Determinants of Total Factor Productivity: Evidence from US Compustat Firms and Triadic Patent Families

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Abstract

This study examines the determinants of total factor productivity (TFP) in US firms. Moreover, the firms' technology diversification and its effects on TFP is explored. This study uses the US Compustat database during the period 1976-2009. The overall results indicate that both firm and industry characteristics can be important factors for TFP. In addition, the determinants of TFP are examined during economic recession and economic growth periods. The results show the firms that their business activities are more related within similar technologies are able to report higher productivity, especially during economic recession periods. As such, firms can monitor productivity for strategic reasons such as corporate planning and organisation improvement. It can also be used for tactical reasons such as project control or controlling performance to budget.

Keywords: Firm and Industry Characteristics; Innovation Knowledge; Panel Data; Procyclical and Countercyclical Factors; Relatedness Measure; Total Factor Productivity; US Firms; Triadic Patents

1. Introduction

TFP growth can lead to economic growth and welfare increase. Therefore, it is worthwhile to examine the determinants of TFP and to explore in which of these determinants the policy should focus on, in order to boost the performance of TFP. The economists have long found that economic growth can be explained by inputs of production, such as labour and capital, only by a portion. The unexplained or residual portion, which has been firstly developed by Solow (1957), reflects advances in production technologies and processes and it is defined as the TFP growth. Solow (1957) suggest that cross-country differences in technology may generate important cross-country differences in income per capita. This pivotal role of TFP in explaining growth has been examined by subsequent studies (Romer, 1986; Lucas, 1988). Most empirical studies examining this residual, support this prediction (Krugman, 1994; Hall and Jones, 1999; Easterly and Levine, 2001). On the other hand, other studies implicitly consider all determinants of output growth as inputs. However, Miller and Upadhyay (2000) suggest that many of these determinants may affect the output only through their effect on the efficiency use of the real inputs, as the human and physical capital. Therefore, these potential determinants of output growth have a direct effect on TFP and it is important to understand and model the sources of TFP growth.

The main aim of this paper is to examine the determinants of the TFP, including firm characteristics, such as firm's size, age, short-term and long-term debt, liquidity, value added index, weighted average relatedness measure, market share and financial constraints. In addition, industry-sector characteristics are explored, including the *Herfindhal* index, the average industry growth and the entry and exit of firms. Productivity is an important indicator that represents the growth of each economic agent and the analysis of the firm's technical efficiency is important. Inefficiency occurs from a firm's external and internal factors. Therefore, a firm should identify such internal and external factors of inefficiency in order to eliminate these factors and thereby to enhance its competitiveness and achieve growth in the long-run period. This is why it is necessary to analyse the efficiency of firms and conduct researches on the determinants that promote efficiency.

The question of whether firm or industry characteristics determine the firm's TFP is important and has implications for welfare analysis and, ultimately, for the design of competition policy. Using a dynamic firm-level panel data set, as well as, a stochastic frontier analysis approach, this study identifies the determinants of TFP and assesses the relative importance of firm and industry effects. The TFP model includes firm-specific and time-varying estimates accounting for both firm heterogeneity and industry effects.

Several studies found that firm characteristics, like market share, firm growth, Research and Development (R&D) and advertising account for the differences in long term profits (Teece et al., 1981; Rumelt, 1991; Yurtoglu, 2004). Teece et al. (1994) found that coherent firms are more likely to be successful than incoherent ones due to the economies of scope that they enjoy by sharing similar and complementary scientific and technical competencies. Mogha et al. (2015) examined the TFP in 50 private sector hospitals in India applying data envelopment analysis (DEA) and Malmquist productivity index (MPI) method. Mogha et al. (2015) found that productivity change is largely explained by efficiency change rather than the technology change. Similarly, Mogha et al. (2014) using DEA, examined the TFP in 27 governmental hospitals in Uttarakhand of India. Their findings suggest that TFP has been increased by 4.9% per year. A slightly higher growth is observed in technical efficiency (TE) by 2.6% than in technology by 2.2%. Mogha et al. (2014) suggest that TFP could be improved by reallocating staff from inefficient hospitals to the efficient ones and investing on new medical technology. Sufian (2012) examined the changes of TFP in Philippines banking sector during the post-Asian financial crisis period using the MPI method. The findings show that both domestic and foreign banks have exhibited increases in productivity due to technological regress rather than on efficiency decline. Sufian (2010) examined the impact of the 1997 Asian finacial crisis in Malaysias and Thailand banking sectors using Data Envelopment Analysis (DEA). Sufian (2010) found that the most efficient banks are those with higher loans intensity and higher proportion of income originated from non-interest sources, while liquidity and expense preference behaviour have negative relationship with bank efficiency.

The remainder of the paper is organised as follows: Section 2 presents the data, while the econometric framework is developed in Section 3. Section 4 presents the empirical results and in section 5 the concluding remarks are reported.

2. Data

The data used in this study have been derived from the US Compustat Database and the period of study is 1976-2009. US Compustat Database provides financial, statistical and market information on active and inactive companies in USA.

Regarding the TFP, labour and capital are the two inputs considered. More specifically (L_{it}) is defined as the number of employees in firm *i* and at time period *t*. Capital (K_{it}) is defined as the market value of total assets using the adjustment approach which has been proposed by Salinger and Summers (1983) and it is explained in details by Whited (1992). The capital is converted into real terms using the cost of capital deflator. This definition is consistent with the notion employed in the previous literature, that financial factors matter for productive and investment purposes (Gertler, 1988; Fazzari et al., 1988; Gilchrist, 1990; Whited, 1992; Dhawan 1997).Output Y_{it} usually is the value added or gross revenue. In this study Y_{it} is defined as the sales minus the cost of goods plus inventories, and it is converted into real terms using the GDP deflator. The variables used in the estimation analysis are split in two categories: firm and industry sector characteristics and have been chosen based on the study by Ospina and Schiffbauer (2010) including also additional factors.

3.1 Firm characteristics

The first factor is the *age* of the firms, while *Size* is another important factor and it is defined as the logarithm of the total sales revenue. Regarding debt two measures are obtained: *short-term and long-term indebtedness*. These variables are calculated as the ratio of short-term and long-term debts respectively over the total assets. *Liquidity* is the ratio of current assets to short-term debt and it is used in order to determine a company's ability to pay off its short-terms debt obligations, while *value added index* is the ratio of sales revenue to the cost of sales. Other factors include the *assets to sales ratio* and *Market share*, which latter is calculated by dividing firm’s annual sales to the total sales of the industry for each period. Part of the differences in profitability and profit persistence, thus in TFP, may be due to the differences in risk and how financially constrained the firms are. Therefore, a *risk proxy* and a financial constraint index are used in the analysis. The risk proxy is defined as the deviation between firm’s profits and the average profit of the sector. The financial constraint index employed in this study, is the *Whited-Wu Index* (Whited and Wu, 2006) and it is defined as:

$$WW_{it} = -0.091 CF_{it} / K_{it} - 0.062 PD_{it} + 0.021 DLT_{it} / TA_{it} + \\ - 0.044 \log(TA_{it}) / K_{it} - 0.035 FSG_{it} + 0.102 * ISG_{it} \quad (1)$$

CF_{it} denotes the cash flows which is equal to Income before Extraordinary Items plus Total Depreciation and Amortisation. Extraordinary Items are defined as the gains or losses which are infrequent and unforeseen. Total Depreciation represents the decline of fixed assets, such as buildings and equipment, while amortisation shows the decline in the value of liabilities, like debt. CF_{it} is divided by K_{it} where the latter indicates property, plant, and equipment, PD_{it} denotes the positive dividend which is a dummy variable that equals one if cash dividend is positive and 0 otherwise. In this case, cash dividend is defined as the money which is paid to stockholders out of the firm's current earnings. DLT_{it}/TA_{it} is the ratio of the long term debt to total assets, where total assets refer to the total amount of assets owned by the firm including fixed assets like buildings and equipment, cash and accounts receivable among others. $log(TA_{it})$ is the natural logarithm of total assets, FSG_{it} denotes the sales growth in firm *i* at time *t* and ISG_{it} expresses the industry sales growth in the firm's industry. Financially more constrained firms have higher *WW* index, while *WW* index is lower for the less constrained firms. Firms falling within the top (bottom) two deciles of the *WW* index score are classified as financially constrained (unconstrained).

The final firm-level factor examined in this study is the weighted average relatedness of neighbours (WARN) applied by Teece et al. (1994) and Nesta and Saviotti (2005). *WARN* measure requires the preliminary construction of a *maximum spanning tree* (MST). This measure captures the strength of the association between activity-technology *k* and its closest neighbours. Thus technology classes can be paired in *n(n-1)/2* possible ways but only *n-1* of these pairs have to be chosen in order to produce a graph that connect all of them. Such a tree is defined as M_{kl}=1 if a link between technological activity *k* and *l* is a part of the tree and 0 otherwise. Given the maximum spanning tree, the *WARN* index is defined as:

$$WARN_{kit} = \frac{\sum_{l \neq k} q_{lit} M_{kl} \tau_{kl}}{\sum_{l \neq k} q_{lit} M_{kl}} \quad (2)$$

$WARN_{kit}$ is defined as the degree to which technology *k* is related to all other technologies $l \neq k$, present within the firm, weighted by patent count $q_{lit.}$, for firm *i* and time *t*. $WARN_{kit}$ may be either positive or negative, where the former (latter) indicates that technology *k* is strongly (weakly) related to all other technologies within the firm. The measure τ_{kl} is the relatedness measures between any two technologies *k* and *l* by comparing the observed frequency on which the two technologies are jointly used with the expected frequency of their co-use. An effective innovation system is important for TFP growth. The chief role of an innovation system is to foster R&D that, in turn, leads to new products, processes and knowledge. Therefore, patents can be a good indicator of knowledge as these are the result of R&D that have been invested on new products and knowledge.

Economists have only recently become interested in the effects of social pressure and information spillovers through the effects of social networks on individual behaviour. Measures of relatedness allow us to examine and identify the effects of firms' networks. More specifically, diversification is more likely to be successful within related activities sharing similar business lines and production chains, leading to higher profits and higher productivity levels (Rumelt, 1974; Palepu, 1985; Schoar, 2002).

OECD Triadic Patent Families (TPF) database is used, which covers patent applications filed to the European Patent Office (EPO), the Japanese Patent Office (JPO) and granted by the United States Patent and Trademark Office (USPTO). The data have been compiled using patent linkages provided in Patent Statistical (PATSTAT) Database of April 2013 (OECD, 2013).

3.2 Industry-Sector characteristics

The first industry factor used in the analysis is the *concentration*, which is calculated from the market share obtained for each firm of the industry using the *Herfindhal* index. The second is the *average industry growth* and it is obtained from the sales growth of all firms belonging to the same industry. Changes in the size of industry may be an important factor on explaining profit differentials, which profits are used for investments and consequently lead to TFP growth.

The next variables used in the analysis are the *entry and exit of firms*. These variables are obtained by dividing the number of firms that enter and exit respectively to each industry by the number of firms in the same industry. The entry is used in order to estimate the barriers to entry. In this case a relatively greater number of entries would be associated with lesser barriers to entry, while a higher number of exits would imply lesser barriers to exit. A negative impact of entry of firms is expected as an increase in product market competition will reduce the expected future profits from innovations and hence will reduce the rate of technical change- the so-called “rent dissipation effect”. In addition, the intensive competition will decrease the expected durability of new innovations –the so-called “creative destruction”- and hence the incentive of innovation will be reduced. *Country* is a dummy variable which indicates and controls for the location of the headquarters. While the majority of the firms’ headquarters on the sample are based in USA, there are however firms whose headquarters are located in other countries. This variable is used to examine the firm's behaviour in domestic and international level, as investments, taxes and bureaucracy. *Sector* is a dummy variable indicating the sector where the firm is active and controls for the economic and technological activity. Finally, *economic recession* is a dummy variable obtaining value 1 whether a period is characterised as economic recession and 0 for economic expansion-growth. This time series is an interpretation of US Business Cycle Expansions and Contractions data provided by The National Bureau of Economic Research (NBER) available at www.nber.org/cycles/cyclesmain.html.

3. Methodology

3.1 Panel Stochastic Frontier Analysis (PSFA) and Total Factor Productivity

The stochastic frontier analysis (SFA) has been introduced by Kumbhakar (1987). The general stochastic production frontier model is described below, where y is the vector for the quantities produced by the various firms, x is the vector for production factors used, and β is the vector for the parameters defining the production technology.

$$y_{it} = f(t, x, \beta)\exp(v_{it})\exp(-u_{it}), \quad u_{it} \geq 0 \tag{3}$$

The subscripts i and t denote firm and year respectively. The v and u terms (vectors) represent different error components. The first one refers to the random part of the error, while the second is a downward deviation from the production frontier, which can be inferred by the negative sign and the restriction $u \geq 0$. Thus, $f(t, x, \beta) \cdot \exp(v)$ represents the stochastic frontier of production and v has a symmetrical distribution to capture the random effects of measuring errors and exogenous shocks that cause the position of the deterministic nucleus of the frontier, $f(t, x, \beta)$. The level of technical efficiency (TE), is the ratio of the observed output to the potential output, given by the frontier, and it is captured by the component $\exp(-u)$. Assuming a translog technology with two production factors, capital (*K*) and labour (*L*), the model can be expressed as:

$$\begin{aligned} \ln y_{it} &= \beta_0 + \beta_t t + \beta_K \ln K_{it} + \beta_L \ln L_{it} + 0.5\beta_{tt} t^2 + 0.5\beta_{KK} (\ln K_{it})^2 + \\ &+ 0.5\beta_{LL} (\ln L_{it})^2 + \beta_{KL} \ln K_{it} \ln L_{it} + \beta_{Kt} \ln K_{it} t + \beta_{Lt} \ln L_{it} t + v_{it} + u_{it} \end{aligned} \tag{4}$$

The components of productivity change can be identified from algebraic manipulations from the deterministic part of the production frontier depicted in (4) and combined with the usual expression for the productivity change becomes:

$$\delta TFP = \frac{\dot{y}}{y} - s_k \frac{\dot{K}}{K} - s_L \frac{\dot{L}}{L} \tag{5}$$

From the deterministic part of (5) we have:

$$\frac{\dot{y}}{y} = \frac{\partial \ln f(t, K, L, \beta)}{\partial t} + \varepsilon_k \frac{\dot{K}}{K} + \varepsilon_L \frac{\dot{L}}{L} - \frac{\partial u}{\partial t} \tag{6}$$

In the expressions that follow, *RTS* denotes returns to scale with $RTS = \varepsilon_K + \varepsilon_L$, δ_K is the growth rate of capital $\dot{K}/K$ and g_L is the growth rate of labour $\dot{L}/L$, while ε_K and ε_L denote respectively the labour and capital elasticities. The terms $\lambda_K = \varepsilon_K/RTS$ and $\lambda_L = \varepsilon_L/RTS$ are defined as normalised shares of capital and labour in income. Combining (5) and (6), we have:

$$\begin{aligned} \delta TFP &= TP - \dot{u} + (RTS - 1)[\lambda_K \delta_K + \lambda_L \delta_L] + \\ &+ [(\lambda_K - s_K)\delta_K + (\lambda_L - s_L)\delta_L] \end{aligned} \tag{7}$$

That is, total factor productivity growth can be split into four elements:

- The technical progress, measured by TP = $\partial \ln f(t, K, L, \beta)/\partial t$
- The change in technical efficiency, denoted by $-u$
- The change in the scale of production, given by $(RTS-1)\cdot[\lambda_K \delta_K + \lambda_L \delta_L]$
- The change in allocative efficiency, measured by $[(\lambda_K - s_K)\delta_K + (\lambda_L - s_L)\delta_L]$.

3.2 Dynamic System Generalized Method of Moments (GMM)

Having panel data allows us to identify the model from changes in levels of the TFP persistence determinants within firms rather than between firms. This reduces the possible endogeneity bias in the estimates since unobservable characteristics of the firm and industry characteristics may be correlated with explanatory variables. The model considered is a fixed effects model with lagged dependent variable and it is defined as:

$$TFP_{i,j,t} = a_i + \beta_1 TFP_{i,j,t-1} + \beta' X_{i,j,t} + \mu_i + l_j + \theta_t + \varepsilon_{i,j,t} \quad (8)$$

$TFP_{i,j,t}$ and $TFP_{i,j,t-1}$ is the total factor productivity, calculated as in previous section, in levels and with one time lag respectively, subscript i denotes the firm, in location j and in time t. X is a vector of the explanatory variables, discussed in the data section. Set μ_i denotes the firm-fixed effects, l_j is a location fixed effects; θ_t is a time-specific vector. Finally, $\varepsilon_{i,j,t}$ expresses the error term which is assumed to be independent and identically distributed (*iid*). Standard errors are clustered at the zip code level.

This study uses the Blundell- Bond (1998) system GMM estimator in order to solve various problems. Firstly, such as the correlation of time-invariant fixed effects, firm effects and geographical characteristics the explanatory variables and the rise to autocorrelation due to inclusion of the lagged dependent variable. Additionally, the

GMM system estimator was designed for small- time sample (*T*) and large- number of firms (*N*) panels. In addition, the regressions control for the economic recession periods, examining in this way which factors are procyclical and which are countercyclical. Moreover, both the surviving and non-surviving firms are included in the analysis by controlling with the number of firms that enter and exit in an industry giving a more comprehensive depiction of the US economy during the period examined. Furthermore, including the relatedness measure *WARN*, it is useful to identify whether diversification is more likely to be successful within related activities in similar business activities and networks.

4. Empirical Results

4.1 Production Function and SFA

The μ is statistically significant indicating that the half-normal distribution is more appropriate in relation to the normal truncated distribution. The value of *gamma* is significant indicating that the firms do not operate at full capacity. Also *gamma* measures the variability of the two sources of error (white noise disturbance and inefficiency error), reached the level of 0.7815. This result means that about 78% of total variance of composed error of the production function is explained by the variance of the technical inefficiency term. This represents the importance of incorporating technical inefficiency in the production function. The term η refers to technical inefficiency. In the case that this term is positive (negative), technical inefficiency will be decreasing (increasing) in time. If the value is null then it is considered that technical inefficiency does not vary in time - also called persistent inefficiency.

The results show the capital – as machinery and equipment- has a significant and positive effect on output as it was expected. In order for the capital to be even more successful the allocation of resources should be dealt with under two headings: Firstly, is the structural change, which is the allocation of resources to the most productive sectors or parts of the individual firm. Secondly, is the allocation of savings to investments with the highest returns, where high-quality investments imply a higher probability for TFP growth. Regarding the coefficient of the labour is positive and significant; however in the case examined, because of the data unavailability, only the number of labour is obtained. This is the main drawback of this analysis as the human capital -for example, schooling, health and training- can be a more informative input. Nevertheless, this study suggests the use of human capital in future research applications. Overall, the positive sign of the above-mentioned coefficients are positive indicating that the two inputs are complements. The positive sign of coefficients β_t *and* β_{tt} indicates that the neutral part of technical progress has a positive effect over production. The positive sign of the coefficients β_{KK} *and* β_{LL} indicates that the non-neutral part of technical progress is positively associated with capital and labour. Finally, the cross coefficient β_{KL} is negative indicating that the demand for labour reacts positively to a decrease in the quantity of capital (especially in skilled labour). Therefore, the use of more detailed information on human capital can provide a more precise estimate about the substitution between capital and labour.

Based on the Wald statistic, the null hypothesis that all coefficients are jointly insignificant or equally to zero- including the second order coefficients and the cross products- is rejected. Thus, the translog production function is preferred over Cobb-Douglas specification form.

(Insert Table 1)

However, the purpose of this study is to examine the determinants of TFP and the results are presented and discussed in the next section.

5.2 Determinants of TFP using GMM

In Table 2 the GMM estimates for the determinants of the TFP using the linear and non-linear specification models are presented. All the results are robust for the following reasons: First, the instruments used in the regressions are valid, because the Hansen test does not reject the null hypothesis of exogeneity. In addition, based on the Hansen test, the validity of the lagged variables in levels and in difference as instrumental variables is accepted. Thirdly, we note that there is no second-order autocorrelation of errors for the difference equation, because the test of the second order autocorrelation (AR2) does not allow us to reject the null hypothesis of absence of the second-order autocorrelation. Moreover, the null hypothesis of over-identification restrictions is not rejected at 1% and 5% level. Generally, the rule of thumb is to keep the number of instruments less than or equal to the number of groups – defined as the number of firms-and this rule of thumb is met in the case examined.

The *age* is significant only in linear terms and it is positive. The *size* itself presents a positive sign, while the quadratic term becomes negative and significant. This could mean that the inclusion of other relevant variables and the alternative non-linear specification into analysis shed true light on the relationship between firm size and its TFP. Moreover, this indicates that size after some point contributes in a negative way on TFP. Positive sign of *size* variable implies that if a firm grows in size, the TFP of the firm is increased. Possible reasons for such size-TFP behaviour can be due to the market power and the market experience. However, the quadratic negative term shows that the size of the firm has negative effects on TFP after some point, indicating the administrative layers and bureaucracy factors.

Short-term, *long-term debt* and *assets* present a significant quadratic relationship. More specifically, the relationship between TFP and the short-term indebtedness is positive and significant, while the effects of long term indebtedness on TFP are negative. The results suggest that *short-term* debt has a positive effect on TFP, such as allocation of debt on investments. However, after some point, based on the non-linear model in Table 2, the *short-term* debt reduces TFP. Regarding *long-term* debt only the linear specification is significant. On the other hand, the asset to sales ratio presents negative effects on TFP. This may indicate that companies either over-invest in the fixed assets or do not improve their performances or they do not use their fixed assets efficiently. In addition, the negative effects of assets can be attributed to the start-up firms which usually present low performance at the beginning of their activity. However, based on the non-linear model, the asset to sales ratio is negatively associated with TFP at the beginning, while after some point this factor affects positively the TFP.

As it was expected, the value added index, the market share, the industry concentration index, the industry growth and the *WARN* index present a positive and significant effect on TFP. More specifically, the market share and the concentration index lead to lower production costs and higher efficiency, especially for the larger firms, which apparently are capitalised based on economies of scale. The liquidity and the value added index present a positive effect on TFP. This is explained by the fact that the productivity in the illiquid firms is strongly constrained by the availability of internal finance. *WARN* relatedness measure has positive effects on TFP. Knowledge portfolio characteristics such as the diversity and the coherence have to affect productivity as they reflect synergies among pieces of heterogeneous knowledge. Scott and Pascoe (1987) and Teece et al. (1994) among others find that the distribution of firm's activities is not random. Firms distribute their activities into areas, where they can apply their knowledge (Nerkar and Roberts, 2004). The existence of these synergies suggests that there are knowledge spillovers between different pieces and areas of knowledge. A firm that expands its knowledge in related areas, will be hence more efficient than other firms.

Also *WARN* index based on patents has two faces: the first is innovation, while the second facilitates the understanding and imitation of others' discoveries. The latter is related to the absorptive capacity and the allocation of efficient technology. Patents and relatedness measures are likely to take place at firm or industry level, but they will ultimately promote overall economic development through enhanced productivity. Innovation through patents has two sources, domestic or it can be generated from international spillovers. However, this study goes one step further. It uses a relatedness measure based on patents as a proxy to knowledge, rather using only the number of patents, like previous studies did (Chen and Dahlman, 2004).

Generally, value added presents the strongest positive effects on TFP followed by the lagged TFP, *WARN* and *size.* On the other hand the *entry of firms* presents the strongest negative effects on TFP because the increase in product market competition reduces the expected future profits from innovations and hence decreases the rate of technical change.

(Insert Table 2)

In table 3 the regression estimates for TFP during economic recession and economic growth periods are reported. The results are similar with those reported in table 2. It should be noticed that the *WARN* measure has significantly higher positive effects on the TFP during the economic recession than in economic growth periods. This indicates that the firms, where their business activities are more related within similar technologies, are able to report higher productivity. Furthermore, this indicates that these firms are also more sustainable during the economic recession periods. Additionally, this measure becomes a more significant factor during the recession periods, suggesting that firms which are diversified in related technologies are more able to correspond to the risks of economic recession periods and are more able to sustain their efficiency.

(Insert Table 3)

5. Conclusions

This study examined the main firm and industry determinants of TFP. Initially, a stochastic frontier analysis (SFA) was implemented in order to calculate the TFP. The translog function is found to be a more flexible specification form for the production function than the Cobb-Douglas.

The findings support that firms and managers should consider both firm characteristics. More specifically, the TFP is positively associated with the firm’s age, liquidity and value added index, as more liquidity implies additional investments and capability for the firm to repay its debt, while “older” firms seems to be more productive. The financially constrained firms face lower levels of TFP, while the size and short-term debt after some point are associated negatively with TFP. In addition, increasing the market share the firm can improve the TFP.

In addition, industry factors can be very important for the TFP, including the concentration and the entry and exit of firms. The findings suggest that the entry of the firms has a negative effect as it increases the competition, while on the other hand exit of firms is associated with higher TFP. The *Herfindhal* concentration index and the average industry growth have a positive relationship with TFP, while during the economic recession periods, firms are more likely to report lower TFP growth.

In addition, one of the main aims and contributions of this study is the inclusion of the relatedness measure *WARN* in the analysis, as an extra determinant of TFP. In particular it is found that *WARN* has the strongest effects on TFP after value added index, average industry growth and the exit of firms. Thus, firms that allocate knowledge in similar technological activities are more likely to present a higher growth of TFP, even during the economic recession periods.

Organisations have many options for examining other kinds of productivity, namely the labour productivity, machine productivity, capital productivity, energy productivity, and others. A productivity ratio may be computed for a single operation, a department, a facility, an organisation. Then the firm and sector determinants can be explored in order to improve the productivity of main interest.

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Table 1. Stochastic Frontier Analysis (SFA) for the Translog Production Function

Coefficients (Linear Terms)		Coefficients (Quadratic Terms)		Coefficients (Interaction Terms)	
β_t	0.0093 (0.0198)	$(1/2)\beta_t^2$	-0.0002*** (1.4e-0.5)	β_{KL}	-0.1093*** (0.0012)
β_K	0.5871*** (0.0294)	$(1/2)\beta_K^2$	0.1680*** (0.0015)	β_{Kt}	-0.0029*** (0.0029)
β_L	0.3138*** (0.0289)	$(1/2)\beta_L^2$	0.0153*** (0.0013)	β_{Lt}	0.0019*** (0.0001)
μ	3.7463*** (0.3505)	η	0.3138*** (0.0289)	γ	0.7815*** (0.0028)
No obs.	182,888	Log-Likelihood	-230.578	Wald Statistic	88,742.69 [0.000]

Standard errors between brackets, p-values between square brackets, *** denotes significance at 1% level

Table 2. GMM estimates for Total Factor Productivity

	Linear Model	Non Linear Model		Linear Model	Non Linear Model
Panel A: Firm Level Characteristics			*Panel B: Industry Level Characteristics*		
Variables	***Coefficients***	***Coefficients***	***Variables***	***Coefficients***	***Coefficients***
Profitability with one lag	0.3969*** (0.0045)	0.3147*** (0.0044)	HERF	0.0262*** (0.0008)	0.0188*** (0.0009)
Age linear term	0.0031*** (0.0008)	0.0088** (0.0036)	HERF*Market Share	-0.0217*** (0.0014)	-0.0156*** (0.0013)
Size linear term	0.0404*** (0.0006)	0.1114*** (0.0015)	Entry of firms	-0.1131*** (0.0048)	-0.1020*** (0.0048)
Size with quadratic term		-0.0060*** (0.0002)	Exit of firms	0.0449*** (0.0038)	0.0304*** (0.0038)
Short-term indebtedness linear term	0.2327*** (0.0023)	0.2296*** (0.0028)	Average industry growth	0.1852*** (0.0012)	0.1793*** (0.0011)
Short-term indebtedness quadratic term		-0.0101*** (0.0002)	WARN	0.0409** (0.0194)	0.0487** (0.0232)
Long-term indebtedness linear term	-0.0058*** (0.0007)	-0.0097*** (0.0017)	Recession Period (Yes)	-0.0195** (0.0086)	-0.0220** (0.0106)
Liquidity linear term	0.0218*** (0.0023)	0.0204*** (0.0022)	No. observations	122,528	122,528
Value added index linear term	0.4029*** (0.0033)	0.4208*** (0.0033)	Wald Statistic	25,681.62 [0.000]	29,858.39 [0.000]
Asset to sales ratio linear term	-0.0004*** (1.2e-0.5)	-0.0073*** (0.0011)	Sargan Statistic for over identification restrictions	819.72 [0.085]	769.81 [0.135]
Asset to sales ratio quadratic term		3.9e-04*** (6.2e-06)			
WW Index	-0.0051** (0.0025)	-0.0046** (0.0022)	Difference-in-Sargan exogeneity test	511.79 [0.811]	500.95 [0.862]
Risk proxy linear term	0.0046*** (0.0010)	0.0321*** (0.0038)	Arellano-Bond test for AR(2)	1.40 [0.883]	1.35 [0.825]
Risk proxy quadratic term		-0.0043*** (0.0003)			
Market share	0.0107** (0.0003)	0.0179*** (0.0025)			

Standard errors between brackets, p-values between square brackets, *** and ** denote significance at 1% and 5% level.

Table 3. GMM estimates for Total Factor Productivity during Economic Recession and Economic Growth Periods.

Panel A: Firm Level Characteristics	Economic Recession Periods	Economic Growth Periods	*Panel B: Industry Level Characteristics*	Economic Recession Periods	Economic Growth Periods
Variables	***Coefficients***	***Coefficients***	***Variables***	***Coefficients***	***Coefficients***
Lagged Total Factor Productivity	0.0108** (0.051)	0.0021* (0.0011)	HERF	0.0119*** (0.0025)	0.0143*** (0.0015)
Age	-0.0040 (0.0027)	0.0022** (0.0010)	HERF*Market Share	-0.0083* (0.0044)	-0.0104*** (0.0027)
Size	0.1185** (0.0024)	0.1371*** (0.0013)	Entry of firms	-0.0852*** (0.0154)	-0.0781*** (0.0097)
Short-term indebtedness	0.0451*** (0.0059)	0.0423*** (0.0031)	Exit of firms	0.0062 (0.0117)	0.0025*** (0.0011)
Long-term indebtedness	-0.0038* (0.0077)	-0.0025** (0.0011)	Average industry growth	0.0070** (0.0030)	0.0072*** (0.0016)
Liquidity	0.0345*** (0.0058)	0.0376*** (0.0030)	WARN	0.0378*** (0.0144)	0.0062* (0.0033)
Value added index	0.0198** (0.0091)	0.0045 (0.0048)	No. observations	15,674	93,144
Asset to sales ratio	-0.0028*** (0.0005)	-0.0005*** (0.0002)	Wald Statistic	6,568.71 [0.000]	14,566.03 [0.000]
WW Index	-0.0480*** (0.0121)	-0.0255*** (0.0068)	Sargan Statistic for over identification restrictions	33.97 [0.314]	70.61 [0.205]
Risk proxy	0.0319*** (0.0032)	0.0297*** (0.0017)	Difference-in-Sargan exogeneity test	56.63 [0.362]	74.70 [0.197]
Market share	0.0045 (0.0262)	0.0444*** (0.0147)	Arellano-Bond test for AR(2)	-0.57 [0.568]	1.07 [0.339]

Standard errors between brackets, p-values between square brackets, ***, ** and * denote significance at 1%, 5% and 10% level