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A micro-macro-economic modelling approach to major welfare system reforms: The case of a Universal Basic Income for Scotland

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ABSTRACT

This paper develops – and applies – a micro-macroeconomic modeling approach for assessing major welfare system reforms. With a growing interest in the value of bold welfare reforms in the light of persistent and widening inequalities, we demonstrate the value of a comprehensive analysis of both the (micro) impact upon the distribution of household incomes and wider (macro) impacts upon national income, unemployment and government spending. By combining microsimulation with CGE modeling, we argue that our findings demonstrate the importance of any major social welfare or broad fiscal reform being the subject of a micro-macro modeling approach. We illustrate this through an application to the introduction of a universal basic income in Scotland.

1. Introduction

In circumstances where policies imply substantial changes in the distribution of incomes among households, such as major reforms of the welfare system, they are also likely to have macroeconomic impacts. Similarly, significant changes to the macroeconomic system are likely to have microeconomic effects, including on the distribution of income. In such circumstances, where welfare (and fiscal) reforms effectively induce structural change, there are major advantages to pursuing both micro- and macroeconomic modeling approaches. The former provides rich detail on household outcomes that is typically absent from macroeconomic models. The latter capture system-wide impacts that the microeconomic models neglect.

Much of the evidence of major shifts in welfare policy – such as the introduction of a universal basic income, which is our illustrative application here – relates to static microsimulation analyses of the costs and redistributive consequences of such a policy (e.g. Mackenzie et al. (2016), Martinelli (2017) and Painter et al. (2019)). But such substantial changes in transfers and tax rates inevitably imply macroeconomic impacts. There is a dearth of studies of the macroeconomic impact of major welfare reforms, with little or no attempt until now to provide a full analysis of both micro- and macroeconomic effects.

In general, there are a range of potential micro and macroeconomic models that could possibly be used for micro-macro modeling. For example, MacCurdy (2015) combines micro-simulation with an Input-Output model of the US to assess the impact of a minimum wage. There are however, a growing number of applications that combine microsimulation with CGE modeling. Examples include Bourguignon et al., 2010; Breisinger and Ecker, 2014; Debowicz, 2016; Liyanaarachichi et al., 2016; Peichi, 2016; Verikios and Zhang, 2015 (Cockburn et al., 2014, provides a survey.) Distinctions have been drawn between fully integrated approaches, which incorporate detailed individual household data into the CGE directly (Decaluwe et al., 1999), and those which, like the present analysis, apply the models sequentially (e.g. Bourguignon et al., 2005). If the sequence involves micro-(to-) macro modeling, the approaches are sometimes labelled bottom-up with macro-micro sequencing labelled top-down. While there is a degree of bi-causality and iteration between the micro and macro models in our approach (see e.g. Savard, 2005 for an early example), the critical first stage involves the micro-macro or bottom-up linkage (Colombo (2010) provides a comparison of approaches using a common (synthetic) database.) We follow this literature but our modeling framework is

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distinctive in that it allows us to provide what is, as far as we are aware, the first micro-macro analysis of a major welfare reform and the first to incorporate a dynamic CGE, which also allows for the presence of imperfect competition in the labor market.

Accordingly, we develop and apply a modeling framework that allows us to track the economic dynamics of policy-induced structural change through combining micro- and macroeconomic modeling to capture both the detailed microeconomic impacts on households as well as the wider macroeconomic impacts of a major policy shift designed to fundamentally alter the distribution of incomes in society. We use the proposed introduction of a Universal Basic Income (UBI) in Scotland to illustrate its implementation, paying particular attention to the modeling approach rather than the detailed results.

A UBI would represent a major policy shift and structural change. It is often defined in terms of a payment made to all citizens in a region/nation that is unconditional, permanent and substantial. Support for the adoption of a UBI has been growing, in part due to a perception of increasing inequality and precarity (Martinelli, 2017). A recent survey of 12,000 people in Europe found that 71 % supported the introduction of a UBI (The Times, 2020). Such debates have become particularly pronounced in the UK. During the 2021 Scottish general election for example, four out of the five main political parties declared themselves to be in favor of the principle of a UBI.

The paper is structured as follows. Section 2 discusses our modeling framework and in Section 3 we apply that framework to the case of a Universal Basic Income. Section 4 provides a discussion of our findings and a brief conclusion.

2. The modeling framework

In this section we discuss our modeling framework and the three different stages involved. This includes a first stage of microeconomic simulations, followed by a discussion of how this can be extended to incorporate likely individual labor supply responses to the introduction of a major welfare reform – the micro (behavioral) approach. The second stage discusses what we term the micro-macro and micro (behavioral)-macro simulations where we trace the macroeconomic changes flowing from the microeconomic outcomes obtained in our first stage. Finally, we use the long-run results of the macroeconomic simulations to update the micro data base and generate new microsimulation results and so implement Stage 3 of the modeling process.

Fig. 1 illustrates the sequential nature of our overall modeling approach.

Stage 1: Microsimulation modeling

Stage 1 makes use of microsimulation modeling with the main purpose, the estimated likely gross fiscal cost of introducing a major welfare reform and the changes in benefits and tax required to finance it. The principal functionality of a microsimulation model is to take a population sample and apply tax and benefit rules to each family within the sample to produce an estimate of net income for a given year. Microsimulation models are the standard tool for assessing the distributional effects and the aggregate fiscal effects of changes to tax rules and means-tested benefits (HM Treasury, 2021).

The underlying data for such microsimulation modeling typically draws upon detailed survey questions that capture characteristics of tax liability and benefit entitlement. In the UK, the most appropriate tool is the Family Resources Survey (FRS). This is a survey of 19,000 households, consisting of 23,000 nuclear families (benefit units[1]), and 33,000 adults (Department for Work and Pensions, 2020).[2] Of these, 2800 households, 3100 families and 4600 live in Scotland. For our study, to increase the effective sample size to allow more fine-grained distributional analysis, data for the last three years was pooled (reflecting the approach taken by the Scottish Government for poverty Analysis (Scottish Government, 2020)), giving an effective sample of 8300 Scottish households.

Of course, such micro-datasets are made available after the survey work has taken place. In reality, the requirement for policy analysis is usually prospective: to be able to estimate the likely effects of a reform at some point in the future. The standard approach to resolve this issue is known as uprating whereby each household's earnings, rent payments, childcare costs, and other financial values, are adjusted (i.e. increased) from the value reported in the survey to the chosen policy period. In our illustrative application, the 2023/24 financial year, uprating is undertaken by UK national statistics time series for key elements of data and forecasts from the UK Office for Budget Responsibility (OBR) (Office for Budget Responsibility, 2019). Earnings, pension contributions and investment income are uprated in line with average earnings growth, childcare costs in line with the Consumer Prices Index (CPI), and rents in line with the appropriate OBR rent forecast. Similarly, policy parameters – tax thresholds and benefit rates – also have to be uprated to bring into line the model with current policy rates (McInnes, 2019).

Finally, for each benefit, a probability equation needs to be estimated to account for the fact that not all entitlements to benefits are taken-up. Uniform random numbers can be drawn for each family and the difference between the random number and the estimated probability calculated. Families simulated to be entitled to the benefit can then be ranked in order of this difference and selected to take-up the benefit until the alignment total – based on published official statistics of take-up rates – is reached.

From this baseline, the tax and benefit schedule can then be varied to generate changes in net income in both a counterfactual scenario and a policy reform scenario. By being based upon a detailed account of a country's tax and welfare system they can capture how different taxes and benefits interact with each other. Finally, in summing the change in family incomes across a weighted sample representative of the county as a whole, the net aggregate change in government-citizen transfers – i.e. the net increase in tax receipts/benefit expenditure – can be estimated. In effect, these microsimulation results capture the immediate effects of the policy change, prior to any behavioral response or induced longer-term impacts.

Stage 2: CGE modeling

Stage 1 provides the first-round effects of modeling a major welfare policy shift. To examine the potential impacts upon the economy as a whole, our methodology employs a multi-sectoral computable general equilibrium "macro" model of the economy – a CGE model.

CGE models provide a detailed description of the economy that captures the key interlinkages between the private sector, households, government, international trade and the labor market. These models allow extensive simulation of the impact of a wide range of policy interventions.

For our specific illustration of modeling a Universal Basic Income in Scotland, we use a modeling framework called A macroeconomic Model Of Scotland (AMOS), calibrated on an eighteen industrial sector Social Accounting Matrix for Scotland for 2013. (See Harrigan et al., (1991); Lecca et al., (2013) and Figus et al., (2018)). The core equations of

[1] The benefit unit is used for assessment of entitlement to means-tested benefits in the UK and consists of a single adult or adult couple plus their children up to the age of 16, or 19 if in full-time education. A household can consist of multiple benefit units.

[2] It is recognised that surveys under-report incomes at the top of the distribution. For this reason, when estimating, datasets often adjust to ensure those on high incomes are more line with detailed obtained from tax returns. In the UK, the Households Below Average Income (HBAI) dataset and publication does just that and, in our study, we use the same methodology.

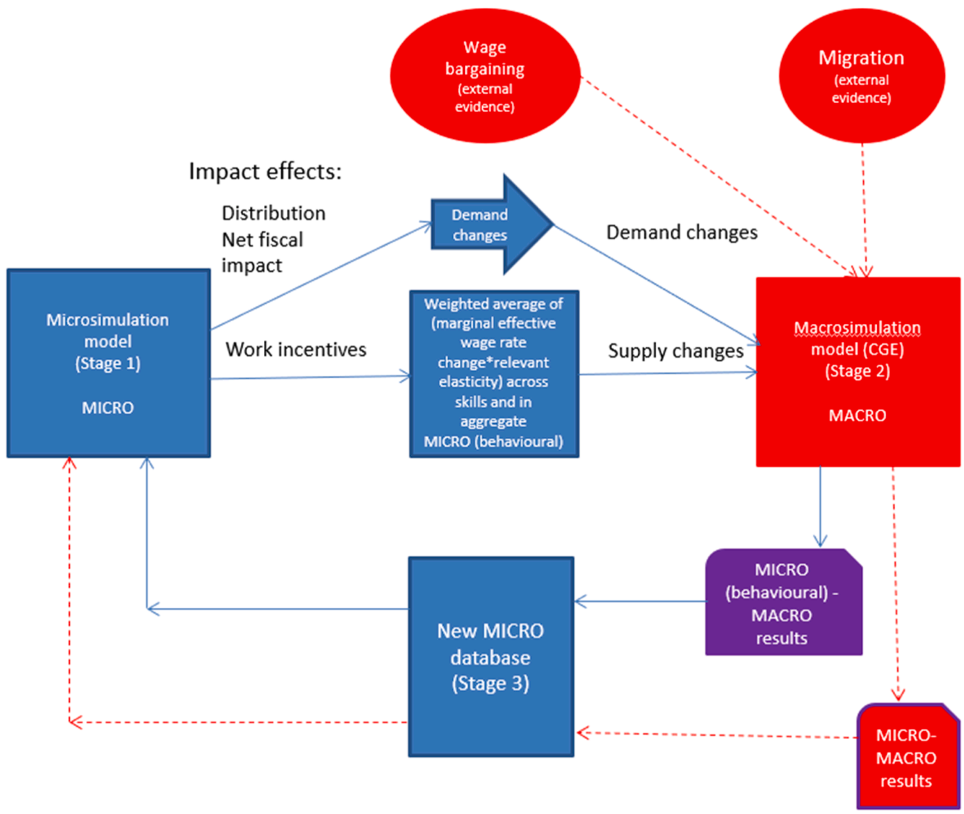

Fig. 1. The structure of the modeling framework.

AMOS are presented in online Appendix B. This is the same model used in Connolly et al., (2022), where we focus solely on the potential of a regional-specific UBI as an instrument of regional development.

Within the model there are three internal institutions – households, firms and governments – and two external, the rest of the UK (RUK) and the rest of the world (ROW). Certain technical assumptions are required to be made about components of the model. For example, in our case Scotland is a small, open, regional economy so that external RUK and ROW prices are exogenous. Commodity markets are assumed to be competitive. Financial flows are not explicitly modelled, and the interest rate is assumed to be exogenously determined at UK level. The numeraire is the external price level; prices in the rest of the UK and the rest of the world are exogenous.

This framework has been used extensively in a wide range of applications including for example, environmental (Allan et al., 2014) and trade analysis (Figus et al., 2018). A variant is used by the Scottish Government for policy analysis. The model allows for a degree of flexibility in the choice of model closures and parameters. The version used in this paper assumes myopic expectations. Fundamentally, the model assumes that producers minimize cost using a nested multilevel production function. The combination of intermediate inputs with RUK and ROW inputs is based on the Armington function (Armington, 1969). Output is produced from a combination of composite intermediates and value added, where labor and capital combine in a constant elasticity of substitution (CES) function to produce value added, allowing for substitution between these factors in response to relative price changes.

There are four components of final demand in the model: household consumption, investment, government expenditure and exports. Household consumption is a linear function of real disposable income. Real Government expenditure is constant in the model, while exports are determined again through an Armington function and so are dependent on relative prices.

The model is initially assumed to be in steady-state equilibrium, implying that, with no exogenous disturbance, the model simply replicates initial values over all subsequent time periods.

The supply side of the economy determines the use of capital and labor in the model. Capital, in the first period, is fixed but in subsequent periods each sector's capital stock is updated through investment, which responds partially to the gap between the desired and actual (adjusted for depreciation) levels of capital stock – in line with the neoclassical investment formulation (Jorgenson, 1963). Capital is immobile between sectors.

Once properly specified and data inputted, it is possible to 'shock' the model and simulate the subsequent short and long-term effects. In the context of modeling a major welfare reform, the scale of the shock can be taken directly from the results in Stage 1 in terms of both the scale of change to benefits for some, the required tax increase to pay for it and the first-order impacts upon the income distribution.

What is crucial in determining the direction and scale of any response to a major welfare reform is the changes in an individual's labor supply financial incentives.

Two main approaches are possible - one where individuals respond to changes in their wages in a more competitive market (Micro (behavioral)-to-Macro) and another where there is bargaining across the economy as a whole (Micro (bargaining)-to-Macro).

The first approach treats labor markets as competitive, with the supply side of the labor market reflecting the aggregate of all individuals' labor supply decisions. This is the vision of labor markets that has typically characterized previous micro-macro analyses; labor market institutions (employer organizations and unions) are effectively a veil. In this context it is appropriate to use the detailed results of the microsimulation model, combined with (here externally provided) evidence on individuals' labor supply elasticities to build up a picture of the aggregate change to labor supply implied. The impact of this change is then simulated within the CGE model, in combination with the demand side changes noted above. This micro (behavioral) – macro approach is tracked through the inner (blue) modeling cycle in Fig. 1.[3] There is a rich literature to draw upon of possible estimates, albeit subject to various uncertainties. It is therefore useful to undertake sensitivity analysis and model a range of different assumptions about the degree of responsiveness to financial work incentives.

Our particular method used in our illustration builds on an approach developed by the Institute for Fiscal Studies (Adam and Phillips, 2013) to estimate, ex ante, the potential labor supply response to a change in tax/benefit policy. The approach involves two stages. First, we measure how much the financial incentive to work changes because of a change in tax/benefit policy, for each individual. Second, based on an estimate of how responsive individuals (of given characteristics) are likely to be to a change in financial incentive, we calculate the likely change in labor supply for all individuals who are in employment in the base case (see online Appendix A for details).

An alternative approach treats the labor market as imperfectly competitive, characterized by bargaining behavior as captured in a wage curve, in which the net real consumption wage is inversely related to the unemployment rate – an (inverse) indicator of workers' bargaining power. Within this framework it is possible to model several possible alternative responses to the policy change by wage bargainers and by migrants (i.e. employees either within a labor market or potential employees available through in-migration). In this micro-macro approach, all of the behavioral responses are modelled within the CGE component and the sequence is captured in the outer red loop (supply impacts) and intermediate blue loop (depicting demand effects) in Fig. 1.

In the case of a major social reform, the resultant real wage curve can be augmented to allow for a non-zero value to be attached to the specific welfare policy in the bargaining process (Layard et al., 2005):

$$ln\left(\frac{w^S}{cpi^S}\right) = c - 0.113\ln\left(u^S\right) + \alpha\ln(1-\tau) \qquad (1)$$

There is very substantial international evidence in favor of the wage curve as well as evidence that it is an appropriate aggregate characterization of the labor market in Scotland. The parameter α represents the extent to which workers value the major welfare policy and reflect that in their wage bargaining behavior. Empirical evidence on the value of the α parameter is likely to be sparse so a range of possible values should be used. In a conventional bargaining model α=0 and workers respond to the *net* real wage; bargaining is completely unaffected by the level of the new social welfare policy. In the "social wage" model workers value all such payments as much as their loss of disposable income through the rise in income tax. Here α=1 and workers bargain over the *gross* real wage; they feel as well off after the introduction of the welfare policy as before because they fully value all welfare payments (even those made to individuals outside of the workforce) and so do not put upward pressure on wages. Intermediate values of α reflect workers valuing part of the new welfare payments when bargaining over wages but not all. One example we use below is where workers value payments of their own personal entitlement, but not other family members' receipts. τ is the employment taxes levied on employees which for Scotland is income tax and national insurance.

While the vast majority of the CGE models used in micro-macro modeling applications have been static, the model used here is dynamic. In the short-run capital stocks and population are fixed but employment, wages, value added, and profitability are all endogenous. The implicit time interval here is long enough to capture initial behavioral responses, in contrast to the focus of the microsimulation on the instantaneous effects of the policy shift. In the long run all stocks fully adjust, so that all investment is ultimately for replacement purposes and there is zero net migration. During the adjustment from the short-run to the long-run capital stocks are gradually updated through investment expenditures that reflect, on a period by period basis, the gap between actual and desired stocks and regional population adjusts in response to net migration flows driven by real wage and unemployment differentials (see below for a full discussion of the model). The long-run results therefore allow sufficient time for all of the induced behavioral responses to be completed - Typically it takes 15 to 20 years for the CGE model to converge on a new long-run "macro" equilibrium.

Stage 3: Long term impacts upon households and families: further rounds of simulations for both Micro-Macro (bargaining) and Micro (behavioral) – Macro Modeling Approaches

Stage 3 estimates the distributional consequences of the long-run macroeconomic impacts from Stage 2. It takes the results from the long-run economic simulations – including changes in employment, wages and population – to identify the potential long run effects on the distribution of household incomes and measures of poverty. Of particular interest is whether the long-term macroeconomic effects would change significantly the picture identified in the Stage 1 microsimulation.

The approach taken is to run the microsimulation modeling in a similar way to Stage 1, but with the model dataset adjusted in line with the aggregate estimates produced in the Stage 2 macroeconomic modeling. The intention is to estimate whether and to what degree long-term dynamic effects change the results obtained in Stage 1.

An initial step is to produce an altered version of the FRS sample which reflects the long-run macroeconomic outputs of the Stage 2 macroeconomic modeling. The Stage 2 macroeconomic modeling will generate estimates of the likely long-run impact of a policy shift on: price inflation (Consumer Price Index); wage growth; size of the population; size of the labor force; unemployment rate and full-time equivalent employment. To generate amended population totals, and amended numbers of people in employment, grossing values can be altered using a raking algorithm so that weighted results produced from the amended dataset provide population, unemployment, and full and part-time employment totals consistent with the results from the Stage 2 macroeconomic modeling – see Table 1. This approach is similar to that used in Barnard, Heykoop and Kumar (2018) where estimates from a general equilibrium model of the macroeconomic effects of alternative Brexit trade scenarios were used to alter uprating series and grossing variables to allow a microsimulation-based estimate of the effects of these trade scenarios on poverty.

3. Application of modeling framework to introduction of a Universal Basic Income in Scotland

3.1. Policy simulation background

We demonstrate this modeling approach through the application to a specific UBI policy in terms of its level and funding. The values seek to replace the standard allowances already in place in much of the UK social security system – and follow the detail set out in Fraser of Allander (2020). This is simply to illustrate the value and detail of our approach, with other welfare reforms – more or less generous – entirely possible. Accordingly, we provide a range of outcomes, each highlighting the possible scale and direction of changes under various assumptions and scenarios.

We test a Universal Basic Income that is based on benefit levels

[3] Cockburn et al (2014) uses the micro behavioural label to apply to microsimulation models that incorporate behavioural responses within them. Here the micro behavioural responses are calculated in what is a distinct stage in the modelling process, that can be contrasted with the alternative (macro) treatment of behavioural responses.

Table 1
Adult re-grossing algorithm.

Step	Title	Coverage (People whose grossing value was changed at this stage of the algorithm)	Control totals used to adjust grossing values
1	Population	All adults	Population change
2	Labor force / inactive split	All adults in the labor force All inactive adults	Change in the size of the labor force
3	Employment / unemployment split	Employed adults Unemployed adults	Change in the unemployment to labor force ratio
4	Full-time / part-time split	Adults working full-time Adults working part-time	Change in the balance between part-time and full-time workers implied by the difference between the change in people in employment and the change in full-time equivalent employment
5	*Re*-adjust working age / pensioner split	Working age adults Pensioners	Ratio between working age adults and pensioners after Step 1
6	*Re*-adjust work status groups among working age with kids	Working age adults with children	Ratio between full-time workers, part-time workers, unemployed and inactive obtained after Step 4
7	*Re*-adjust child/ childless split among working age	Working age adults with children Childless working age adults	Number of children after Step 1

(rather than some minimum income standard).[4,5] The 2019/20 value of the hypothetical UBI is shown in Table 2.

We assume that the tax and benefit changes summarized in Table 3 would be made as part of the introduction of the UBI policy:

For illustrative purposes, we assume that any reform option is fiscally neutral: that the net costs of the policy should be close to zero. In the case of the Universal Basic Income option, after the policy is introduced, and the above benefit and tax changes are made, there remains a fiscal cost. To remove this, we then increase income tax rates (by whole percentage points) in Scotland until we reach fiscal neutrality.

Also, for ease of presentation and discussion, we keep all income tax rate rises to whole percentage points. To accommodate this restriction, we treat any final net cost of within £300 million per annum of zero as being effectively cost neutral. We also test a comparator policy in Stage 1

Table 2
Universal basic income values in 2019/20 (per week).

Age band	UBI
0 to 15	84.54
16 to 19	84.54
20 to 24	57.90
25 to below State Pension Age	73.10
State Pension Age or over	163.00

Table 3
UK Tax and benefits changes when UBI applies in Scotland.

Benefit	Approach for benefit units subject to the UBI
Carers Allowance	Set to zero
Child Benefit	Set to zero
State Pension	Reduced by the value of the person's UBI
(Set to zero if their UBI is greater than their State Pension)	
Pension Credit	Set to zero
Universal Credit Adult Element	Element set to zero
Universal Credit Child Element	Element set to zero
Income Tax Personal Allowance	Set to zero

Note that in our modeling, the UBI does not replace those elements of Universal Credit designed to help with housing and childcare costs or the elements that provide additional support for families containing disabled adults or children. In technical terms, the standard adult and child elements were set to zero but the rest of the benefit is left unchanged.

which involved not introducing a UBI but instead making changes to current benefits to maximize the impact on child poverty in Scotland.[6] In this, we abolish the two-child limit for Universal Credit, abolish the Benefit Cap, and increase the 2019/20 s and subsequent child element of Universal Credit by £40 per week. The first child element is then set to the new, higher, second and subsequent child element.

With this policy option, because the gross costs are much lower, there is no need to make wide-ranging changes to taxes and benefits to achieve fiscal neutrality: the only changes that are needed are increases in income tax rates for the top two bands of the Scottish Income Tax system.

3.2. Stage 1 results

Table 4 below shows the costs and savings of introducing each policy in Scotland.

The gross costs for the UBI are £26.7 billion per annum. The net annual costs of introducing the UBI, reducing the specified benefits, reducing the State Pension and abolishing the Income Tax Personal Allowance are £7.3 billion. An 8 point across-the-board increase in income tax rates would be required. Comparing the UBI option with the

Table 4
Costs and new income tax rates in Scotland required to achieve fiscal neutrality.

	UBI	Universal Credit comparator
Gross cost	-£26.7 bn	-£1.0 bn
Savings from benefit reductions	£4.0 bn	£0.0 bn
Savings from state pension reduction	£6.3 bn	£0.0 bn
Savings from PA abolition	£9.1 bn	£0.0 bn
Savings from tax rate rises	£7.2 bn	£0.9 bn
Net cost	**-£0.2 bn**	**£0.0 bn**
Income tax rate rises needed to achieve fiscal neutrality	+8 points on <u>every</u> band	+6 points on top two bands (<u>only</u>)
New Scottish income tax schedule[11]	27:28:29:49:54	19:20:21:47:52

[11] Scottish Income Tax bands: Band 1: £1 to £2049; Band 2: £2050 to £12,444; Band 3: £12,445 to £30,930; Band 4: £30,931 to £150,000: Band 5: £150,001 plus.

[4] Note that the pensioner rate of £163 per week is slightly less than the rate of the Pension Credit Guarantee Credit (£167.25) and the rate of the New State Pension (£168.60).

[5] We also tested a high-level UBI based on the Joseph Rowntree Foundation Minimum Income Standard, but this required unfeasibly high marginal rates of income tax, so we do not report the results here. See https://www.jrf.org.uk/report/minimum-income-standard-uk-2019 for more details on the JRF Minimum Income Standard

[6] The comparison is not carried over to Stages 2 and 3, given the already large number of cases to be considered. In any case, the macroeconomic consequences of the comparative policy are very modest in scale.

Universal Credit comparator, the latter policy comes at a substantially lower cost. The gross cost of £1.0 billion per annum can be recovered by raising income tax rates on only the top two Scottish Income Tax bands by 6 percentage points.

Table 5 shows the average change in weekly benefit unit income[7] for people in each quintile of the income distribution in the base case. Note that the distributional impact relates to the average among all people (not among all benefit units).

In both policies, the shape of the distributional effects is similar: the largest gains go to people at the bottom of the income distribution and the bill is paid by people at the top. The main difference between the options is the scale of change. With the UBI, the average gains in the bottom quintile are around £3700 per year whilst average losses in the top quintile are around £5300 per year. As a more targeted policy, the Universal Credit comparator affects fewer people and so the average effects are smaller: +£1600 in the bottom two quintiles and -£2000 in the top quintile.

Table 6 identifies the gainers and losers from the policy. What is notable is that, whilst the general trend is that the UBI is redistributive – those on lower incomes are much more likely to gain and those on higher incomes are much more likely to lose – the effect is not uniform. 370,000 people in the bottom two quintiles are likely to see a drop in income whilst 520,000 in the top two quintiles will see a rise in income.

3.3. Stage 2 results

We first explore the micro-to-macro modeling that is predicated upon an imperfectly competitive vision of the labor market, captured through the wage curve.

To begin, we assume the conventional bargaining case in which workers focus on their net-of-tax/ take-home wage with no migration. In effect, workers attach a zero weight to UBI receipts in the bargaining process (since it is paid irrespective of labor market status).

In this simulation, the increase in government spending on UBI is funded by an increase in the average income tax rate, but this has the adverse supply side impact of workers bargaining for higher wages in an attempt to restore their net of tax real consumption wage.[8] This has negative competitiveness effects on trade and therefore would, in the absence of any other impacts, induce a contraction in economic activity and employment.

The first two columns of Table 7 report the economic impacts of the UBI when workers bargain over their net of tax real wage and there is no migration. (Except where otherwise stated, all the reported results are expressed in real terms.) The first column reports the short run (SR) results when capital stocks are fixed and the LR column relates to the long run results, when capital stocks have fully adjusted. Fig. 2 illustrates the time path of GDP and employment. The result is a contraction in economic activity in the long run with real GDP falling by 8.8 %, employment by 9.7 %, and investment falling by less than employment (8.9 %), reflecting some substitution away from labor in favor of capital. Workers are only partially successful in restoring their real net of tax wage, which ultimately falls by 9.9 %. The relative weakening in economic activity pushes up the unemployment rate to

Table 5
Change in weekly benefit unit income (rounded to nearest £).

	UBI	Universal Credit comparator
	Average change in weekly benefit unit income	
All people	**£13 pw**	**£6 pw**
People in bottom quintile	£71 pw	£31 pw
People in 2nd quintile	£56 pw	£31 pw
People in middle quintile	£36 pw	£7 pw
People in 4th quintile	£3 pw	-£2 pw
People in top quintile	-£102 pw	-£40 pw

Table 6
Number of gainers and losers (rounded to nearest 10,000).

	UBI	Universal Credit comparator
	Gainers	
All people	**2900,000**	**830,000**
People in bottom quintile	940,000	280,000
People in 2nd quintile	780,000	390,000
People in middle quintile	650,000	130,000
People in 4th quintile	420,000	30,000
People in top quintile	100,000	0,000
	Losers	
All people	**2360,000**	**970,000**
People in bottom quintile	100,000	0,000
People in 2nd quintile	270,000	10,000
People in middle quintile	400,000	70,000
People in 4th quintile	680,000	210,000
People in top quintile	920,000	680,000

Table 7
Short and long run impacts of an income tax financed UBI with bargaining (no migration).

	SR	LR
GDP (£m)	-2.61%	-8.79%
Consumption	0.40%	-4.65%
Investment	-7.57%	-7.86%
Total Exports	-3.43%	-10.52%
Total Imports	-0.18%	-1.77%
Nominal Gross Wage	10.17%	13.22%
Real take home wage	-6.01%	-9.93%
CPI	1.62%	4.00%
Real cost of capital	1.19%	3.16%
Unemployment Rate (pp difference)	4.38%	9.14%
Employment	-4.66%	-9.73%
Total HH Tax	43.22%	50.89%
Income Tax	84.08%	102.01%
Transfers to HH from Gov	117.37%	117.37%
Real Scottish Government Consumption	0.00%	0.00%
HG1 Lowest income group's consumption	29.76%	26.68%
HG2 Second quintile's consumption	14.79%	10.72%
HG3 Third quintile's consumption	4.02%	-0.27%
HG4 Fourth quintile's consumption	-5.10%	-10.22%
HG5 Highest income group's consumption	-11.95%	-18.38%

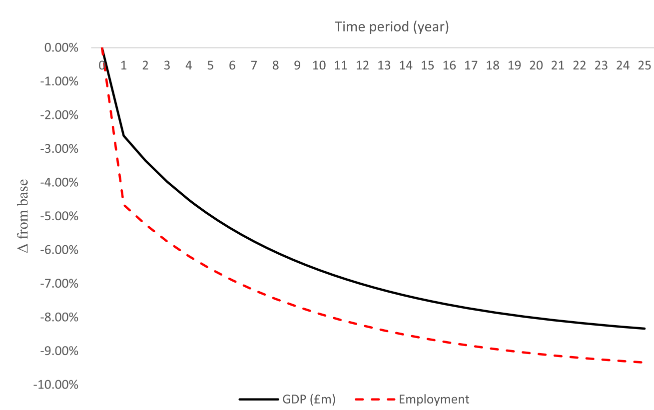

Fig. 2. Adjustment paths of real GDP and employment of income tax financed UBI with bargaining over the net of tax real wage.

[7] A benefit unit is a single adult or adult couple plus their children aged up to 16, or up to 19 if in full-time education.

[8] Income tax is by far the most important devolved tax in Scotland. Corporation tax, National Insurance and VAT (currently) are all reserved to Westminster.

9.1 %.

There is a substantial fall in economic activity even in the short run, and this grows through time, as is apparent in Fig. 2. Capital rental rates fall substantially in the short-run, but rise gradually as sectoral capital stocks contract until rental rates are again equal to the user cost of capital in the long-run.

Note that there is a fall in aggregate real consumption of 4.7 %. Of course, higher income groups are impacted disproportionately so there is significant redistribution, with the consumption of the lowest income group growing by 26.7 %, while the highest income group's consumption falls by 18.4 %. The scale of the effects reflects the fact that the UBI is not linked in any way to employment status: it is paid entirely unconditionally to workers (and non-workers). With a UBI, workers continue to put in the same effort, but the return from working is now reduced (in relative terms).

These results contrast markedly with those from micro case studies of UBI-type interventions, reviewed by Gibson et al., (2018) and Standing (2017), which typically report non-negative economic impacts. The main reason for this is that these micro studies typically relate to schemes that are small in scale, of limited scope and effectively imply zero cost to UBI recipients.[9] In the present case, in contrast, the UBI is substantial and has to be funded through an increase in the income tax rate, which has a significant effect on macroeconomic impacts. Such effects are, of course, to be expected. This is a major, radical reform of the welfare system that has substantial supply side effects emanating primarily in this case from wage bargainers seeking to restore their net of tax pay – the behavior implied by most estimated wage curves. The consequence here is a rise in the equilibrium rate of unemployment; the "natural rate" is sensitive to major supply side interventions. Often experiments that are labelled as "UBI" interventions in fact involve payments that are neither universal nor substantial (and often externally funded), and so system-wide effects are unlikely to be present at all or to be so minor as to not be discernible. In contrast, here we have a major policy intervention that would certainly be expected to have permanent macroeconomic impacts.

However, the conventional wage bargaining model captures only one possible way in which workers may react to the introduction of a UBI and the associated rise in income tax. All of the macroeconomic impacts identified in Table 7 are in no small part implied by the *conventional* version of the wage curve (in which $\alpha=0$ in equation 2). We next focus on two further cases; workers fully valuing their own UBI payment and the social wage case.

It is possible that workers may account for the value of their personal UBI receipts (in excess of foregone other benefits and the personal allowance) when pressing for "compensating" wage rises.[10] The difficulty is the unconditional nature of the UBI. But what if policymakers successfully persuade workers to fully value their own personal UBI so that they modify their wage claims accordingly? Clearly, this would moderate the scale of the "wage push" response relative to the conventional bargaining case: workers in this case "only" seek compensation for the reduction in their net personal income arising from the introduction of the UBI (i.e. the excess of the value of their own UBI over the value of the loss of benefits and the personal allowance.)

The "social wage" concept is based on an assumption that workers may feel as well off after the introduction of the UBI as before it. This would be the case if workers value the UBI that they (and their families) receive and also the reduction in poverty and inequality in society more generally, just as much as the reduction in their real net wage. In this case, there is no pressure to restore the net of tax real wage, since workers feel as well off after the change as they did before.

With both cases, the adverse competitiveness effects on trade are substantially reduced. The first two columns of Table 8 reflect the case where workers value their own UBI payment when bargaining for wages, and the social wage results are reported in the final two columns.

When workers account for their own UBI payment, the result is still a significant long-run contraction in economic activity with real GDP ultimately being 4.4 % and employment 5.0 % below where they would have been in the absence of the UBI. However, while the adverse impacts on economic activity are moderated it does imply a greater fall in the take home wage – workers give up some of their wages for the UBI (11.5 % reduction as compared to 9.9 %). Unemployment eventually increases by 4.7 percentage points.

The presence of a social wage clearly improves the macroeconomic outcomes significantly. Here, GDP falls, but only slightly, in the short-run (by 0.1 %) and rises slightly in the long run (0.2 %). In the long-run there is an increase in investment of 0.5 % but still a small reduction (0.05 %) in employment. The reduction in CPI leads to an increase in imports and consumption but this increased economic activity comes at a cost to workers as real take home pay falls by 13.1 %.

Since the relevant wage falls and the unemployment rate rises in the absence of migration (Tables 7 and 8) there is an incentive for out-migration where that is possible, which reinforces the negative macroeconomic consequences of the tax financed UBI. Indeed, the pure flow model of migration in the model implies a strong migration response, according to which labor is ultimately perfectly mobile and this can generate some (unrealistically) large contractions (which would be countered in practice by further policy intervention if they ever threatened to become a reality). (Online Appendix C provides a full discussion.)

Table 8
Short and long run impacts of an income tax financed UBI with workers fully valuing their own UBI payments (and no migration).

	Workers' UBI		Social Wage	
	SR	LR	SR	LR
GDP (£m)	-1.63%	-4.35%	-0.07%	0.19%
Consumption	0.21%	-2.31%	-0.15%	0.04%
Investment	-4.51%	-3.71%	0.41%	0.54%
Total Exports	-2.20%	-5.28%	-0.21%	0.11%
Total Imports	-0.14%	-0.88%	-0.08%	0.01%
Nominal Gross Wage	6.08%	6.29%	-0.29%	-0.12%
Real take home wage	-8.82%	-11.50%	-13.31%	-13.09%
CPI	1.00%	1.95%	0.02%	-0.04%
Real cost of capital	0.75%	1.54%	0.05%	-0.03%
Unemployment Rate (pp difference)	2.79%	4.68%	0.17%	0.04%
Employment	-2.97%	-4.98%	-0.18%	-0.05%
Total HH Tax	40.55%	43.61%	36.41%	36.69%
Income Tax	79.70%	87.32%	72.99%	73.35%
Transfers to HH from Gov	117.37%	117.37%	117.37%	117.37%
Real Scottish Government Consumption	0.00%	0.00%	0.00%	0.00%
HG1 Lowest income group's consumption	30.12%	28.73%	30.12%	30.80%
HG2 Second quintile's consumption	14.92%	12.99%	14.92%	15.27%
HG3 Third quintile's consumption	3.84%	1.70%	3.84%	3.69%
HG4 Fourth quintile's consumption	-5.61%	-8.25%	-5.61%	-6.28%
HG5 Highest income group's consumption	-12.19%	-15.40%	-12.19%	-12.42%

[9] This reflects external funding through e.g.the Alaska Permanent Fund (Jones and Marinescu, 2018), casino profits (Akee et al, 2010), or the willingness of a government to fund an intervention of this kind for a targeted group.

[10] Recall that we simulate the taxes and transfers required to fund the UBI *net* of the reduction in other benefits and personal allowances. The assumption is that individuals feel fully "compensated" for these losses by the payment of the UBI. Only the tax rate changes required to fund the net transfers induce behavioural change and it is only that part of UBI in excess of the value of reduced other benefits and the absence of personal allowances that is responsible for the rise in income tax rates in the model.

The previous section used the micro distribution results of a UBI to inform the macro modeling, investigating the macroeconomic impact under alternative assumptions about the valuation of UBI in the migration and wage bargaining processes. We again use the micro results discussed above, but here we also focus on the labor supply changes that would result if these were governed by individual labor supply responses in a competitive market, analyzed in Appendix A, and explore their likely impact on the macro-economy.

In this approach individuals are effectively in control of their own labor supply. The change in labor supply at the macroeconomic level is then a weighted average of groups' responses, where the weights reflect the importance of each group of individuals in overall labor supply.

Recall that the microsimulations identify the changes in effective marginal tax rates relevant to participation and hours decisions for a wide range of household groups. These are matched to estimated elasticities of participation and hours decisions with respect to changes in effective marginal tax rates. These combine to provide the likely labor supply responses to the marginal tax rates and finally, these are aggregated to produce an overall estimated change in FTE employment.

The base case from Appendix A implies an overall contraction in labor supply of 4.27 %.

Columns 1 and 2 of Table 9 summarizes the long run impacts of the implied contraction in labor supply with an inelastic aggregate labor supply curve. This constitutes an adverse supply shock, which pushes up real wages, and so reduces competitiveness, exports and investment. In the long run GDP falls by 3.8 % and employment by 4.3 %.

In reality, the labor supply curve may not be inelastic but responsive to the real wage with these results found in columns 2 and 3 of Table 9.

Again, there is a negative impact on economic activity, but here it is reduced relative to most of the bargaining cases (although not the social wage case): the impacts on employment and the real wage are smaller than under the perfectly wage-inelastic case, as we would expect. As the real wage increases this induces an extension in labor supply, which moderates the scale of the increase in the real wage and the adverse impact on competitiveness, and so limits the fall in employment. Note that the results only incorporate the supply side impact of the UBI, hence the reduction in all households' consumption.

The third column of Table 9 summarizes the impact of adding the demand side impact of the UBI (the household transfers). The small stimulus to demand moderates the scale of the adverse supply effect but is insufficient to offset it. GDP falls by 2.3 % and employment by 2.8 %. The scale of the macroeconomic impact from the micro (behavioral)-macro simulation corresponds to the more optimistic results of the macro-micro simulations. The competitive vision of the labor market suggests that the macroeconomic costs of implementing the UBI could be more modest.

Table 9
The macroeconomic impact of a labor supply shock derived from the microsimulations.

	Inelastic	Elastic	Elastic + Demand
GDP (£m)	-3.84%	-2.53%	-2.26%
Consumption	-0.81%	-0.54%	0.03%
Investment	-3.52%	-2.32%	-1.62%
Total Exports	-5.23%	-3.45%	-3.39%
Total Imports	-0.01%	-0.01%	0.42%
Nominal Gross Wage	6.22%	4.04%	3.96%
Real take home wage	4.21%	2.74%	2.69%
CPI	1.93%	1.26%	1.24%
Real cost of capital	1.52%	1.00%	0.98%
Unemployment Rate (pp difference)	0.00%	-1.42%	-1.40%
Employment	-4.27%	-2.82%	-2.84%
Total HH Tax	1.09%	0.71%	0.72%
Income Tax	1.69%	1.10%	1.00%
Transfers to HH from Gov	0.00%	0.00%	0.00%
Real Scottish Government Consumption	0.00%	0.00%	0.00%
HG1 (Lowest) Consumption	-1.19%	-0.78%	29.71%
HG2 Consumption	-1.24%	-0.82%	17.08%
HG3 Consumption	-0.86%	-0.57%	7.27%
HG4 Consumption	-0.57%	-0.38%	0.09%
HG5 (Highest) Consumption	-0.69%	-0.45%	-20.03%

3.4. Stage 3 results

Recall that of particular interest is whether the long-term macroeconomic effects would significantly change the outcomes identified in the Stage 1 microsimulation. That is, might the macroeconomic changes to employment and output for example, change the distribution of household incomes (separate to the direct effects of the welfare policy itself).

In the Stage 3 microsimulation, we modelled the two macroeconomic scenarios summarized in Table 10.

Table 11 shows the long-run macroeconomic effects of the UBI for each of these scenarios:

We first adjust the population in line with any migration/population change outputs from the macroeconomic modeling. We then adjust labor market status in line with the labor force, unemployment and full-time equivalent employment levels discussed above. These changes also produce alterations to the ratio of working age adults to pensioners and changes to the number of children in the weighted population. So, we next ensure that the number of working age adults, pensioners and children in the final results are unaffected by the adjustments to employment totals. This is important in the context of modeling a Universal Basic Income because the effects of the policy, and its costs, are dependent on the number of people in each of these three age groups.

The final step in the re-grossing process is to produce benefit unit-level and household-level grossing variables by taking the mean values of the new adult-level grossing variables within each benefit unit and household.

The results of the simulations are reported in Table 12. The first column in Table 12 shows the first-order net costs and effects on poverty of the UBI. The subsequent columns show the net costs and effects on poverty when taking into account the macroeconomic changes estimated by the Stage 2 macroeconomic modeling.

In each of the three macroeconomic scenarios, the UBI causes a fall in employment but an increase in wage rates. Recall that means-tested benefits have not been abolished under the UBI – just restricted to providing support for housing and childcare costs, and for disabled people. This means that the fall in employment will increase the net costs of the policy because more people will be relying on state support. On the other hand, the increase in wages will increase income tax receipts, thereby reducing the costs of the policy. The results show that in the case of the micro-to-macro scenario, the former effect will be slightly larger and the long-term macroeconomic effects will have the effect of slightly increasing the costs of the policy. In the bargaining scenario, the effects cancel out and the costs will be similar the level suggested in the Stage 1 first-order microsimulation.

In both scenarios, the reduction in the poverty rate is slightly less as a result of the longer-term macroeconomic effects of the policy. In the bargaining scenario there is however some reduction in poverty numbers due to outward migration caused by the macroeconomic impacts of the policy.

Overall, once long-term macroeconomic effects are taken into account, the UBI policy costs about the same or is slightly more expensive, and it is slightly less effective at reducing poverty than suggested by the

Table 10
Macroeconomics scenarios modelled in Stage 3 microsimulation.

Micro (behavioral)-to-macro	Labor supply scenario (assumes competitive labor market)
Micro-to- macro (bargaining)	Macro-to-macro scenario (with migration). Imperfectly competitive labor market and workers' bargaining taking full account of their own UBI

Table 11
Long-run macroeconomic effects of the UBI modelled in Stage 3 microsimulation.

	Micro (behavioral) -to-macro	Micro-to -macro Bargaining
Consumer Price Index	+1.14%	+7.16%
Average earnings	+3.65%	+24.50%
Population	0	-10.65%
Labor force	-4.34%	-16.39%
Unemployment	-1.3pp	0
FTE Employment	-3.02%	-16.39%

Table 12
Stage 3 microsimulation results (taking into account macroeconomic effects).

Summary of macro effects	Micro-simulation results	Stage 3 microsimulation results (including macroeconomic effects)	
		Including income and substitution effects (Micro-to-macro)	**Wage bargaining adjusted for workers' UBI**
Effect of UBI on no of people in paid work (base = 2560,000)		-90,000	-420,000
Effect of UBI on average wages		+3.65%	+24.50%
Net cost of UBI	-£0.2 bn	-£0.6 bn	-£0.2 bn
Effect of UBI on poverty (base = 1140,000)	-280,000	-250,000	-280,000
Effect of UBI on child poverty (base = 270,000)	-90,000	-80,000	-80,000
Effect of UBI on poverty (base = 21.6%)	-5.4 pp	-4.7 pp	-3.3 pp
Effect of UBI on child poverty (base = 27.8%)	-9 pp	-8 pp	-6 pp

Stage 1 first-order microsimulation modeling.

4. Discussion and conclusions

Single-model analyses continue to dominate the literature on assessing the impact of major welfare and fiscal reforms. In the context of analyses of UBI, the most sophisticated analyses - that have explored the costs implied by the need to finance the UBI, as well as its benefits - have involved the application of microsimulation models (e.g. Mackenzie et al., (2016), Martinelli (2017) and Painter et al., (2019). Such models are useful given the richness of information they yield, particularly on distributional impacts. In our illustrative case, our microsimulation modeling reveals that a UBI would be an expensive policy even after eliminating many benefits and the personal income tax allowance; nearly everyone is impacted by the introduction of such a policy; and while a UBI does shift the distribution of income in favor of poorer households in the aggregate, it is not a simple "rich-to-poor" policy – some poor households become poorer and rich households richer.

However, while invaluable insights, such findings do not provide a full analysis of the impact of substantial changes to the welfare system such as the introduction of a UBI.

In particular, such analysis does not incorporate behavioral changes in response to the substantial changes in transfers and taxes that are likely to accompany any radical fiscal or welfare system intervention. It is "as if" the time interval under consideration is sufficiently short to preclude such responses. It would be natural for the policy community to consider what further behavioral responses are likely and to seek to quantify the impact of these. The focus here shifts from the "impact interval" to longer reaction periods, and proper analysis necessitates a dynamic modeling approach.

We argue that such changes should be addressed using a combination of microsimulation and some form of system-wide or macroeconomic modeling. Fully integrated approaches incorporate detailed individual household data into the CGE directly (Decaluwe et al., 1999), whereas others apply the models sequentially (e.g. Bourguignon et al., 2005), which is the approach we adopt here.

Our main sequence involves micro-(to-) macro modeling and so is an example of approaches that are sometimes labelled "bottom-up" (with macro-micro sequencing labelled top-down). Our approach involves a degree of bi-causality and iteration between the micro and macro models (see e.g. Savard, 2005 for an early example). The first stage involves a micro-macro or bottom-up linkage. It seeks to capture two general types of responses. First, the substantial redistribution of net incomes to lower-income households whose propensity to consume is higher than that of high-income households and this impacts consumption (and its composition); these are the demand-side impacts of the UBI. Second, the substantial changes in tax rates and transfers have an impact on the supply side of the labor market; these are the key supply-side responses to the UBI.

Alternative visions of the labor market can be deployed at this stage. Except in the special case where workers in an imperfectly competitive labor market value the welfare reform just as much as their value their own income (i.e. the 'social wage') the macrosimulation reveals the real possibility of (major) contractions in economic activity and employment. These contractions are particularly strong where there this is migration response and wage bargaining. While policy may be used to mitigate some of these effects, for example, if the government was able to negotiate a social contract that limited any "wage push" response to the introduction of a UBI, or stimulate a significant improvement in productivity, it is the complementary use of the CGE modeling that raises awareness of the possible need for such additional interventions.

In assessing major welfare reforms, without a dynamic CGE analysis there may be little understanding of such possible longer-term effects of major welfare policy changes, and no appreciation of their possible scale. But similarly, without microsimulation there would be little understanding of the complex distributional effects of the UBI or the scale of the shocks to the macroeconomic system. Future research could usefully explore the potential for further integration of micro- and macro- modeling (including incorporation of behavioral responses within the microsimulation model) and the impact of various sources of uncertainty surrounding the likely impact of the introduction of a UBI, such as the scale of the supply side response (including any productivity stimulus) and the probability of securing a social contract. From a policy perspective the information sets generated by both micro and macro simulation models are essential; the application of combined micro-macro modeling should become a routine element in the evaluation of any large-scale policy initiative within the welfare and fiscal systems.

Declaration of Competing Interest

We confirm that none of the authors have any financial and/or personal relationships with other people or organizations that could inappropriately influence (bias) the work.

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Data availability

The data that has been used is confidential.

Supplementary materials

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