K}
73)* weights = 101
70) emp_d == {E large, E small}
74)* weights = 315
69) region == {B, F, G}
75) emp_d == {E large, E small}; criterion = 0.992, statistic = 13.246
76)* weights = 240
75) emp_d == {E medium}
77)* weights = 174
58) region == {A, H, W, X}
78) emp_d == {E micro, E small}; criterion = 1, statistic = 27.132
79) region == {A, H}; criterion = 1, statistic = 25.179
80)* weights = 269
79) region == {W, X}
81)* weights = 393
78) emp_d == {E large, E medium}
82)* weights = 234
37) year == {2000, 2001, 2002, 2003, 2004}
83)* weights = 4658

```

10.4.8 Ranger Output from Section 7.1.2.1 (p. 194)

```

Type:                Regression
Number of trees:     500
Sample size:         15077
Number of independent variables: 6
Mtry:                2
Target node size:    5
Variable importance mode: permutation
OOB prediction error (MSE): 0.04512334
R squared (OOB):     0.3501332
> importance(r_fit)

```

emp_d	turn_d	labour_prod	year	sect	region
0.012859	0.018546	0.023243	0.031834	0.01471253	0.0136837

Prediction error full dataset

0.140831

Prediction error when just 75% of the data is used and then tested on 25%

[1] 30.89183

10.4.9 Unbiased REEM form Section 7.2.2 (p. 198)

Response: AdjustedTarget

Inputs: SBRR, SBRR_lagged2, SBRR_lagged3, SBRR_lagged4, SBRR_lagged5, SBRR_lagged,

Ther_i, region, SBRR_f, HGF, age, ult_foc_d, imm_foc_d, TPS, jacob, rd, sect

Number of observations: 15042

- 1) SBRR_lagged2 <= 0.002713661; criterion = 1, statistic = 121.197
- 2) region == {H}; criterion = 1, statistic = 85.308
- 3) sect == {st}; criterion = 1, statistic = 119.12
- 4) ult_foc_d == {1}; criterion = 1, statistic = 83.268
- 5) Ther_i <= 0.02676917; criterion = 1, statistic = 42.963
- 6)* weights = 61
- 5) Ther_i > 0.02676917
- 7)* weights = 11
- 4) ult_foc_d == {0}
- 8) age <= 18; criterion = 0.999, statistic = 15.557
- 9) TPS <= -0.3825368; criterion = 1, statistic = 18.073
- 10)* weights = 73
- 9) TPS > -0.3825368
- 11)* weights = 297
- 8) age > 18
- 12)* weights = 370
- 3) sect == {ca, cn, pd, pr, re, wh}
- 13) rd == {0}; criterion = 1, statistic = 20.025
- 14)* weights = 669
- 13) rd == {1}
- 15) TPS <= -0.4742959; criterion = 1, statistic = 25.604
- 16)* weights = 19
- 15) TPS > -0.4742959
- 17)* weights = 91
- 2) region == {A, B, D, E, F, G, J, K, W, X}
- 18) age <= 32; criterion = 1, statistic = 74.811
- 19) jacob <= 0.8347701; criterion = 1, statistic = 32.074
- 20) sect == {cn, pd, pr, re, st, wh}; criterion = 1, statistic = 108.512
- 21) SBRR_lagged5 <= 0.1030314; criterion = 1, statistic = 63.928
- 22) SBRR_lagged <= 0.6992277; criterion = 1, statistic = 56.151
- 23) region == {F, G, J}; criterion = 1, statistic = 64.596
- 24) age <= 16; criterion = 1, statistic = 32.982
- 25)* weights = 883
- 24) age > 16
- 26) SBRR_lagged3 <= 0; criterion = 1, statistic = 20.204
- 27) jacob <= 0.7714286; criterion = 0.991, statistic = 16.031
- 28) sect == {pd, re, wh}; criterion = 1, statistic = 30.007
- 29)* weights = 311
- 28) sect == {cn, st}

30)* weights = 126
 27) jacob > 0.7714286
 31)* weights = 869
 26) SBRR_lagged3 > 0
 32)* weights = 17
 23) region == {A, B, D, E, K, W, X}
 33) Ther_i <= 0.008165094; criterion = 1, statistic = 29.139
 34) SBRR_lagged3 <= 0.01467797; criterion = 1, statistic = 21.592
 35) rd == {0}; criterion = 0.997, statistic = 18.1
 36)* weights = 1728
 35) rd == {1}
 37) sect == {pd, pr, re, st, wh}; criterion = 1, statistic = 37.06
 38)* weights = 365
 37) sect == {cn}
 39)* weights = 46
 34) SBRR_lagged3 > 0.01467797
 40)* weights = 25
 33) Ther_i > 0.008165094
 41) region == {A, E, K, W}; criterion = 0.999, statistic = 29.312
 42)* weights = 676
 41) region == {B, D, X}
 43)* weights = 776
 22) SBRR_lagged > 0.6992277
 44)* weights = 79
 21) SBRR_lagged5 > 0.1030314
 45) SBRR_lagged <= 0.2062243; criterion = 0.999, statistic = 16.396
 46)* weights = 177
 45) SBRR_lagged > 0.2062243
 47)* weights = 10
 20) sect == {ca}
 48) age <= 18; criterion = 1, statistic = 46.769
 49) jacob <= 0.7776184; criterion = 1, statistic = 33.006
 50)* weights = 25
 49) jacob > 0.7776184
 51)* weights = 38
 48) age > 18
 52) region == {K}; criterion = 1, statistic = 33.42
 53)* weights = 10
 52) region == {D, E, W, X}
 54)* weights = 29
 19) jacob > 0.8347701
 55)* weights = 2983
 18) age > 32
 56) ult_foc_d == {1}; criterion = 1, statistic = 85.118
 57) jacob <= 0.7931034; criterion = 1, statistic = 19.111
 58)* weights = 41
 57) jacob > 0.7931034
 59)* weights = 15
 56) ult_foc_d == {0}
 60) age <= 38; criterion = 1, statistic = 79.408
 61) sect == {pr, st, wh}; criterion = 1, statistic = 60.592
 62) region == {A, D, E, F, G, J, K, W, X}; criterion = 1, statistic = 40.229
 63)* weights = 311
 62) region == {B}

64)* weights = 30
 61) sect == {ca, cn, pd, re}
 65) region == {B, D, E, F, G, K, X}; criterion = 1, statistic = 52.178
 66)* weights = 703
 65) region == {A, J, W}
 67)* weights = 194
 60) age > 38
 68) HGF == {0}; criterion = 1, statistic = 32.612
 69) region == {A, E, X}; criterion = 0.993, statistic = 30.239
 70)* weights = 112
 69) region == {B, D, F, G, J, K, W}
 71)* weights = 265
 68) HGF == {1}
 72)* weights = 67
 1) SBRR_lagged2 > 0.002713661
 73) Ther_i <= 0.1368429; criterion = 1, statistic = 76.996
 74) region == {A, B, D, E, F, H}; criterion = 1, statistic = 80.156
 75) sect == {cn, pd, pr, re, st, wh}; criterion = 1, statistic = 60.226
 76) ult_foc_d == {1}; criterion = 1, statistic = 26.099
 77)* weights = 30
 76) ult_foc_d == {0}
 78) SBRR_lagged5 <= 0.397831; criterion = 1, statistic = 20.139
 79)* weights = 981
 78) SBRR_lagged5 > 0.397831
 80) jacob <= 0.87; criterion = 0.993, statistic = 12.555
 81)* weights = 228
 80) jacob > 0.87
 82) SBRR_lagged3 <= 0.5; criterion = 0.994, statistic = 12.65
 83)* weights = 10
 82) SBRR_lagged3 > 0.5
 84)* weights = 10
 75) sect == {ca}
 85)* weights = 21
 74) region == {G, J, K, W, X}
 86) SBRR_lagged5 <= 0.3842167; criterion = 1, statistic = 18.499
 87)* weights = 940
 86) SBRR_lagged5 > 0.3842167
 88)* weights = 282
 73) Ther_i > 0.1368429
 89)* weights = 38

10.4.10 Survival Tree from Section 7.3.1 (p. 207)

Node number 1: 15047 observations, complexity param=0.01412019
 events=213, estimated rate=0.9872724, mean deviance=0.1100632
 left son=2 (14522 obs) right son=3 (525 obs)

Primary splits:

as.factor(imm_foc_d) splits as LR, improve=23.58767, (0 missing)
 as.factor(sect) splits as LLRLLLL, improve=16.09901, (0 missing)
 TPS < 0.4537595 to the left, improve=13.90591, (0 missing)
 Ther_i < 0.0006941195 to the left, improve=13.07639, (0 missing)
 prodWRDG < 179429.5 to the left, improve=11.66135, (0 missing)

Surrogate splits:

prodWRDG < 318533.4 to the left, agree=0.965, adj=0.002, (0 split)

Node number 2: 14522 observations, complexity param=0.009060683
events=191, estimated rate=0.9137517, mean deviance=0.1039696
left son=4 (7820 obs) right son=5 (6702 obs)

Primary splits:

as.factor(sect) splits as LLRLLLL, improve=13.554180, (0 missing)
Ther_i < 0.0006941195 to the left, improve=11.614860, (0 missing)
TPS < 0.4655493 to the left, improve= 9.024202, (0 missing)
SBRR < 0.008620319 to the right, improve= 7.984590, (0 missing)
as.factor(region) splits as RLRLRLLLLLL, improve= 7.741308, (0 missing)

Surrogate splits:

Ther_i < 0.007563241 to the left, agree=0.627, adj=0.191, (0 split)
TPS < 0.3562317 to the left, agree=0.616, adj=0.168, (0 split)
as.factor(region) splits as LRRRLLLLRLR, agree=0.589, adj=0.110, (0 split)
as.factor(HGF) splits as RL, agree=0.570, adj=0.068, (0 split)
as.factor(rd) splits as LR, agree=0.563, adj=0.053, (0 split)

Node number 3: 525 observations

events=22, estimated rate=3.006936, mean deviance=0.2340746

Node number 4: 7820 observations, complexity param=0.009060683
events=79, estimated rate=0.6938388, mean deviance=0.08204731
left son=8 (6206 obs) right son=9 (1614 obs)

Primary splits:

Ther_i < 0.01630127 to the left, improve=16.465080, (0 missing)
jacob < 0.8317756 to the right, improve=11.030890, (0 missing)
TPS < -0.7302228 to the right, improve=10.309100, (0 missing)
as.factor(region) splits as RLRLRRRLRL, improve= 9.074925, (0 missing)
as.factor(old) splits as RRL, improve= 6.259138, (85 missing)

Surrogate splits:

TPS < -0.6386625 to the right, agree=0.811, adj=0.084, (0 split)
prodWRDG < 237211.3 to the left, agree=0.795, adj=0.004, (0 split)

Node number 5: 6702 observations, complexity param=0.008536462
events=112, estimated rate=1.179109, mean deviance=0.1275267
left son=10 (2934 obs) right son=11 (3768 obs)

Primary splits:

prodWRDG < 135313.5 to the left, improve=11.316460, (0 missing)
as.factor(region) splits as RLRRRLRR, improve=11.025350, (0 missing)
SBRR_lagged3 < 0.0002618941 to the right, improve= 7.225316, (0 missing)
SBRR < 0.4826693 to the right, improve= 5.415101, (0 missing)
SBRR_lagged2 < 0.0002618941 to the right, improve= 5.410041, (0 missing)

Surrogate splits:

SBRR_lagged2 < 0.002912079 to the right, agree=0.592, adj=0.069, (0 split)
SBRR_lagged3 < 0.01060165 to the right, agree=0.591, adj=0.066, (0 split)
SBRR_lagged < 0.002296636 to the right, agree=0.589, adj=0.062, (0 split)
SBRR_lagged4 < 0.005841728 to the right, agree=0.587, adj=0.056, (0 split)
SBRR_lagged5 < 0.0886938 to the right, agree=0.585, adj=0.052, (0 split)

Node number 8: 6206 observations, complexity param=0.007707709
events=39, estimated rate=0.4859578, mean deviance=0.05547351
left son=16 (3243 obs) right son=17 (2963 obs)

Primary splits:

jacob < 0.7942652 to the right, improve=12.858420, (0 missing)
 SBRR_lagged2 < 0.8655489 to the left, improve=10.557630, (0 missing)
 SBRR_lagged < 0.7650706 to the left, improve=10.191080, (0 missing)
 as.factor(old) splits as RRL, improve= 8.772043, (67 missing)
 SBRR_lagged5 < 0.734662 to the left, improve= 8.651518, (0 missing)
 Surrogate splits:
 as.factor(region) splits as LRLRLRLRLR, agree=0.605, adj=0.173, (0 split)
 prodWRDG < 130273.7 to the right, agree=0.575, adj=0.109, (0 split)
 SBRR_lagged5 < 0.001356831 to the left, agree=0.573, adj=0.106, (0 split)
 SBRR_lagged4 < 0.001356831 to the left, agree=0.567, adj=0.093, (0 split)
 as.factor(rd) splits as LR, agree=0.564, adj=0.087, (0 split)

Node number 9: 1614 observations
 events=40, estimated rate=1.205819, mean deviance=0.1740291

Node number 10: 2934 observations, complexity param=0.008536462
 events=46, estimated rate=0.8548913, mean deviance=0.1258084
 left son=20 (2201 obs) right son=21 (733 obs)

Primary splits:
 as.factor(region) splits as RLRLRLRLRL, improve=16.282360, (0 missing)
 SBRR < 0.9777969 to the right, improve= 7.041286, (0 missing)
 SBRR_lagged < 0.9773902 to the right, improve= 6.502461, (0 missing)
 prodWRDG < 104054.6 to the right, improve= 6.492487, (0 missing)
 TPS < -0.1184181 to the left, improve= 6.001894, (0 missing)
 Surrogate splits:
 TPS < 0.8657923 to the left, agree=0.758, adj=0.031, (0 split)
 Ther_i < 0.1567363 to the left, agree=0.756, adj=0.022, (0 split)
 jacob < 0.04079228 to the right, agree=0.751, adj=0.003, (0 split)

Node number 11: 3768 observations, complexity param=0.008536462
 events=66, estimated rate=1.600184, mean deviance=0.125863
 left son=22 (2259 obs) right son=23 (1509 obs)

Primary splits:
 as.factor(region) splits as RLLLRLRLRL, improve=14.907050, (0 missing)
 jacob < 0.9299691 to the left, improve= 7.023843, (0 missing)
 prodWRDG < 135397.7 to the right, improve= 6.696602, (0 missing)
 Ther_i < 0.05736955 to the right, improve= 5.006725, (0 missing)
 as.factor(HGF) splits as RL, improve= 4.723643, (0 missing)
 Surrogate splits:
 jacob < 0.6778797 to the right, agree=0.635, adj=0.087, (0 split)
 Ther_i < 0.1053371 to the left, agree=0.606, adj=0.015, (0 split)
 prodWRDG < 176705.7 to the left, agree=0.602, adj=0.007, (0 split)
 as.factor(status) splits as LLR, agree=0.602, adj=0.007, (0 split)
 SBRR_lagged < 0.7372459 to the left, agree=0.602, adj=0.006, (0 split)

Node number 16: 3243 observations
 events=6, estimated rate=0.1991876, mean deviance=0.01987756

Node number 17: 2963 observations
 events=33, estimated rate=0.7056603, mean deviance=0.09012514

Node number 20: 2201 observations
 events=22, estimated rate=0.5503635, mean deviance=0.08405021

Node number 21: 733 observations
events=24, estimated rate=1.760553 , mean deviance=0.2290305

Node number 22: 2259 observations
events=25, estimated rate=0.9957268 , mean deviance=0.08787011

Node number 23: 1509 observations
events=41, estimated rate=2.504248 , mean deviance=0.1728956

10.5 KEY OUTPUTS

10.5.1 Regional Studies

Accepted abstract and invited to submit for potential publication in Regional Studies under the Special Issue 'Shaping Enterprise Policy: Theory and Practice in Different Contexts.'

Note that the following manuscript is formatted according to the journal's requirements. Thus, it is inconsistent with the rest of the thesis.

Trees Discover Small Business Property Tax Reductions do not Liberate Productivity

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Trees Discover Small Business Property Tax Reductions do not Liberate Productivity

We model and investigate the effect of deep reductions in property taxes for small businesses on their productivity and survival and hence their expected ability to enable local transformative growth. To define and capture the complex interaction and clustering of hierarchical effects, we use the recently developed non-parametric Random Effects Expectation Maximisation Decision Tree algorithm for productivity analysis and a Survival Tree algorithm for interval-censored observations. We employ rich microdata for all UK firms and show, contrary to policy expectations, that generic tax reductions are associated with lower productivity and do not affect survival. We further show local output diversity is more relevant to higher productivity.

Keywords: Productivity, Survival, Business Rates, Taxation, Policy

Subject classification codes: C14 C54 D24 H22 H71

Introduction

This study utilises non-parametric hierarchical analyses to analyse whether the homogeneous reductions in commercial property taxes for small firms has released putative pent up animal spirits and led to gains in firm productivity or ability to survive demand shocks. These reductions, termed Small Business Rate Reliefs (SBRR), were first introduced in Scotland in 2003, England in 2005 and Wales in 2007. The most recent extension to reductions from April 2017 and 2018 will further reduce tax revenue across England by £9 billion over five years and remove 600,000 firms from liability (HM Treasury 2017). This is just as we see the gradual return of Business Rate (BR) revenue to local control in England via devolution of powers or greater revenue retention. Powers have already been devolved to Scottish and Welsh national governments.

These recent reductions are framed on one side by high profile concerns about ever-tighter funding for local authorities, which will become increasingly dependent on local property taxes. Whilst on the other, the strong perception from firms paying BR, i.e. commercial property taxes levied on business occupiers, that the tax is an antiquated burden on entrepreneurial spirits. The pressures from firms have seen central governments incrementally move away from BR as a flat tax with the introduction of ever-deeper SBRR.

The weak narrative (Shane, 2009, Anyadike-Danes et al., 2015, Gobey and Matikonis, 2018) underlying the policy of reductions is one of enabling small firms to lead local growth (HM Treasury 2016b, 2017) through a reduction in financial constraints which are believed to disproportionately limit their ability to invest and innovate, relative to larger firms. This feeds off the wider narrative. For instance, the Chief Executive of Tesco (BBC, June 2018), the largest supermarket chain in the UK, linked closures of high-street shops to BR. The Financial Times reported in July 2018 naïve research with the title 'How UK Business Rates Shake-up is Deepening High Street Gloom' (Bounds, 2018). These comments echo the influential position of the Federation of Small Businesses that the tax is an expensive, unfair burden discouraging growth and investment (FSB website, no date).

Our theoretical model clarifies how SBRR could change the decision thresholds for firms around exit, the use of current capacity, expansion or relocation. We show how survival could be enhanced following a negative shock but following positive shocks the reliefs may become an impediment to investment. For instance, in the decision between maintaining or increasing capacity at the current premises, a positive shock would need to cover both the increased tax and loss of reliefs. Hence, instead of enabling firms to overcome putative growth frictions, they could be less likely to invest, relative to the counterfactual of no reliefs.

Our initial modelling framework shows that the investment story is rather more nuanced than initially presented. We also have to assume capitalisation of reliefs into rents is far from perfect, with market frictions differentially delaying the process sufficiently to affect investment. The model focuses on firm-level decisions, but these are not independent from the critical hierarchical effects of regions and industries, which themselves are modified by industry concentration, Marshall Specialisation or Jacob diversity. All these will interact with firm-level factors in a non-linear manner to complicate the decision points.

In order to capture the complex clustered nature of the data fully, our empirical methodology is to employ the Sela and Simonoff (2012) and Fu and Simonoff (2015) Random Effects Expectation Maximisation (RE-EM) decision tree algorithm for productivity analysis. This algorithm allows the data to define non-parametrically the interaction of effects, whilst also controlling for firm-level differences. We further employ the Fu and Simonoff (2017) Survival Tree (ST) algorithm, which accounts for left truncated and right censored observations to identify complex effects on exits.

We base the empirics on rich and detailed micro data from the Office of National Statistics' recently combined Annual Respondents Dataset X (ARDX) and out of sample

administrative data from the Business Structure Database (BSD) for all UK firms. This microdata enables us to use coarsened exact matching across a wide range of characteristics to create a well-balanced dataset of small firms divided on whether they receive relief and ensure our results are less model dependent.

We find observations for firms with higher levels of lagged SBRR are consistently associated with lower levels of total factor productivity (TFP), calculated using Wooldridge's (2009) one-step GMM approach. Whilst region also plays a consistent defining role in grouping observations, there is interesting evidence of greater Jacob (turnover) diversity increasing productivity in small two-digit postcode areas. This suggests nuanced and targeted policy on understanding local drivers and constraints could be more fruitful than the current generic firm based policy. We find no association between survival and SBRR.

We structure the rest of the paper as follows. In section two, we discuss the tax and construct a model of the production decision points. In section three, we discuss our empirical approach. In section four, we discuss our data and construction of the matched dataset, in section five we present the findings and in section six we conclude.

Model

We adopt and adapt the Duranton et al. (2011) BR model in order to establish how the property taxes of the different nations (England, Scotland, Wales) and the tax reductions for small businesses could influence decisions on survival, production and investment. The model is simple but importantly allows us to incorporate the relevant empirical peculiarities of the British tax framework.

Policymaking tends to ignore any divergence between the statutory and economic incidence of taxation (Oates and Fischel, 2016), yet this divergence is central to the effectiveness of SBRR and the support for the policy. BR is levied on property occupiers and this makes it particularly salient to firms and puts policy makers on the defensive. Yet the relative inelasticity in the supply of business properties to the flexibility of demand means economic incidence transfers to property owners through capitalisation into rental prices. We should then observe in response to a reduction in taxation property owners increasing rents such that the total cost of taxes plus rents stays consistent. The degree and time it takes for SBRR and other changes to capitalise, provide space in which the tax and policy could influence production and survival decisions.

We assume property taxes and expected increments are fully capitalised into new rental contracts. Otherwise, tax shocks take time to be (partially) capitalised due to market rigidities. In the empirical section, we control for the heterogeneous capitalisation due to levels of concentration or diversity in small areas. Rigidities also drive from standard contracts, in which rent reviews usually occur at five-year intervals and are only upward. The annual national tax adjustments are reasonably predictable as they are revenue neutral and reflect inflation. Shocks are likely following the implementation of BR revaluations, which should take place every five years and can both lower and raise the obligation.

Additionally, governments can introduce shocks and distortions to the flat tax through the introduction of loosely targeted reductions, like SBRR. The SBRR, depending on the nation and period, reduces the tax obligation in steps or sets a maximum tax reduction, which then tapers linearly. E.g. in England, for 2010-17 the 100% threshold was up to £6,000 rateable value after which it tapered to zero at £12,000 (please see Appendix One for details). All these frictions may reduce the degree of capitalisation and the time it takes.

In the sparse literature on BR and capitalisation Bond et al. (1996) used rental data for the period 1987-1992, to explore the 1990 shift in tax setting powers from local authorities to the national government. They found rents fell in response to BR rises more than in areas that saw a fall in BR during this transition period. They do not reject a pound for pound negative relationship between rents and BR, although with a wide confidence interval⁵¹. Their priors were that market rigidities would delay the process, but they further show it took only two years for the incidence to shift in retail properties. Bond et al. (2013) found a similar impact in Enterprise Zones where rates were reduced and planning restrictions relaxed.

In order to focus more on property taxes, we make a number of simplifying assumptions. We first conceptualise supply as;

$$Q_{ijt} = [\beta_{vf}VF_{ijt} + \beta_{of}OF_{ijt}] + \beta_{rs}RS_{ijt}, \quad (1)$$

where Q is the output of firm i in nation j at time t , VF are the general variable inputs, (such as labour and materials) OF are other fixed factors (such as machinery, installations or overheads) excluding rented space (RS) which we consider separately. The β s represent their relative weights in output. We take all variable and other fixed inputs together as

⁵¹ Commercial research employing rental data finds 75% capitalisation of BR over a period of two to three years (Regeneris, 2015)

numeraire. Firms live for up to two periods and can enter at any point. During the firm's first period, demand is normalised to unitary. Period one profit is given by;

$$\pi_{ijt} = [p_t - r_{ijt} - \tau_{ijt}(1 - \alpha_j)], \quad (2)$$

where p is the exogenous final good price, r is rent, τ is property tax and α is the proportionate reduction in the tax for small firms within a given nation and period. We express rent and tax in units of output in order to relate them directly to price and unit profits. These values represent the input value divided by total output value and as such can reflect changes in productivity. We fix rents in both periods to reflect rigidities in the contractual norms. In period two, we observe a demand shock;

$$d_{ijt+1} = 1 + \rho_{ijt+1}, \quad (3)$$

where ρ_{ijt+1} is a realisation from a random draw over a continuous distribution at the beginning of the period. The draw can be positive or negative. We consider responses to the shock and the influence of reliefs.

In extremis, a negative shock ($\rho_{ijt+1} < 0$) will lead to firm exit (E), in which case; $\pi_{it+1} = \pi_{iE} = 0$. The level of reliefs could affect exit thresholds, with greater relief adding greater resilience. If a firm has negative draw but survives (S), we assume a fall in output and productivity. This means the unit cost of the fixed rent and tax increase, as does the relative value of any relief. This captures why since the great recession BR is at the principle concern of small business groups (Adam and Miller, 2014 and Cabinet Office, 2014) and led to significant political pressure for reform. Profit in period two is;

$$\pi_{ijt+1} = (1 + \rho_{ij})[p - r_{ij} - \tau_{ijt+1}(1 - \alpha_j)] \quad (4)$$

If the demand shock is negative, then $[r_{ijt} + \tau_{ijt}(1 - \alpha_j)] < [r_{ij} + \tau_{ijt+1}(1 - \alpha_j)]$, i.e. first period unit costs of rent and tax are lower than second period unit costs. We implicitly assume relocation is too costly. Figure One, page 16, in which we plot the evolution of productivity nicely captures the marked dip in average productivity following the 2008 great recession.

If a firm faces a positive shock ($\rho_{ijt+1} \geq 0$), it has three choices. The first is to continue (C) in the current premises and increase output within capacity limitations, the unit cost of rent and tax decline as they are defrayed over a larger production run and productivity would increase. In which case we would now see $[r_{ijt} + \tau_{ijt}(1 - \alpha_j)] > [r_{ij} + \tau_{ijt+1}(1 - \alpha_j)]$ in period two profits. This means reliefs would reduce this gain from lower unit costs given they neutralise the tax costs. Moreover, tighter capacity constraints for

small firms and limited scale effects in some industries, would see constraints bite more quickly and we may see increases in variable unit costs offsetting the fixed factor or productivity gains. In which case, the decision thresholds we now discuss are more relevant to small firms.

Secondly, the firm could expand production within the current premises. This would result from, say, changing the way in which the space is utilised or installing fixed capital. This may increase total rent, but we assume that any per unit change only derives from productivity changes. The adjustment to property usage could lead to a Valuation Office Agency⁵² revaluation. This revaluation process considers a number of elements beyond the simple building space. It would look at the amount and type of installed capital (capital integral to the property from furnaces to air conditioning) and gives different values to different zones. Spaces near windows in small retail units have greater values than other spaces such as storerooms. These factors underscore the complexity of the tax and why there are 300,000 appeals currently under consideration (Sandford, 2017). Any increase in the rateable value may in turn trigger a reduction in any relief. Again, this means firms in receipt of reliefs have a different threshold to those which do not. Profits in this growth (G) scenario are then;

$$\pi_{ijt+1} = \pi_{iG} = (1 + \rho_{ij}) \left[p - r_{ij} - \left(\gamma \tau_{ij+1} (1 - \delta \alpha_j) \right) \right], \quad (5)$$

Where $\gamma \geq 1$ represents a revaluation of the rateable value per unit of output and $\delta \leq 1$ the associated reduction in relief.

Duranton et al. (2011) principally demonstrate that the increase in BR following expansion can deter expansion of large manufacturing firms. This was in the period 1984-1989, before centralisation and SBRR. They show manufacturing occupiers still bear some of the incidence and the tax and this could have an effect on production decisions. However, they do note high relocation costs and the net effect of the tax change would limit any move to lower tax jurisdictions. This brings us to our final decision threshold.

If the demand shock is sufficiently positive, a firm may decide to relocate (R) to larger premises. We assume unit rental and taxation per unit are the same or lower, than staying in the current premises and producing at the same level or intensifying production. However, such relocation will lead to lower reliefs, given the firm will probably now face a higher total initial tax. Hence, in addition to relocation costs (c) there would be small extra

⁵² The Valuation office Agency is a UK government agency, which values properties for taxation purposes.

tax costs for growing small firms. Nonetheless, we would expect relocation costs to be greater than relief losses.

$$\pi_{ijt+1} = \pi_{iR} = (1 + \rho_{ij})[p - \bar{r}_{ij} - \bar{\tau}_{ij}(1 - \delta\alpha_j) - c_{ij}], \quad (6)$$

where \bar{r} and $\bar{\tau}$ represent reduced unit values than in period one which do not derive simply from productivity changes.

The above, simplified scenarios provide us with a number of differentiated decision thresholds which vary depending on a nation's property taxes and degree of relief. Namely, exit (π_{iE}), survive but reduce production (π_{iS}), continue within existing capacity (π_{iC}), invest at the same premises (π_{iG}), or invest at a new larger premises (π_{iR}). Our above modelling shows exits will be positively related to higher rents and taxes and negatively related to reliefs. Some small firms may then survive a given shock, irrespective of productivity. If a firm survives a negative demand shock, it will reduce output from installed capacity and higher absorption of the reduced turnover by fixed rent and taxes. This increase the salience of the tax, whilst reliefs ameliorate the effect.

Once we move to positive shocks, the reliefs may become an impediment to productivity gains within existing supply constraints. In the decision between maintaining or increasing capacity at the current premises, the positive shock would need to be sufficient to cover the increased tax and loss of reliefs after revision of rateable values. Instead of enabling firms to overcome putative growth frictions, they could be less likely to invest, relative to the counterfactual of no reliefs. This would be in line with Duranton et al. (2011). Reliefs would also impede the decisions to relocate, relative to no relief, as the positive demand shock would need to be greater to induce firms receiving reliefs to change location and feasibly improve productivity.

The static argument supporting the reliefs is that the higher relative cost of property taxes for small firms in their fix costs (repeated in HM Treasury 2016) disproportionately reduce profits and ability to invest. Givord et al. (2013) argue small firms tend to be more financially constrained than larger firms and might be more responsive to tax incentives. Whereas Holtz-Eakin (2000) challenges this narrative, arguing studies that suggest finance restrictions limit small firms have not shown too few or the wrong firms are funded. The conclusions from this basic modelling show that the story is rather more nuanced than the arguments supporting the reliefs. Firms may be better placed to survive negative shocks, but they are also more likely to be less productive, with higher investment thresholds. Capitalisation will also reduce the putative negative effects of the property tax, but this could vary by the degree of competition for commercial

space. That said the statutory incidence on occupiers makes this a highly salient tax irrespective of economic incidence.

Regional clustering factors add further complexity to these firm-level decisions. Regional levels of competition can have differential effects on investment, relocation or exit thresholds. Porter (2003) and Hausmann and Rodrik (2003) argued greater competition might drive more or less investment in processes or product differentiation depending on the degree and speed with which competitors adopt competitive advances. In turn, any local Marshall intra-industry or Jacob diversity externalities could modify the source and rate of absorption. Finally, we can layer age effects on these complications. We may see learning by doing effects as firms age, but we may also see slower adoption of new techniques or machinery, relative to new firms. In turn, most new firms are simple “copycat” firms and they do not drive incremental innovation.

Rather than trying to model these complex factors, which would be messy and provide little insight, we employ an empirical strategy, which combines random effects with decision trees that allows the data to discover how these factors group firms and consequentially any influence of the tax reliefs. We now discuss this approach.

Empirical Methodology

Our modelling draws out some of the nuanced implications SBRR could have on survival and investment boundaries. We also observe other firm characteristics such as age and clusters by region or sector may influence decisions. These factors will not be solely additive but interact such that the path along which any effects of the universal policy operate on survival or productivity will be difficult to identify a priori.

These considerations lead us to adopt two recently developed decision tree algorithms rather than standard parametric multilevel estimators. For our productivity analysis, we exploit the Random Effects Expectation Maximisation (RE-EM) decision tree approach of Sela and Simonoff (2012) and subsequently Fu and Simonoff (2015). The Random effects element accounts for the constant differential firm-level factors whilst the decision tree allows the data to discover the complex groupings of firms and their different levels of productivity without imposing a complex parametric structure.

The RE-EM model is:

$$\omega_{it} = Z_{it}b_i + f(.) + \varepsilon_{it}, \quad i = 1, \dots, I \quad t = 1, \dots, n \quad (7)$$

$$\begin{pmatrix} \varepsilon_{i1} \\ \vdots \\ \varepsilon_{in} \end{pmatrix} \sim N(0, R_i),$$

$$b_i \sim \text{Normal}(0, D),$$

$$f(.) = f\left(\sum_{j=0}^4 (SBRR_{t-j}), \rho_{it}, a_{it}, r_{it}, s_{it}, PS_{it}, PD_{it}, HHI_{it}, R\&D_{it}, HGF_{it}, FO_{it}, IO_{it}\right)$$

The dependent variable ω_{it} , is our bootstrapped estimate of total factor productivity, as discussed below, for each firm i in period t . Z is a matrix of independent variables which may vary over time and firms and b_i is the vector of random effects. $f(.)$ contains the same variables as Z , although they can differ, which we use to estimate the fixed effects via the decision tree.

Within $f(.)$ we have $SBRR$ and four lags to capture medium-term effects and account for the periodicity of the reliefs. We complement these variables with the dummy variable ρ to capture the initial⁵³ effects of receiving any relief or the uplift in relief, irrespective of level.

We next include basic classification variables of firm age (a), the regions and nations (r) of Wales, Scotland, North East, North West, Yorkshire and Humberside, East of England, East Midlands, West Midlands, London, South East and South West. We classify firms into the broad sectors (s) of wholesale, catering, construction, production, property, retail and other services.

In order to account for the effects of local industry structure and competition on productivity, we include indices for Jacob diversity (JD) and Marshall production specialisation (PS). We control for industry concentration at the national level via a Herfindahl-Hirschman Index (HHI). We capture the Marshallian Specialisation externalities by calculating the specialisation index as suggested by Feldman and Audretsch (1999) and Paci and Usai (1999). We exploit our access to firm-level micro data to calculate the specialisation within small two-digit postcode areas, relative to national SIC (2003) two-digit industry output. We further exploit the data and use firm turnover rather than

⁵³ Scotland in 2003, England in 2005, Wales in 2007, with increase in relief in 2010

employment. This produces a less noisy control for TFP than employment and a much more accurate perspective on the concentration and value of activity. The index is:

$$PS_{i,j} = \frac{T_{ij}/\sum_i T_{ij}}{\sum_j T_{ij}/\sum_i \sum_j T_{ij}}, \quad (8)$$

where T is industry i turnover in area j . We calculate the turnover of a given industry (i) in an area (j) as a proportion of all turnover in a given area and then place it in relation to national turnover from the same industry as a proportion of national turnover. For given levels of local infrastructure and public pool of research knowledge, the index helps to capture whether greater proximity enables the creation of better labour pools, supplier services or the spillover of incremental process and product innovations. SBRR may interact with these local factors as they may help reduce the assumed financial barriers to adoption or creation of incremental changes. That said, we may also observe increased competition for specific types of premises and as such a more rapid capitalisation of any tax reliefs. Proximity may also diminish innovation if spillovers occur before firms can exploit monopoly rents and as such there may be a negative association with SBRR as it leads to greater mark-up rather than innovation, although survival may improve as productivity differentials do not widen.

We capture any local Jacob (Production) Diversity effects via an index based on the reciprocal of the Gini Coefficient as proposed by Paci and Usai (1999).

$$PD_j = \frac{2}{(n-1)Q_n} \sum_{i=1}^{n-1} Q_i, \quad (9)$$

where n is the number of industries in region j , Q_i is the cumulative turnover up to industry i , then ordered by ascending size. The index, bounded by zero and one, increases with variety. Differently to SBRR or PS location rather than the firm or industry is at the centre of analysis and driving change (Florida et al., 2017). Innovation is aided by access to ideas and procedures that firms can copy or modify from a diverse set of industries or knowledge generating institutions within small areas or given the positive correlation with urban areas more diverse and stable demand. That said, at our two-digit postcode level we will observe a good degree of variation even within urban areas. In the same vein, we also control for the choice to invest in Research and development with the variable R&D, this comes from the survey element of the ARDx dataset and asks whether a firm intends to invest in such activity within the next two years.

The Office of National Statistics (ONS, 2017), building on a well-established body of literature, e.g. Harris and Moffat (2015), calculates that UK firms receiving foreign

investment have 74% higher productivity than firms which do not attract foreign investment, after controlling for firm characteristics. There are of course selection effects which bias these findings. Consequently, we include the dummy variable *FO* that takes one for firms with a foreign majority owner. In this era of concerns about complex ownership structures and use of complex taxation schemes, we also use the variable *IO* to denote a foreign country registration of the firm's immediate parent firm, this is also the variable *ONS* used in their calculations. This can be different to *FO*, which denotes the ultimate country of the owner. *HGF* controls for high growth firms, *HGF* is a dummy taking the value of one in the years it meets the Eurostat-OECD (2007) definition, namely average annualised growth in employment greater than 20% per annum, over a three-year period with initial employment not lower than ten.

The error term ε_{it} , is assumed to be uncorrelated with the random effects and independent across observations. R_i is a non-diagonal matrix to account for autocorrelation within firms. The algorithm proceeds by initially setting the random effects to zero and building a decision tree. The random effects are then estimated, given the decision tree and the process iterates until the random effects converge using a restricted maximum likelihood estimator. The decision tree values are then finally updated.

Dependent Variable: Total Factor Productivity

Total Factor Productivity (TFP) is not directly observable from production functions and consequently needs to be extracted once the weighted sum of inputs has been estimated with controls for simultaneity and selection biases. We estimate TFP using Wooldridge's (2009) one-step GMM estimator, which has been successfully employed in a range of settings and has been cited in at least 205 different papers since its publication (Repec, 2018). Wooldridge builds on the influential work of Olley and Pakes (1996) and Levinsohn and Petrin (2003) and overcomes the identification issues of variable inputs such as labour. We estimate TFP assuming a Cobb Douglas functional form:

$$\omega_{it} = \ln GVA_{it} - \beta_k \ln K_{it} - \beta_l \ln L_{it}, \quad (10)$$

where ω_{it} is TFP of the *ith* firm in period *t*, $\ln GVA_{it}$ is the firm's logarithmic gross value added in order to simplify the model and eliminate intermediate inputs, *K* is logarithmic capital and *L* is logarithmic labour. We bootstrap through thousand estimates to reduce serial correlation.

Survival Analysis

The Fu and Simonoff (2017) Survival tree (ST) algorithm advances previous work through its combination of controls for the typical left truncated right censored nature of panel data. Decision trees have traditionally struggled to cope with such structures when there are time variant repressors. The authors argue that this non-parametric approach is preferable to the standard Cox proportional hazards model as the required parametric assumptions are not met or unrealistic.

Unlike the RE-EM, this algorithm does not control for firm-level intercepts, although clustering on firm is feasible with Huber-white standard errors. We use the author's LTRCART extension of existing models, which control for left truncation. Given space limitations, please see their paper for the full details. Our report employs the same independent variables as in the RE-EM algorithm with the addition of TFP.

We test the stability and validity of the ST and RE-EM using standard approaches. First, we use the k-fold validation method, in which we compare the predictive capacity of our trees to OLS. We then split our sample into ten random subsamples and use each subsample as a validation subset for the estimates coming from the remaining nine subsamples. To test the stability of the results, we employ the random forests algorithm, which does not include the longitudinal aspect of the tree, but gives guidance as to which are the most influential variables. The output is provided in Appendix Two.

Data

We base our analysis on the U.K. Office of National Statistics (ONS) Annual Respondents Database X (ARDx) first released in July 2016 combined with Business Structure Database (BSD) and Prices Survey Microdata (PSM).

The ARDx combines two existing surveys, the Annual Business Inquiry (1998-2008) and the subsequent Annual Business Survey (2009-14) which firms' representatives are legally required to complete, producing high response rates. It is a census of firms with 250 plus employees and complex stratified sample across size, sector and region of smaller firms. The sample framework is constructed using administrative data on employment and turnover from PAYE⁵⁴ and VAT registered firms. Importantly for our purposes, it captures information at both the enterprise and local unit levels. We do however need to calculate firm's rateable value and SBRR from the survey reported BR. The calculations are set out in Appendix One.

⁵⁴ Pay as you earn, is the taxation withholding mechanism whereby employers deduct taxation from employee income on behalf of the tax authorities.

We combine this data source with the BSD to acquire the annual observations of smaller firms that were not included in the ARDx sample in some years and as such fills in some missing variables. The BSD contains an annual release of a small number of critical variables on all UK registered firms and is complementary to the above business surveys.

There are nevertheless still missing observations particularly on the smaller firms, which would tend to attract SBRR. To ensure a representative sample, we clean and impute the data where appropriate. We use predictive mean matching, with the key variables of turnover, employment, region, sector and legal status that have almost no missing data from the ARDx or BSD data sources. To estimate TFP, we then bootstrap over a thousand samples and average their coefficients and standard errors in order to reduce serial correlation⁵⁵.

The ARDx and BSD do not directly provide controls for input price changes that we require for estimation of TFP. To control for omitted price bias (as defined by Van Beveren, 2010), we do not use the typical approach of employing the inherently biased general GDP, but use the PSM data, which contains more precise regional and sector level prices. We devalue to 2016 prices.

Finally, we exploit our large representative dataset to recreate the conditions of a social experiment in which firms that receive SBRR are matched to similar single-unit firms which did not. This should make the results less model dependent. Our large dataset enables us to produce good matches by using a wide range of observable characteristics, namely: materials, age, investment, rent, output per employee, employment, sector, legal status, turnover, and GVA. The dependent variable is a dummy taking a value of one for those firms that received the relief at least twice between 2003-2015 and zero otherwise.

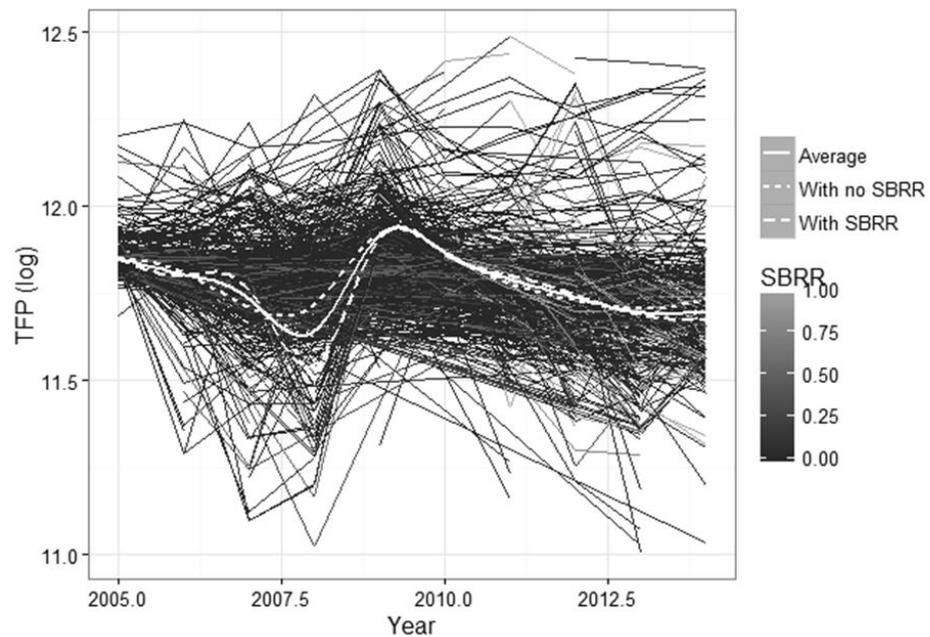
We match using Coarsened Exact Matching (CEM). CEM does not use the random pruning applied in Propensity Score Matching, which is shown to increase the level of imbalance (King et al., 2011 and 2016). The broad mechanism behind CEM is to group each variable by recoding so that nearly similar values are assigned the same value (Iacus et al., 2009). The firms were matched one year prior to the SBRR introduction or for youthful firms their first observable year. This produced a final dataset for the years 2000 to 2015 of 15,047 observations for 1,092 firms, 546 SBRR recipients matched to 546 firms that never received the relief but with similar characteristics.

⁵⁵ We also run estimates on non-imputed data and these results are available on request. TFP estimates of capital coefficient sometimes differs but other estimates (or major splits) are consistent.

Findings

In Figure One, we provide the firm-level evolution of estimated TFP during 2005-2015 and link this to receipt and degree of SBRR. We see a dramatic drop and rebound just after the start of the economic crisis in 2008 that we discussed in the modelling section. The average level of TFP was similar whether firms did or did not receive SBRR, although those in receipt of SBRR saw a steeper drop in 2008. The degree of relief does not produce any particular pattern in TFP, even after reliefs became more generous post 2010. Overall, there is diverse and complex variation around the average levels of productivity even among these carefully matched firms.

Figure 1. Estimated TFP 2005-2015 by SBRR



TFP estimates as described in the method section

The white lines correspond to the annual averages of all firms

The white dotted line is the average firms SBRR recipients

The white dashed line is the average for non-recipients

The other lines are shaded by the proportionate level of SBRR. Where black is 0% and light gray is 100%.

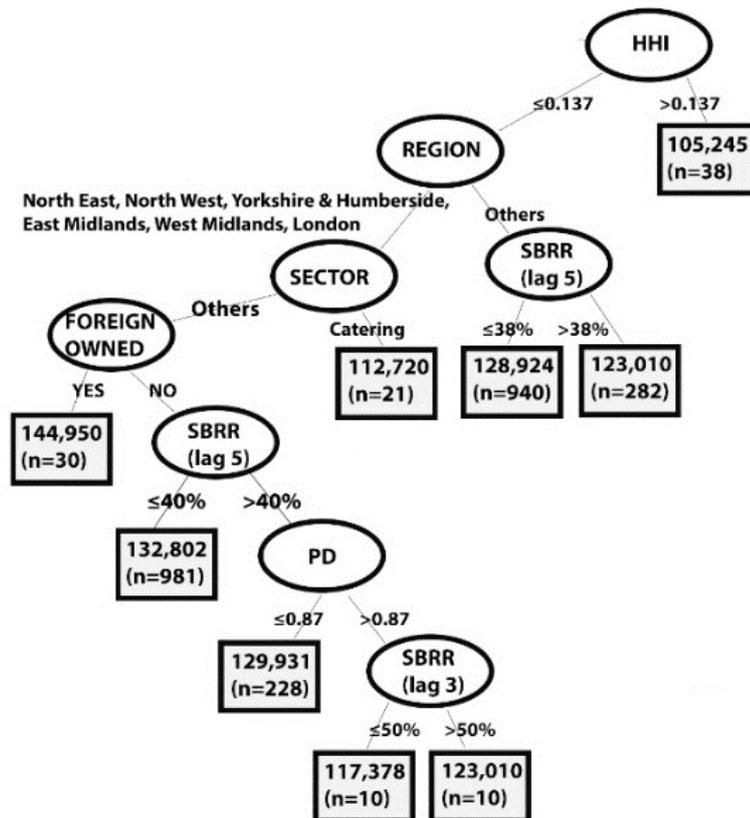
ONS Data, Author's calculations

We present the full TFP decision tree in Appendix Three, but for clarity and to isolate SBRR effects, we focus on the two extracts in Figures Two and Three. The Decision tree algorithm works by allowing the data to define ever more "pure" groups of firms which explain variation in the dependent variable (reduce the RSME), in that the firms in the final

groups (nodes) are increasingly homogeneous. The final nodes give the number of firms in the group and the average level of TFP, in terms of GVA. The splits are not strictly hierarchical as variables can enter a branch more than once but with different sub-values for points at which the data split.

The principle split is on a two-year lag of SBRR, 12,502 with zero relief and 2,540 with some relief. In Figure Two, we follow the 2,540 observations for firms receiving SBRR. The weighted average TFP of these observations is six percent lower than the other observations of firms not in receipt of SBRR. We focus on the most influential branches, those with the greatest numbers of firms in the final nodes.

Figure Two: TFP Tree Extract Following Firms Receiving Two Year Lagged SBRR



Figures in final nodes: TFP in terms of GVA and n is number of observations in the final node

ONS Data, Author's Calculations

The next significant grouping along this branch is by region. In the Southern and Eastern regions of England, Wales and Scotland (other in Figure Two), we identify a group of 1,222 observations on the five year lagged SBRR at 38% relief. Observations for the 940 firms receiving less relief have higher TFP. Nonetheless, weighted TFP for all observations

in these regions is over three percent lower than for observations in the Northern, Midlands and London regions of England. In fact, for these English regions, the next significant node is equally five-year lagged SBRR at a similar value of 40%. The pattern of TFP is the same, with lower TFP for the 248 observations from firms receiving higher relief than the 981 observations with lower or no relief. We conclude from this branch that irrespective of region and sector (excluding catering in some regions), the firms which consistently receive the higher levels of SBRR are those with lower TFP. This aligns with our basic model, which suggested firms receiving SBRR would be less likely to invest, but it could also simply mean capitalisation strips the relief of any meaningful long-term effect.

Following the observations for firms which did not receive two year lagged SBRR, we find the specific characteristics of London firms make them different to observations in other regions. We first consider the 10,911 observations outside of London which next group on age 32. In Figure Three, we follow the 9,173 younger observations as these are influenced by SBRR. The 1,738 observations from firms at least 32 years old (not shown) have no grouping on SBRR and ultimately the observations group by sector and then by region. The weighted TFP of these older observations is approximately five percent lower than for the younger observations, but with significant variation. For 2,983 of the younger firm observations (shown), we quickly come to an end node defined by high levels of local diversity, above 0.84 on the PD index⁵⁶. The Jacobian diversity hypothesis is that greater local diversity enables innovation. Here we find some support for this, as the weighted average TFP of these observations is approximately 3.6% higher than the TFP of others in two-digit postcode areas with a lower level of diversity. In the entire tree, we only find splits on Marshall Specialisation for areas of London.

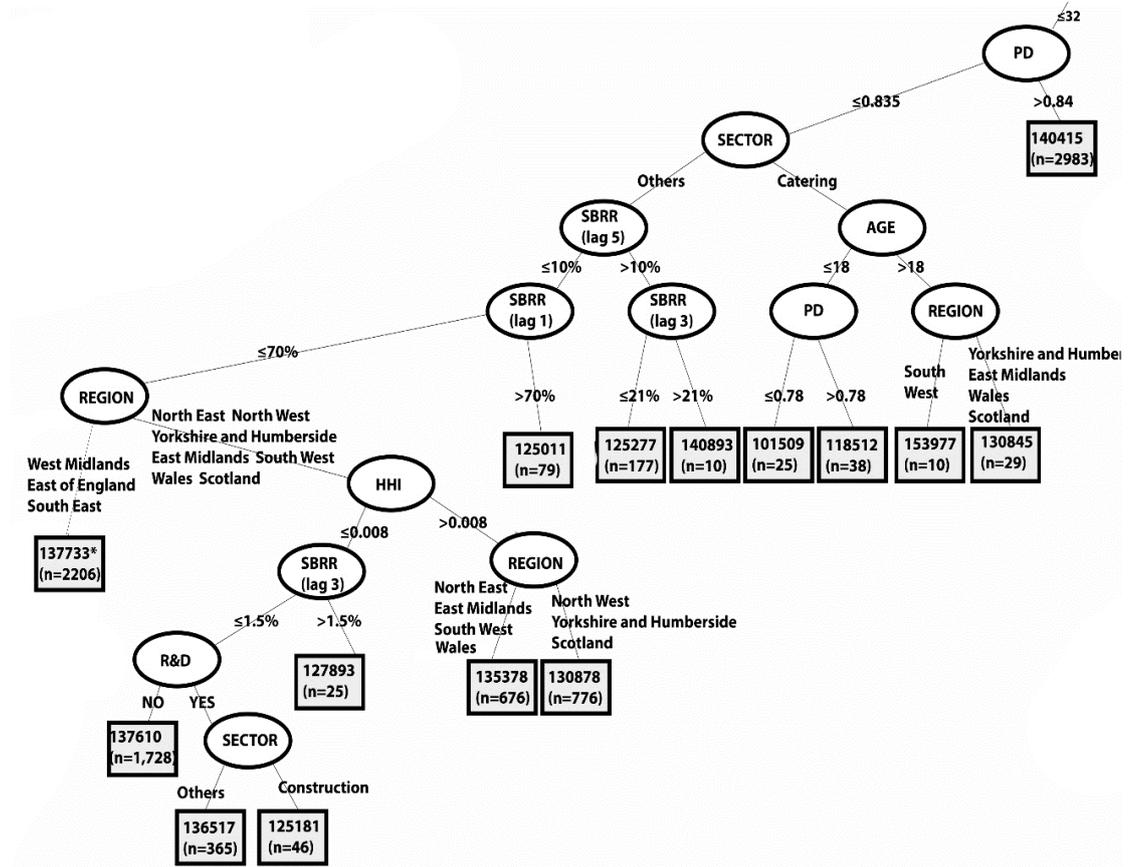
Moving down the branch for the majority of firms, those with lower PD, we see for all sectors except catering that there is a complex division between long-term and short-term reliefs. In particular, observations with five year lagged SBRR below 10% and one year lagged SBRR below 70% are associated with TFP generally higher than those which have five year lagged relief above 10%. We do see some subsequent small divisions with similar TFP. Overall, we find the recipients of greater SBRR are those with lower TFP.

The 1,591 observations from London have a weighted average TFP five percent higher than in the rest of the UK, this seems to be driven by a relatively small number of

⁵⁶ We observe similar pattern further down the branch for the regions, West Midlands, East and South East of England that we do not show in figure, for space reasons. 869 Firms in these regions between 16 and 32 years old with a PD above 0.77 have TFP greater than that for the 437 firms in areas with lower PD, although the difference is only around 2.5%. Central part of the tree in Appendix Three.

observations in sectors other than catering, construction, production, property, retail or wholesale. However, we find no association with SBRR.

Figure Three: TFP Tree Following Firms Not Receiving 2 Year Lagged SBRR, outside of London



Figures in final nodes: TFP in terms of GVA and n is number of observations in the final node

* denotes that this is a truncated branch for the regions West Midlands, East of England and South East England which does not subsequently group on SBRR. The TFP figure is a weighted average for the 2,206 observations

ONS Data, Author's Calculations

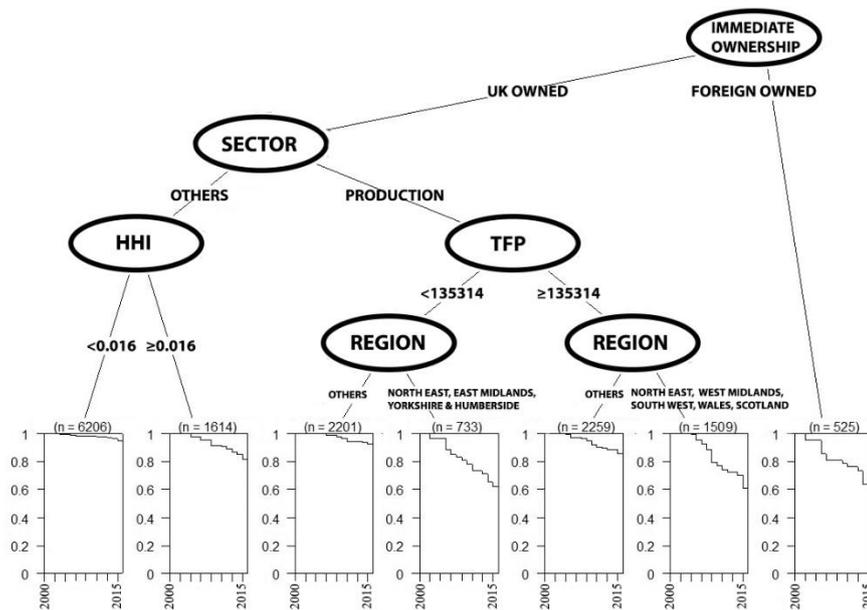
Overall, our findings on SBRR and TFP are in line with our model, which shows continued receipt of higher reliefs are associated with lower TFP. This is not the only explanation, as capitalisation of consistent reliefs into higher rents becomes easier over a longer period, increasingly shifting any benefit to property owners. Other than SBRR regional effects consistently explain variation in TFP, but we cannot say, except for London, there is a simple dominant geographical pattern. Interestingly we find nearly 4,000

observations in small areas with greater turnover diversity have better TFP. This would suggest the underlying institutional factors stimulating diversity would be a more logical policy target than generic tax reductions.

Survival

Above we assume SBRR would help survival when firms face an extreme demand shock. However, we find no groupings on current or lagged SBRR. The complete tree in Figure Four shows an initial division on immediate ownership, with firms with a legal ownership not in the UK going straight to a final node where the Kaplan-Meier curve shows survival probability drops of quickly and is similar to the most precarious UK registered firm groups. For UK firms we see production sector firms differ from all others. These do divide on TFP, but in the subsequent groups region play a greater role. The North East is consistently in groups with the worst survival probability and Northwest, East of England, South East and London consistently in the better groups. The 7800 observations in other sectors divide on HHI. Survival is higher for small firms in the less concentrated towards several major players sectors.

Figure Four: Survival Decision Tree



The graphics on the final nodes are Kaplan -Meier Survival Curves, showing the decay in survival probability over the period.

n is the number of observations in the final nodes

ONS data, Author's Calculations

Conclusions

This study utilises recently developed non-parametric algorithms to discover complex hierarchical relations and analyse whether property taxes reductions for small firms enable them to grow and become more productive or on the contrary, whether the tax policy is poorly targeted at has the long tail of small firms with consistently lower than mean TFP.

The estimates from the RE-EM productivity analysis align with our initial model in that the dominant grouping and all subsequent groupings on variously lagged SBRR, are associated with current lower levels of productivity. SBRR has not demonstrably enabled over reasonable periods recipients to invest and align with matched firm's TFP. This would suggest BR are not the growth impediment that a wide circle of commentators and policy makers claim. The tax reductions do not achieve their objective of enabling small firms to release untapped growth potential. On the contrary, they have been gone to the least productive small firms and property owners through capitalisation of long-term reductions into rents. We also show SBRR do not aid survival either, which again could be due to capitalisation.

In addition to SBRR, regional differences consistently play a role in explaining TFP. There is no simple consistent regional pattern, except for London, which also has no relationship with SBRR. This region has higher weighted average TFP, although just a small number of extreme firms cause this difference, most observations are in-line with the rest of the country. More interestingly, for approximately one quarter of observations⁵⁷ greater Jacobian Diversity explains their higher productivity. The mainstream logic underlying the SBRR focuses on firm-level constraints and sees tax reductions, subsidies as solutions. Whereas the Jacobian argument is urban areas facilitate innovation through its institutional organisation and attraction of economic actors, i.e. innovation is spatial rather than firm orientated (Florida et al. 2017). Our findings support this latter case, but not for all areas and as such we would argue research and policy focused on diverse location factors rather than generic subsidies would prove to be more fruitful.

Clear policy implications and future research agendas flow from these findings. Tax reductions failed to liberate economic growth. Policy makers and firms failed to understand the mechanisms underlying how the incentives are used and how capitalisation of the benefits may occur. This makes challenging and changing policy difficult and as such

⁵⁷ This figure principally comes from combining end nodes for firms which are in the branch for observations of firms younger than 32.

requires the support of considered research. If the research finds overwhelming capitalisation, then governments would have the opportunity to reduce the salience of the tax and consequential political pressure by aligning the economic and statutory incidence of BR on property owners and removing the reliefs. If research finds this is not the case and the least productive firms are simply absorbing the gains and not innovating, again there would be a clear-cut case for removal of the reliefs. Both of these outcomes lead to the revocation of the policy, but without an evidence base, any policy change could prove to be politically complicated. The findings on Jacobian Diversity also hint at an alternative locally directed policy based on rigorous analysis of local constraints and opportunities.

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10.5.2 Small Business Economics Journal

Co-author of the following paper which is currently in the second round of review and revisions for the potential publication in the Small Business Economics Journal.

Note that the following manuscript is formatted according to the journal's requirements. Thus, it is inconsistent with the rest of the thesis.

Small Business Tax Policy: Reductions, Capitalisation, Age and No Growth

Dr Matthew Gobey⁵⁸ and Karolis Matikonis⁵⁹

Abstract

The incomplete devolution of English Local Government taxation powers has been constrained by central government's doubling of reductions in property taxes for small firms. The aim is to stimulate local growth, but we question the economic logic. We analyse reductions in place since 2005, with a newly linked dataset for all firms that incorporates administrative data down to local units. We find the reductions do not overcome supposed market failures, do not stimulate growth and once we control for firm age, that the targeted small firms do not produce extra employment. Young firms and larger firms have better growth rates, but there is no systematic size effect. High growth firms enjoy some locational benefits. We conclude that the tax reductions fail because they do not account for tax capitalisation, the basic characteristics of the average small firm or develop a clear mechanism for change among heterogeneous economic actors.

JEL CODES: C55 D22 H22 H25 J21 L25 O43

Keywords: Local Property Taxation, Capitalisation, Devolution, Growth, Firm Age

1. Introduction

The UK Government announced the “*end of the national tax on local growth*” (HM Treasury 2016 p. 9) in the autumn of 2015. The Government planned to devolve the setting and administration of English⁶⁰ Business Rates (BR), a property-based tax historically levied on all firms, from the national to local governments in 2020⁶¹. A principle element of this policy was greater local flexibility to reduce (not increase) rates set nationally for specific projects or types of firms and stimulate local growth. Yet in the March 2017 Budget, the same national Government undermined this flexibility. The Government significantly expanded and made permanent the current policy of National (English) reductions in the property tax for small firms (called Small Business Rate Reliefs or SBRR). The reductions now remove 600,000 firms (i.e. one third of all firms) from local tax bases and will reduce revenue by £9bn over 5 years (HM Treasury 2017). This raises concerns about future revenue, greater reliance on a small number of large firms and restrictions on local autonomy to achieve local objectives.

The policy to expand and reduce the property tax follows a persistent campaign by the small business community. The then Prime Minister told the Federation of Small business in 2014 that small business' number one complaint was Business Rates, which had risen relative to other costs (Adam and Miller 2014 and Cabinet Office 2014). In April 2017, we also saw a vociferous campaign against BR increases in areas such as London that led to some minor changes in that year's budget. Yet at the same

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⁶⁰ Northern Ireland, Scotland and Wales have slightly different BR systems and devolved control.

⁶¹ The timetable for the devolution of local finance has become unclear following the unexpected national elections in June 2017, which interrupted the legislative progress of the Local Government Finance Bill 2017. 50% Retention of BR began in April 2013, with 50% returned to central government for redistribution. Increasingly BR funds local activities, but the ability to vary rates is restricted and infrequently employed.

time, there were offsetting declines in rates across most of the country given the instruments revenue neutral structure, which received much less attention.

The narratives supporting this high profile policy draw together preconceptions about the universal negative effects of tax on firm growth and small firms' transformative growth potential, both of which are superficially plausible. In a novel combination of economic literatures, we question the theoretical and empirical cogency of these arguments using rich newly linked micro data. In support of SBRR, introduced in 2005, it is argued (e.g. repeated in HM Treasury, 2016) that BR forms a greater proportion of small firm's fixed costs than those of large firms and limits their ability to compete or innovate. This is not a sufficient condition for differential tax reductions, unless there is a greater social benefit from small firm's growth and becomes immaterial, if through tax capitalisation, the economic cost/benefit transfer to property owners.

We first address the policy mechanism and contribute to the tax capitalisation literature by exploring where the economic incidence falls and hence how the tax reduction could generate growth or innovation. Secondly, we explore the policy's target of small firms, which is based on the perception small firms contribute more to employment levels than their share of gross value added. This is a fundamental issue, as whether firm size has a systematic effect on employment has not been clearly resolved for the U.K. (Hijzen et al. 2010).

Critical to our novel combination of literature and analysis of the current tax reductions is our access to rich administrative data. We base our analysis on the Office of National Statistics (ONS) Annual Respondents Database X (ARDx). The ONS recently (July 2016) released this dataset, which is a combination of the Annual Business Inquiry and the subsequent Annual Business Survey. These are the largest datasets collected by the ONS, as they are an annual census of large firms and a sample of smaller ones. Importantly they include firm level administrative data on employment and turnover at both local unit and parent firm levels, making it a reliable and rich source, which overcomes a number of limitations on earlier work.

Our analysis of the tax reductions in place between 2005 and 2014 shows these tax reductions have not enabled any growth in employment; in fact, we argue there is no feasible channel through which they could. We then show that even if there were a mechanism the principle recipients, small old firms, are the least likely to be the catalyst for local employment growth. These findings bring into question the Treasury's homogeneous micro management of local property taxes.

We structure this paper in the following manner. In section two, we describe BR and their relevance. In section three, we discuss the two strands of theory that this policy combines on capitalisation and employment growth and confront them with the existing empirical evidence. In section four, we describe the data source and in section five, we discuss the estimation framework. We report the findings in section six and then conclude.

2. The Business Rates System

Business Rates (officially known as Non Domestic Rates) is a tax levied on all occupiers of commercial properties based on the property's estimated rental value. BR constitute a significant UK tax instrument, which raised £29bn in the 2017 tax year (office of Budget Responsibility 2017). For context, this is equivalent to over half that raised by the more widely analysed Corporation Tax. The U.K. is the most reliant country in the OECD on property taxes. In 2015 the U.K. collected 13% of tax revenue from properties (including domestic property), whilst the OECD average was 6% (OECD

2017). BR are particularly salient to the business community because the statutory incidence falls on all commercial property *occupiers* rather than the property *owners* and consequently they perceive it as a substantial additional fixed cost. However, we argue below that this is a perception given economic incidence ultimately transfers to property owners following capitalisation into rents.

Prior to 1990, each local government set its own BR, however since 1990 central government (and latterly devolved governments of the UK nations) has this power. The Valuation Office Agency (VOA) assesses the rateable value (RV) of each commercial property based on type of property, location, some types of installed machinery and other specified factors. The VOA revalues RVs on a five-year cycle, except for the 2010-15 cycle, which was extended to 2017. The 2010 revaluation was based on 2008 valuations.

Firms pay a proportion (multiplier) of the RV, e.g., for the financial year 2013-14 it was 47.1%. This can constitute a significant fixed cost and underscores the salience to firms. As and when BR are devolved, local governments would use the setting of the multiplier to encourage specific economic or social activities. Until April 2018, the annual increases in the multiplier were limited to increases in the Retail Price Index (RPI). Following wider pressure, they are now linked to the generally lower Consumer Price Index, rather than the RPI or indeed underlying property valuations.

The Local Government Act of 2003 introduced Small Business Rate Relief (SBRR) from 2005, until then BR was principally a flat tax. This relief (reduction) is partially funded by a supplement on the BR of firms occupying properties with slightly higher RVs. Initially the supplement was on RVs above £15,000 (£21,500 in the city of London) then from 2010 above £18,000 (£25,000) and from 2017 above £51,000. The SBRR started at 50% for properties with RVs up to £5,000 and tapered to zero at £10,000. In 2010, SBRR increased to 100% for properties with RVs up to £6,000 and tapered to zero at £12,000. This increase was for one year, but following pressure became permanent. As discussed in the introduction, the government brought forward from 2020 to 2017 the doubling of reliefs. The 100% threshold rose to £12,000 and tapered to zero at £15,000. This change increased from 400,000 to 600,000 the number of firms not paying BR and 900,000 (approximately half of all firms) receiving some reduction. The cumulative five-year reduction in revenue of this and other changes from 2017 is estimated at £9 billion (HM Treasury 2016b, 2017).

Table One provides a summary of the SBRR in England for the period we study. The nominal value of the relief rose rapidly to over £1 billion in 2014-15, more than double the value in 2010-11 and quadruple the 2007-8 revenue loss. The supplement paid by firms in more expensive properties has consistently failed to cover 50% of this relief, yet the multiplier supplement has risen from 0.82% in 2009-10 to 2.3% in 2014-15.

Table One: Business Rates Collected by Councils in England: 2005 to 2015
£ million (nominal values)

Year	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
<i>Net Value of BR Collected</i>	15,677	16,853	17,138	18,722	19,039	18,927	20,661	21,352	20,541	21,610
<i>Cost of SBRR Granted</i>	Not pub	Not pub	-259.9	-298.2	-333.2	-506.5	-784.3	-900.3	-985.9	-1,061.5
<i>Business Funding of SBRR^(a)</i>	Not pub	Not pub	132.3	176.3	176.6	372.8	375.6	399.2	447	543.2
<i>Net SBRR^(b)</i>	104	57	-147.8	-144.8	-187.9	-162.5	-432.1	-550	-590.5	-580
<i>SBRR Multiplier (pence)^(a)</i>	41.5	42.6	44.1	45.8	48.1	40.7	42.6	45	46.2	47.1
<i>BR multiplier (pence)^(a)</i>	42.2	43.3	44.4	46.2	48.5	41.4	43.3	45.8	47.1	48.2
<i>Additional multiplier to fund SBRR (pence)</i>	0.7	0.7	0.3	0.4	0.4	0.7	0.7	0.8	0.9	1.1
<i>Number of Properties ('000)</i>	1,651	1,663	1,681	1,692	1,698	1,718	1,735	1,759	1,771	1,787
<i>Total Rateable Value^(c)</i>	46,280	47,094	47,314	46,888	46,721	56,337	57,864	57,178	57,154	57,069

Notes: £ million (nominal)

Negative figures indicate relief being given

BR = Business Rates; Not pub = Not published

a: The Small business rate multiplier applied to firms with rateable value below £15,000 (City of London £21,500) between the financial years 2005-6 and 2009-10. From 2010-11 the thresholds rose to £18,000 (city of London £25,000). The national Domestic (standard) rate applies from this threshold and incorporates a supplement for the Small Business Rate Relief

b: includes adjusts with respect to any previous year

c: This figure multiplied by the multiplier does not equal the Net Value of BR collected as the net value accounts for reliefs, collection costs, adjudications

Source: Department for Communities and Local Government (DCLG) Official Statistics 2011 to 2015, author's construction

3. Policy Debate and Literature Review

This growth policy through reductions in property taxation covers two bodies of theory and empirical evidence, one for the policy mechanism and one for the economic group driving the desired growth. First, the policy's homogenous changes in taxation for small firms putatively overcome market failure, from financial and market power constraints. Givord et al. (2013) suggest that relative to larger firms, small firms tend to be financially constrained and this may mean they are more responsive to tax incentives. Secondly, the government focuses these reliefs on small firms occupying cheaper properties. This focus reflects policy makers' heuristic position (Shane, 2009), from which entrants and small firms can transform depressed economic regions, as they are believed to be more innovative and create more jobs than larger established firms. We argue that both the mechanism and the choice of the target group are poorly defined.

Occupiers lobby against BR because they face the statutory responsibility for payment but ultimately there is little evidence they face the economic incidence. Policy maker's failure to differentiate between the statutory and economic incidence of the instrument leads them to accept it distorts the decisions of small firms. However, taxation theory (e.g. Stiglitz and Rosengard 2015 or Fischel et al. 2011) illustrates how property taxes will fall on the owners of immobile factors, land and buildings, *ceteris paribus*. Property prices and rents then reflect differences in taxes, with lower taxes increasing the purchase price of property if the statutory incidence falls on the property owner or increasing the level of rent occupants are willing to pay if it falls on the occupant. Whichever the statutory incidence, the relative immobility of the capital would see capitalisation, i.e. economic incidence passes backwards to the property owner. Rents and taxation do not move independently but combine to give a total cost threshold for occupation. If basic theory holds then there would be no social benefit from SBRR as it is captured by property owners, a group very different to the perceived beneficiaries.

Bond et al. (1996)⁶² provide one of the few papers on BR post 1990. They examine the 1990 change from local government rates to the national uniform BR using rental data for a sample of 2,964 properties between 1987 and 1992. They show rents fell in response to BR rises more than in areas that saw a fall in BR during this transition period. They do not reject a pound for pound negative relationship between rents and BR, although with a wide confidence interval⁶³. Bond et al. (1996) thought institutional rigidities in the frequency of rent reviews implied full capitalisation of changes would take a number of years. Yet, over a short two-year period, they find that there is a significant incidence on rents from changes in BR for retail properties. This would suggest there is only a short window in which any variation in BR could influence employment or other outcomes.

Duranton et al. (2011) reinforce this finding on capitalisation of BR, although they also show some negative effect of higher rates on expansion. The authors apply innovative spatial methods to BR during 1984-89, when local governments previously set rates. They focus on large English manufacturing establishments and find BR had a significant negative impact on the level of (logarithmic) employment, for some growing firms. This indicates manufacturing occupiers still bear some of the incidence. The authors suggest that revaluation of a firm's BR obligations following expansion discourages the development of premises and hence employment or encourage them to move

⁶² Also see Bond et al. (2013) for work on capitalisation in Enterprise Zones

⁶³ Commercial research employing rental data finds 75% capitalisation of BR over a period of two to three years (Regeneris, 2015)

to areas with a lower BR. Although these factors will be limited by high relocation costs and because any change in BR will be net of the existing tax costs.

Duranton et al. (2011) find a positive but insignificant association between BR and entry into areas, after matching entrants within one kilometre. I.e., higher BR does not deter entrants. They suggest selection effects may be driving these findings, with capital-intensive firms leaving areas and opening up space for less capital-intensive firms to enter, as commercial space is limited in its supply response. This may be the case, although it would suggest that the vacant space meets new occupants' needs in terms of facilities and access to markets. More importantly, it indicates that there is some capitalisation of BR into new rents, otherwise entry would be in matched areas. In terms of local revenue, we can speculate there would be a limited effect on tax revenue and employment effects would depend on the selection of firms (with young and expanding firms entering as well as exiting) produced by relative BRs and demand conditions across areas.

We cannot simply contribute to the literature on property taxes and capitalisation in isolation if we are to provide comprehensive analysis of the policy framework. Integral to the policy and pressure from the business community is the perceived need to target reductions on small firms, which could transform local communities.

The narrative of transformative small firms implies that SBRR reduces financial constraints and this drives growth-enhancing pass through of lower prices or higher quality. Alternatively or in combination, firms may exploit market power and capture the tax reductions via increased mark ups. The pass through would lead to increases in market share at the expense of other firms, given there is no general demand stimulus. Holtz-Eakin (2000) challenges this narrative, arguing studies that suggest finance restrictions limit small firms have not shown too few or the wrong firms are funded. This finding weakens the efficiency arguments for intervention. Nightingale and Coad (2013) and Anyadike-Danes et al. (2015) show the distribution of growth from small firms is skewed by a very small proportion of high performing firms, away from the vast majority, which produce much lower growth. Consequently, we argue the principle recipients of SBRR will be old small firms creating limited growth. Given these findings, mark up increases would be more prevalent than pass through as old small firms enjoy a softer budget constraint aiding short-term survival, but not growth.

Reinforcing these conclusions is the output from research exploiting rich firm level datasets. The output frequently contests the perception that there is an inverse relationship between firm size and net employment growth (Nightingale and Coad 2013). Rijkers et al. (2014), Lawless (2014) and Anyadike-Danes et al. (2015) attribute this perception to the work of Birch in the late 1970s. Birch's work has subsequently been criticised for its failure to account for attrition and its ability to differentiate between gross and net flows.

Haltiwanger et al. (2013) using US Census Bureau data and Huber et al. (2017) using Austrian data provide the recent leading studies into net employment growth that challenge the view on small firm employment growth. Both these studies use a current average of employment growth as the dependent variable, rather than logarithmic change to overcome regression to mean effects and enable an integrated approach to entry and exit. They both employ a saturated non-parametric OLS approach, whilst Huber et al. (2017) additionally use their own two-step approach, which produces similar findings. These authors find that once they control for age, small firm's average growth is lower than that of larger firms, counter to the perception on which the reliefs are based. These findings are robust across institutional frameworks with Rijkers et al. (2014) work in Tunisia reaching similar conclusions. Haltiwanger et al. (2013) find a very limited positive relationship with size for firms with ten or more employees. This relationship weakens for continuing firms. Huber et al. (2017) and Rijkers et al. (2014)

find a stronger relationship for all firms, but again less so for continuing firms. Lawless (2014) for Ireland finds that there is no systematic effect of size, once she excludes the smallest firms.

These papers consistently show that small firms do not drive growth because young firms, which tend to be small, have a particularly large volatile effect on employment growth if they survive. These large effects dissipate quickly. Haltiwanger et al. (2013), Rijkers et al. (2014) and Lawless (2014) find that the effect of youth is over by year five. Huber et al. (2017) by about year three and in periods of crisis slightly older firms may contribute more to employment growth given their greater stability.

In terms of UK research on small firm employment growth, Hijzen et al. (2010) argue that it is rather limited and confined to the manufacturing sector. They also highlight the important debate over the relevance of firm size in employment growth is far from decided. These authors use decomposition methods on the Inter-Departmental Business register for the period 1997-2008. They conclude small firms across a wide range of sectors contribute a greater proportion of job creation than their employment share and a slightly greater proportion of job destruction. Overall, they find jobs created by small firms are no less persistent than jobs created by large firms. These findings are a little misleading for our purposes.

The findings need challenging. Firstly, they define small firms as those which employ less than 100 people, which seems unnecessary when the data contains finer detail and is at odds with the finer groupings in the papers cited above. Our research divides firms below 100 employees into four groups, 0-9, 10-19, 20-49 and 50-99 to more clearly decipher growth patterns. Secondly, they conflate age and entry. They show entrants, which tend to be small, contribute a significant proportion of growth. The introduction of age is one important additional firm characteristic, which even if it is not sufficient to capture the complexity of dynamic firm environments (Shane 2009, Anyadike-Danes et al. 2015), is sufficient to empirically question the targeting of SBRR.

The literature underscores the clear and significant disparities between basic tax theory, the evidence on small firm's transformative potential and the relevance of the assumptions underpinning the homogeneous SBRR policy. There are also clear points of contention in the application of the property tax as; it leads to a significant level of resistance, it is collected from a group that is not aligned with the economic incidence and it will limit the flexibility of local governments in meeting local needs. Our strategy directly confronts these disparities between the different literatures and practice in order to comprehend how elements may support but not inform policymaking.

4. Data Source

Critical to our novel combination of literature to provide comprehensive policy analysis is our access to rich administrative data. We employ the ONS' Annual Respondents Database X (ARDx) first released in July 2016. The ARDx combines two existing surveys, the Annual Business Inquiry (1998-2008) and the subsequent Annual Business Survey (2009-14). These are the largest datasets collected by the ONS (62,000 questionnaires and over 600 variables) and firms' representatives are legally required to complete the instrument⁶⁴. It is a census of firms with 250 plus employees and complex stratified sample across size, sector and region of smaller firms. The sample framework is constructed using administrative data on employment and turnover from PAYE and VAT⁶⁵ registrations. This can provide key information out of sample on changes in these variables as well as on births of firms.

⁶⁴ Response rates vary by sector and year but overall oscillate between the high 70 and low 80 percent.

⁶⁵ Pay As You Earn (PAYE) tax returns are collected by employers from each employee. Value Added Tax (VAT) registration is for firms above a turnover threshold who must then collect the tax on the goods and services they provide.

The power of the ARDx comes from the detailed information on both the dynamics of firms (*reporting units*) and their constituent units (*local units*). Access to administrative unit level data means we can control for mergers and acquisitions, which, if only observed at firm level, would lead to spurious measures of employment change due to changes in firm structures rather than true employment growth. Whilst data at parent level enables us to control for growth within appropriate age and size categories, as we can differentiate local unit activity from that of small single unit firms. Consequently, we can identify firms' organic growth, within appropriate classifications.

Firms report the BR paid in the survey period (October to October). This is not administrative data and hence it comes with the usual survey reporting issues. From this payment, we recover the rateable value and calculate firm's SBRR for those that observably meet the SBRR criteria. Please see the appendix.

In line with the recent net job creation literature, our dependent variable is the Davis and Haltiwanger (1992) net average job creation measure. This enables an integrated treatment of entering, exiting and continuing firms. It is a bounded symmetrical measure between minus and positive two for exiting and entering firms, between which we find net employment creation of continuing firms. Frequently firm-level employment growth is zero or negative and this precludes the use of logarithmic differences. Huber et al. (2017), Haltiwanger et al. (2013), and Tornqvist et al. (1985) discuss the use of the current average to overcome negative biases from using a base year size classification, resulting from mean revision effects or positive biases from an end year classifications.

At the local unit i , at time t , employment growth g is measured as a change in employment L , from the preceding year relative to the average employment over these years. i.e.

$$g_{it} = (L_{it} - L_{it-1}) / (0.5(L_{it} + L_{it-1})) \quad (1)$$

We aggregate equation one up to the firm/reporting unit as a weighted sum of local unit growth (g_{it}) for the year in which the firm f controls a given unit, i.e.

$$g_{ft} = \sum_{it} (0.5(L_{it} + L_{it-1}) / \sum_{i \in f} 0.5(L_{it} + L_{it-1})) g_{it} \quad (2)$$

This weighted aggregation from local to firm level allows us to account for a number of spurious changes in growth stemming from changes in local unit ownership as well as regression to the mean effects. The growth changes at local units will be greater than for firms given that the method accounts for within firm redistributions as well as non-organic growth⁶⁶.

Figure One about here

In *Figure One*, we report the cumulative distributions of employment growth by the level of relief in the 2005-13 period. We group firms by their maximum relief, zero, up to 25, 50, 75 or 100 percent. We also explode the central portion of these distributions between negative and positive 0.2 growth, given their proximity. This proximity of the distributions strongly suggests relief has little or no systematic effect on employment growth. The darker broader band represents those with zero reliefs.

⁶⁶ In a firm's year of birth there would be a missing value, consequently we insert two if there is any employment or zero if none.

These firms have the greatest proportion of firms with negative growth, but also the largest proportion of firms with positive growth. Over the range of positive values, the differences from other groups, except that for firms with up to 100 percent relief is difficult to untangle. Firms with up to 100 percent relief have the smallest proportion of both negative and positive values. Only 20 percent of this distribution reports positive current growth. The pattern changes sharply as we approach the upper bound of two, indicating there is a larger proportion of entrants that qualify for the highest reliefs.

5. Empirical Strategy

We employ a saturated OLS estimation framework of interacted independent indicator variables⁶⁷;

$$g_{ft} = \sum_{e=2}^6 \beta_e \text{Size} + \sum_{a=2}^6 \beta_a \text{Age} + \sum_{r=2}^6 \beta_r \text{SBRR} + \sum_{n=2}^3 \beta_n \text{BRperiod} + \sum_{s=2}^{96} \beta_s \text{Sector} \\ + \sum_{y=2}^{15} \beta_y \text{Year} + \sum_{x=2}^{\tau} \beta_x (\text{Size}, \text{Age}, \text{SBRR}, \text{BRperiod}) + \sum_{z=2}^{\omega} (\text{Sector}, \text{Year}) + \varepsilon_{ft},$$

where *size* is a vector of indicators, which varies with the employment groupings of 0-9 employees, 10-19; 20-49; 50-99; 100-249 and 250 plus. *Age* is a vector of the categories, *entrants* and years; 1; 2-4; 5-9; 10-19; 20 plus. The division provides detailed information on the critical initial years of young firms. After year one, the other groupings are divided to give balanced numbers and provide reliable estimates. *SBRR* captures categories of percentage reliefs i.e., zero, greater than zero to $\leq 25\%$; $> 25\%$ to $< 50\%$; $> 50\%$ to $\leq 75\%$; $> 75\%$ to $\leq 100\%$. The variable *BRperiod* separates the periods by the revaluation periods 2000, 2005 and 2010. *Sector* is a vector of indicators for 96 two-digit Standard Industrial Classifications (SIC revision 2007). We include indicators for the years 2000-2013, the period we use for the analysis. We do not use the final year of 2014 in the dataset in order to avoid conflation of all observations and subsequent exits. The dataset does not give specific information on local unit and firm exit. However, identifiers are specific to units and are not recycled, as such we use exit from the sample frame as an indicator of exit. The errors are Huber-White cluster robust errors as observations within firms are unlikely to be independent.

Initially, we estimate the average effects of *size* on weighted employment before adding controls for *Age* to assess its effect on the average adjusted effects for all firms and just continuing firms. We then add the *SBRR* and *BRperiod* indicator variables to estimate the average effects of SBRR on current employment growth. Finally, we focus on a subset of high growth firms, as defined by the EUROSTAT-OECD (2007). These are firms, excluding their year of entry, with three or more consecutive years of annualised employment growth of at least 20 percent, and in the initial year at least ten employees.

Given the use of a bounded dependent variable, we employ saturated models of the discrete variables. I.e., we have coefficients for all main and interaction effects possible for all independent variables. Angrist and Pischke (2009), Haltiwanger et al. (2013) and Huber et al. (2017) provide

⁶⁷ We undertook all work within the Secure ONS Virtual Microdata Laboratory on Stata 14. This limited the number of variables. We explored smaller divisions of firm size/age with greater saturation. These produced results in line with this specification.

discussions on this approach, which provides a best estimate of the examined variation in employment. The downside is that we estimate a large number of coefficients (our largest estimate has 1,421 coefficients). Consequently, we only report the average effects of principle variable groupings, adjusted for interactions.

6. Findings

Table Two contains the principle estimated average adjusted effects of firm size and age. It also reports Wald tests of the differences between average effects within each variable grouping. In *Figure two*, we represent these outcomes in a graphical format for easier comparisons.

In the results with no age controls, we simply explore firm size and find that the smallest firms (0-9 employees) are associated with a level of growth that is three times that of the next size grouping. The groups with employees from 20 to 249 employees do not have statistically different growth. However, the subsequent inclusion of controls for the distribution of age produces a dramatic shift in growth patterns.

The estimates with age group controls now show that growth of the smallest firms, 0-9 and 10-19 employees is significantly lower than that of the other size groups excluding the largest group for the firms with 250 plus employees. There is no systematic size effect for firms with 20 to 249 employees. The strong inverse relationship between age and growth leads to this dramatic shift. The average growth for entrants (year zero) is by definition close to the upper bound of two and that for firms a year after entry is still approximately a third of this level. Thereafter, there is a sevenfold fall to the 2-4 years age group and after ten years there is a marginally negative but significant effect of age. The youth effect then dissipates quickly for most firms.

Although the final patterns of average growth by size and age are similar to that in the cited literature, we show *in figure 2.1* the shift in average size effects comes through an increase in the average effects of larger firms, when we hold the age distribution constant, rather than a large reduction in the average effect of small firms. We present both the adjusted average coefficients and graphics with these same effects, whereas the cited authors do not generally present the adjusted average effects and the graphics are relative to the largest or oldest category. If we had simply followed suit, then we would have also presented similar findings, which seem to show a large drop in the average growth effect of small firms.

Finally, for the estimates of continuing firms, i.e. those that do not enter this period or leave in the next, the number of observations falls by 18 percent to just over seven million. The age effects follow a similar pattern to the preceding estimates but there is a consistent uplift in the scale of average effects reflecting the effect of exits and older firms are still worse performers. The size effects are all reduced in scale given the exclusion of entrants. The pattern in coefficients is similar to the preceding estimates, but differences are weaker. Firms with at least 250 employees now have growth greater than that the 0-9 and 10-19 employment reflecting the stronger effect of entry on smaller firms rates.

The findings are consistent with the work of Haltiwanger et al. (2013), Rijkers et al. (2014), Huber et al. (2017), and in particular Lawless (2014), although the shift in estimated size effects comes from increases for firms with more than ten workers, rather than declines for smaller firms. The findings are also in line with the broad-brush findings of Hijzen et al. (2010) for the UK. They established that firms with less than 100 employees in the manufacturing and service sector grew more rapidly than

larger firms do. However, they were not able to distinguish the patterns below this threshold or patterns among older firms. They did not observe that the smallest firms, which generally attract the highest reliefs, had the weakest mean growth. This final point is in line with Anyadike-Danes et al. (2015) and Nightingale and Coad (2013) who characterise the population of small firms as dominated by a large number of small old firms which contribute very little to employment growth.

Figure Two about here

Table Two: Adjusted Average Employment Growth, with Age Controls

Variable	1: No Age Control		2: Age Control		3: Continue Only ^a	
	Average Effect	Difference Test ^b	Average Effect	Difference Test ^b	Average Effect	Difference Test ^b
Size	β /SE	β /SE	β /SE	β /SE	β /SE	β /SE
0-9	0.229***		0.214***		0.094***	
	0.001		0		0	
10-19	0.076***	-0.153***	0.229***	0.015***	0.111***	0.018***
	0.001	0.001	0.001	0.001	0.001	0.001
20-49	0.077***	0.001	0.284***	0.055***	0.164***	0.052***
	0.001	0.001	0.002	0.002	0.002	0.002
50-99	0.078***	0.001	0.271***	-0.013***	0.169***	0.005
	0.001	0.001	0.005	0.005	0.003	0.004
100-249	0.073***	-0.005	0.249***	-0.022***	0.151***	-0.017***
	0.002	0.002	0.006	0.008	0.005	0.006
250+	0.083***	0.009***	0.204***	-0.045***	0.134***	-0.017*
	0.002	0.002	0.01	0.012	0.007	0.009
Age:						
Entrant^c			1.971***			
			0.001			
1			0.732***	-1.239***	0.768***	
			0.001	0.002	0.002	
2-4			0.103***	-0.629***	0.118***	-0.65***
			0	0.001	0	0.002
5-9			0.022***	-0.081***	0.031***	-0.087***
			0	0	0	0.001
10-19			-0.003***	-0.025***	0.003***	-0.028***
			0	0	0	0
20+			-0.009***	-0.006***	-0.005***	-0.008
			0	0	0	0
Year	Yes		Yes		Yes	
Sector	Yes		Yes		Yes	
R²	0.02		0.591		0.199	
N	8,708,887		8,551,485		7,027,722	
DF	1,143		1,172		1,164	

Notes:

(β /SE) In each entry the first row is the adjusted average & the second is the standard error *** 1% ; ** 5%; * 10%

a: Excludes entrants & final year of firms not subsequently in the sample frame

b: Wald test of the hypothesis there is no difference between successive averages

c: firm age in years

DF: number of variables: **Year:** Year controls: **Sector:** 96 2 digit SIC revision 2007controls

Source: ARDX dataset, Author's estimates

Figure Three about here

Table Three: Adjusted Average Employment Growth, with SBRR Controls

Variable	4: Full Model		5: Continue ^a		6: 6: High Growth	
	Average	Difference ^b	Average	Difference ^b	Average	Difference ^b
Size: 0-9	0.116***		0.071***		0.360***	
	0.001		0.001		0.028	
10-19	0.160***	0.044***	0.114***	0.043***	0.315***	-0.044
	0.002	0.002	0.002	0.002	0.012	0.031
20-49	0.179***	0.019***	0.132***	0.018***	0.374***	0.059***
	0.003	0.004	0.003	0.004	0.008	0.014
50- 99	0.173***	-0.006	0.135***	0.003	0.357***	-0.017
	0.006	0.006	0.005	0.006	0.008	0.012
100- 249	0.180***	0.006	0.136***	0.002	0.383***	0.026**
	0.007	0.009	0.007	0.009	0.008	0.012
250	0.160***	-0.02*	0.123***	-0.013	0.336***	-0.047***
	0.008	0.011	0.008	0.011	0.007	0.01
Entrant	1.887***					
	0.009					
Age 1	0.832***	-1.056***	0.844***		0.789***	
	0.01	0.014	0.011		0.081	
Age 2-4	0.153***	-0.679***	0.160***	-0.684***	0.442***	-0.346***
	0.003	0.011	0.004	0.012	0.022	0.084
Age 5-9	0.073***	-0.079***	0.078***	-0.081***	0.367***	-0.075**
	0.002	0.004	0.002	0.004	0.01	0.024
Age 10-19	0.039***	-0.034***	0.041***	-0.037***	0.347***	-0.02*
	0.001	0.002	0.001	0.002	0.005	0.011
Age: 20+	0.023***	-0.016***	0.025***	-0.016***	0.351***	0.004
	0.001	0.001	0.001	0.002	0.004	0.006
SBRRc:	0.142***		0.099***		0.352***	
Zero	0.001		0.001		0.004	
SBRR	0.135***	-0.007	0.092***	-0.008*	0.265***	-0.087***
25%	0.004	0.004	0.005	0.005	0.037	0.038
SBRR	0.140***	0.006	0.096***	0.004	0.442***	0.177***
50%	0.004	0.006	0.005	0.006	0.044	0.057
SBRR	0.142***	0.002	0.100***	0.004	0.674***	0.232***
75%	0.005	0.007	0.005	0.007	0.056	0.069
SBRR	0.129***	-0.013**	0.084***	-0.016	0.408***	-0.266***
100%	0.003	0.006	0.003	0.006	0.027	0.062
R ²	0.416		0.142		0.354	
N (DF)	900,101	(1,421)	795,871	(1,381)	23,413	(1,129)

Note: The first row is the adjusted average & second is the standard error *** 1%; ** 5%; * 10%

a: Excludes entrants & final year of firms not subsequently in the sample frame

b: Wald test of the hypothesis there is no difference between successive adjusted averages

c: SBRR category numbers indicate upper bound of mutually exclusive groups

(DF): number of variables, Estimates include Year, BR period & 96 2 digit SIC (2007) controls

Source ARDx dataset, Author's estimates:

In *Figures Three* and *Table Three*, we report results incorporating the SBRR and BR period controls for all firms, continuing firms and a subset of high growth firms. Even though we see a sharp reduction in the number of observations, small firms continue to have significantly lower average adjusted growth, but the size effects for groups with 20 to 249 employees are no longer significantly different from each other. Age groups maintain the same inverse relationship, but the decline between one year and 2-4 year old firms is now by a factor of 5.4 for all firms and 5.25 for continuing firms, rather than a factor of seven estimated above.

Importantly the SBRR coefficients do not identify any systematic effect on employment for all firms and continuing firms. There is very little difference in mean effects for firms receiving zero relief, through to those receiving 75 percent relief. Thereafter, there is some evidence of lower growth for those receiving up to 100 percent relief by between 11 and 16 percent to both the 75% and zero SBRR groups, respectively. Consequently, we demonstrate the tax mechanism is ineffective in increasing employment and reliefs would seem to capitalise into occupation costs.

Finally, we focus on the subgroup of high growth firms. In *Table Four*, we group firms by the relief rates and observe the proportions, which meet the high growth criteria, decline rapidly from 8.5 percent for firms attracting zero relief to around 0.5 of a percent for firms claiming up to the maximum⁶⁸. Some care is needed with these figures, given that the higher rates of relief will have only been available from 2010 and as such will have been initially affected by the 2007/8 recession. We also calculate Gazelles, firms that become high growth before their fifth birthday, only constitute 0.98 of a percent of pooled observations of firms between three and seven years old. Whilst for older firms the percentage is 1.85.

Table Four:
High Growth Firms, Proportion of Pooled Observations by Relief Level
2000-13

SBRR Maximum	Proportion High Growth
0	0.085
25%	0.018
50%	0.015
75%	0.006
100%	0.004

Notes: some firms will have more than the minimum three years of annualised growth of 10%, Entrants excluded. Source ARDx dataset, author's calculations

Given the size and age thresholds, the employment estimates for high growth firms show a strong rise in overall average effects relative to the preceding estimates. Age is also less important, with a much shallower decline as we move from one year old firms to two-four year old firms of approximately 1.8, compared to the previously estimated fivefold decline in growth.

Importantly, we now find significant differences by SBRR group. Firms that receive up to 25 percent relief have a lower average adjusted effect than those firms that receive zero relief. Thereafter, the average growth effect is significantly higher than both these groups, peaking for firms with up to

⁶⁸ Some firms have more than three years in which they are classified as high growth

75 percent relief. The estimated effect for the 100 percent relief group is now in line with the preceding two groups rather than being significantly lower than all other relief groups.

It would be difficult to say that there is a systematic effect of SBRR on employment growth, given the findings from the larger sample of all firms. This leads us to surmise we are picking up location effects for these very small groups of firms (between 1.5 and 0.4 percent of observations), which are stronger for those occupying cheaper or smaller units. This is something we wish to examine with detailed geographical information in future research.

7. Conclusions

The “*end of the national tax on local growth*” may simply reflect political rhetoric, yet the underlying policy perspective (Shane 2009) of taxation constraining transformative small firms pervades the supporting consultation and policy documentation on SBRR (see HM Treasury 2016). In this paper, we confront the assumptions that taxation restricts growth and small firms produce greater growth than larger firms with rich firm level data.

We show that the chosen policy mechanism of property tax reductions is not associated with employment growth, which we argue reflects their capture by property owners. It also suggests that this tax in general does not have a large long run effect on occupiers, as its level and changes pass backwards via rents and building value adjustments making it an efficient form of taxation. The complications arise from the misalignment of statutory and economic incidences. If property owners became liable, the salience to firms would be significantly reduced, as would the political pressure. It would be clear the tax is on the economic rents (capital gains), which in part derive from the social context rather than a confusion with economic activity. Other gains would be a return to a flat tax, as the power of arguments for preferences reduce and a fall in the number of valuation appeals, if the reformed tax only valued property not the productive additions made by occupiers.

Yet even if the SBRR had an effect on costs, the target group would not provide any greater social returns, once we simply account for age differences. We find medium sized firms provide greater and probably more stable employment growth. Young firms also provide strong employment growth, but this rapidly dissipates and is conditional on these new firms surviving. There may be a positive association between the larger reliefs and high growth firms’ employment, but identifying this small number of firms’ ex-ante is problematic.

In line with Holtz-Eakin (2000), Shane (2009) and Anyadike-Danes et al. (2015), we conclude generic reliefs based on naïve assumptions about homogeneous jobs and supply side restrictions do not provide social returns. Institutional frameworks, which target time constrained assistance on specific complex and shifting productivity and growth constraints as well as the quality and stability of employment may be better alternatives, but these require a richer understanding of firm level dynamics. The OECD (2015) document some viable alternatives that do not erode tax bases. Even these interventions cannot succeed in isolation. They need well-developed local and inclusive infrastructure, education and healthcare and rigorous sectoral analysis if they are to succeed. These factors require locally directed provision, which in turn requires a stable and diversified tax base.

At a time of substantial changes in the powers of English local governments, this paper provides important research in the understudied area of local business taxation and adds to the debate on firm size and age. The results underscore concerns that the current framework for the devolution of tax raising powers could destabilise some local tax bases as local governments become more dependent

on a smaller and smaller number of larger firms restricting their ability to enable communities and economic growth.

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