The Effect of Automatic Stabilisers on UK Business Cycles

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1 Introduction

We perform a quantitative analysis of the effects of automatic stabilisers on the United Kingdom business cycle using a heterogeneous-agent DSGE model with price rigidities and a full set of automatic stabilisers first introduced by McKay and Reis (2013).
We aim at comparing the effectiveness of automatic stabilisers under the 2004-07 and 2015-18 fiscal regimes to establish whether the 2008 financial crisis engendered a quantitatively relevant change in fiscal policy. A further goal is comparing the results from the two fiscal regimes in the United Kingdom to the impact of fiscal stabilisers on the United States business cycle as studied by McKay and Reis (2013). In broad strokes, the United States fiscal regime emphasises unemployment benefits over safety-net transfers, while the opposite is true for the United Kingdom. Furthermore, the United States income tax schedule is relatively flat, similarly to the United Kingdom before the crisis. On the other hand, the income tax became significantly more progressive in the United Kingdom under the more recent fiscal regime. These differences can have potentially important implications on the behaviour of fiscal stabilisers.
There are four main theoretical channels explaining the role of automatic stabilisers in mitigating business cycle volatility. The disposable income channel (Brown (1955)) stipulates that a fiscal instrument that reduces the volatility of after-tax income across the business cycle will stabilise consumption and investment, and so aggregate demand as well. Another possible channel acts through marginal incentives (Christiano (1984)). For instance, a progressive income tax makes the marginal tax rate of workers fall in recessions and increase in expansions, inducing countercyclical substitution of work effort. Furthermore, stabilisers can act through redistribution (Blinder (1975)) by shifting resources from richer to poorer individuals. If low-income households have higher marginal propensities to consume, in recessions the system of transfers will smooth aggregate consumptions as spending on automatic stabilisers increases and receivers will spend a relatively higher portion of resources. Furthermore, Oh and Reis (2012) argue that redistribution can have a labour supply effect: if receivers are unemployed, and hence not working, while payers work more to offset the loss in income, aggregate labour supply will be stabilised as well. Finally, the social insurance channel (Floden (2001), Alonso-Ortiz and Rogerson (2010), Ragot and Challe (2011) works through precautionary savings. In the absence of policies such as safety-net transfers and unemployment benefits, households may engage in precautionary savings when facing unemployment risk, hence reducing their consumption when they are employed. Automatic stabilisers can reduce the need for precautionary savings, hence potentially reducing the volatility of consumption.
The set of stabilisers in the model allows us to investigate all four channels and the analysis of special cases in which some channels are shut off helps us pinpoint the avenue through which each stabiliser works.

2 Automatic Stabilisers in the UK

With the goal of comparing the effect of automatic stabilisers on the business cycle in the UK before and after the financial crisis of 2008, we gathered data on fiscal revenues and expenditures, shown in Table 1, and used it to calibrate our model. We chose two 4-year time periods, 2004-07 and 2015-18, to have a clear distinction between the pre- and post-crisis regimes while comparing similar phases in the business cycle.

On the revenue side, the personal income tax is quantitatively the most significant automatic stabiliser and it acts through all four channels identified by McKay and Reis (2013). Since it has a progressive structure, income tax revenue falls more than income in recessions, and it redistributes from rich to poor households. Additionally, it affects the marginal returns of labour across the business cycle, lowers the volatility of after-tax income and provides social insurance. We include National Insurance Contributions along with the Personal Income Tax because its revenue is not earmarked for a specific type of expenditure and so it constitutes effectively and additional element of income tax.

We also consider three types of proportional taxes in our model: corporate income taxes, property taxes and sales and excise taxes. They all act through the after-tax income stabilisation channel. Concerning property taxes, we included only the Council Tax as it is the only tax levied explicitly on the value of property in the United Kingdom, hence matching the type of property tax included in the model. This choice presents the disadvantage that it is the occupant of residential property who pays the Council Tax rather than the owner, but we found it to be the closest proxy to a model-consistent tax on property value in the UK.

On the spending side, we consider two automatic stabilisers in the form of transfers. One is unemployment benefits, represented by the Jobseeker's Allowance in the time frame of our analysis, which acts countercyclically as spending increases during recessions with the increase of unemployment. The other type of transfers is safety-net programmes, which work through the redistribution, income stabilisation and social insurance channels. Their countercyclical potential lies in the increase of the number of households qualifying for safety-net benefits during recessions. We defined as safety-net benefits non-income related benefits, child benefits, disability benefits (Incapacity Benefit and Income and Support Allowance), Income Support and the Housing Benefit. These programmes are not conditional on looking for employment or being employed, to reflect that only long-term unemployed households receive these transfers in the model. Consistently with this criterion, we included Child Tax Credits together with other child benefits as a safety-net programme because, although formally a tax credit, they are not subject to any requirement of employment.

We included government purchases too, although most of the literature on automatic stabilisers neglects them as they do not respond by law to economic conditions. However, they might still represent an important source of stabilisations if government systematically, although not automatically, increase spending in recessions. To allow for this convention in

Table 1: UK Government Budget (Percent of GDP)

Revenues	2004-07	2015-18	Outlays	2004-07	2015-18
Progressive income taxes			*Transfers*		
Personal income taxes and NICs	15.78	15.42	Jobseeker's Allowance	0.17	0.12
			Safety-net programmes	5.29	5.21
Proportional taxes			Non-income related benefits	1.31	1.49
Corporate income taxes	2.65	2.43	Child benefits and tax credits	1.74	1.65
Council Tax	1.50	1.53	Disability benefits	0.49	0.73
Sales and excise taxes	8.59	8.73	Income Support	0.75	0.13
			Housing Benefits	0.99	1.22
Budget deficits			*Government spending*		
Public deficit	3.01	3.32	Government purchases	18.91	18.74
			Net interest expenditure	1.48	1.49
Out of the model			*Out of the model*		
Others	6.98	8.10	Contributory benefits	4.18	4.95
			Others	8.47	9.03
Total	38.49	39.53	*Total*	38.49	39.53

the literature, we consider both cases in which the government adjusts spending in response to the business cycles and cases in which it does not.
Lastly, our model excludes quantitatively important sources of government spending, including contributory benefits (mainly pensions and the contributory part of Jobseeker's Allowance) because, as most conventional business cycle models, we exclude life-cycle considerations that play a crucial part in healthcare and pension spending.

3 Model

We used the heterogeneous-agent business cycle model with nominal rigidities and a full set of tax and transfers introduced by McKay and Reis (2013), which incorporates all four theoretical channels of action of automatic stabilisers. In addition, this model is close to established frameworks that capture business cycle properties well, such as Christiano et al. (2005). We will describe the model briefly, consult McKay and Reis (2013) for details on the equilibrium equations and solution algorithm.

3.1 Patient households

The economy is populated by two groups of households. The first group is more patient and has access to a complete set of insurance markets that allows them to avoid all idiosyncratic

risk. Therefore, there is a representative patient household in the model, who maximises utility function

$$\mathbb{E}_0 \sum_{t=0}^{inf} \beta^t \left[\log c_t(i) - \psi_1 \frac{n_t(i)^{1+\psi_2}}{1+\psi_2} \right] \tag{1}$$

subject to budget constraint

$$\hat{p}_t c_t + b_{t+1} - b_t = p_t[x_t - \bar{\tau}^x(x_t) + T_t^p] \tag{2}$$

c_t is consumption, n_t is hours worked, $\hat{p}_t$ is the after-tax consumption price, x_t pre-tax real income, b_t is risk-free bond holdings, $\bar{\tau}^x(\cdot)$ is the progressive income tax function and T_t^p is lump-sum transfers, which are calibrated to zero in steady-state but can change over the cycle to balance the government budget in a way that does not affect the stabilisation properties of the fiscal regime. The parameters β, ψ_1 and ψ_2 represent the discount factor, the relative willingness to work and the Frisch elasticity of labour supply, respectively.
The real taxable income of the representative patient household is

$$x_t = \frac{i_{t-1}}{p_t} b_t + d_t + w_t \bar{s} n_t \tag{3}$$

where i_{t-1} is nominal return rate of riskless bonds, d_t represents dividends from owning intermediate-goods firms, w_t is the average wage in the economy and $\bar{s}$ is the fixed skill level of the representative agent.
The first automatic stabiliser in the model is the personal income tax, which follows

$$\bar{\tau}^x = \int_0^x \tau^x(x')dx' \tag{4}$$

where $\tau^x : \mathbb{R}^+ \to [0,1]$ is the marginal tax rate, a weakly increasing function of income that makes the income tax system progressive.

3.2 Impatient households

Impatient households are indexed by $i \in [0, \nu]$, where ν is their mass. They choose consumption, hours worked and bond holdings to maximise the same utility function as patient households except for a discount factor $\hat{\beta} < \beta$, subject to the budget constraint

$$\hat{p}_t c_t(i) + b_{t+1} - b_t(i) = p_t[x_t(i) - \bar{\tau}^x(x_t(i)) + T_t^s(i)] \tag{5}$$

where $T_t^s(i)$ is safety-net transfers and a borrowing constraint $b_{t+1}(i) \geq 0$.
Impatient households face uninsurable idiosyncratic risk on their labour force status, $e_t(i)$ and on their skill $s_t(i)$. Employed households ($e_t(i) = 2$) choose how many hours to work and receive income $s_t(i) w_t n_t$. $s_t(i)$ represents a shock to workers' productivity and it generates a cross-sectional distribution of labour income. With a given probability for

every period, workers can lose their job and become unemployed ($e_t(i) = 1$). In this case, their labour income is zero but the household collects unemployment benefits $T_t^u(i)$, which is taxable in the United Kingdom. When unemployed, households face a probability of finding a new job and a probability of exhausting unemployment benefits and falling in long-term unemployment ($e_t(i) = 0$), which makes the household qualify for non-taxable safety-net transfers. We refer to these households are "long-term unemployed" or "needy" interchangeably, to highlight that they rely on safety-net transfers.
Therefore, impatient households' taxable real income can be summarised as follows:

$$x_t(i) = \begin{cases} \frac{i_{t-1}b_{t-1}}{p_t} + w_t s_t(i) n_t(i) & \text{if employed } e_t = 2 \\ \frac{i_{t-1}b_{t-1}}{p_t} + T_t^u(i) & \text{if unemployed } e_t = 1 \\ \frac{i_{t-1}b_{t-1}}{p_t} & \text{if needy } e_t = 0 \end{cases} \tag{6}$$

The labour market and skill transition matrices are the same used in McKay and Reis (2013).
The automatic stabilisers introduced with this type of agent are unemployment and safety-net transfers. The former follow

$$T_t^u(i) = \bar{T}^u \min\{s_t(i), \bar{s}^u\} \tag{7}$$

while the latter are assumed to be lump-sum

$$T_t^s(i) + \bar{T}^s \tag{8}$$

3.3 Final goods' producers

Final goods producers combine intermediate goods according to the production function

$$y_t = \left(\int_0^1 y_t(j)^{\frac{1}{\mu_t}} dj \right)^{\mu_t} \tag{9}$$

where $y_t(j)$ is input from the j_{th} intermediate goods producer and $\mu_t > 1$ is desired markup, which varies because of shocks to elasticity of substitution across intermediate goods.
The representative final goods firm takes the final-good pre-tax price p_t as given and pays $p_t(j)$ for each input. Final goods are taxed at rate τ^c, so the after-tax price of final goods is

$$\hat{p_t} = (1 + \tau^c) p_t \tag{10}$$

The newly-introduced automatic stabiliser is the proportional consumption tax with rate τ^c.

3.4 Intermediate goods

There is a unit mass of intermediate-goods monopolistic firms indexed j, whose production function is

$$y_t(j) = a_t k_t(j)^{\alpha} l_t^{1-\alpha} \tag{11}$$

where a_t is productivity, $k_t(j)$ is capital and $l_t(j)$ is effective labour, sum of labour input from patient and impatient households,weighted by their productivity.
Intermediate goods producers maximise after-tax nominal profits

$$d_t(j) = (1-\tau^k)\left[\frac{p_{t(j)}}{p_t} y_t(j) - w_t l_t(j) - (\upsilon r_t + \delta) k_t(j) - \xi\right] - (1-\upsilon) r_t k_t(j) \tag{12}$$

where r_t is the rental rate of capital, δ is the depreciation rate, τ^k is the corporate income tax rate, ξ is fixed cost of production and υ is the share of capital expenses that can be deducted from the corporate income tax.
Intermediate firms face price rigidities a' la Calvo (1983), with probability of price revision θ and choose their optimal revision price $p_t(j)^*$ to maximise expected future profits

$$\mathbb{E}_t\left[\sum_{s=0}^{\inf} (1-\theta)^d \lambda_{t,t+s} d_{t+s}(j)\right] \tag{13}$$

subject to $p_{t+s}(j) = p_t(j)$. $\lambda_{t,t+s}$ is the stochastic discount factor of patient households, who own intermediate goods producers. The automatic stabiliser introduced with this agent is the corporate income tax with flat rate τ^k.

3.5 Capital-goods firms

A representative firm owns the capital stock and rents it to intermediate goods producers at the given rate r_t. It invests in new capital $\Delta k_{t+1} = k_{t+1} - k_t$ to maximise after-tax profits subject to adjustment costs

$$d_t^k = r_t k_t - \Delta k_{t+1} - \frac{\zeta}{2}\left(\frac{\Delta k_{t+1}}{k_t}\right)^2 k_t - \tau^p v_t \tag{14}$$

where ζ is the adjustment cost parameter, τ_p is the property tax rate and $v_t = d_t^k + \mathbb{E}_t\left(\lambda_{t,t+1} v_{t+1}\right)$ is the value of the firm. This agent introduces a progressive tax τ^p on capital, the only form of property present in the model.

3.6 Government

The government budget constraint is

$$p_t \left[\tau^c \left(\int_0^\nu c_t(i)di + c_t \right) + \tau^p q_t k_t + \int_0^\nu \bar{\tau}^x(x_t(i))di + \bar{\tau}^x(x_t) \right.$$
$$\left. + \tau^k \left[\int_0^1 \hat{d}^i(j)dj + (1-\upsilon) r_t k_t \right] - \int_0^\nu [T_t^u(i) + T_t^s(i)]di \right]$$
$$= p_t g_t + i_{t-1} B_t + B_t - B_{t+1} + p_t T_t^p \quad (15)$$

where g_t is government purchases and $B_t = \int_0^\nu b_t(i)di + b_t$ is government bonds. In steady state, revenues exceed expenditure from automatic stabilisers, so the budget is balanced by steady-state government purchases $\bar{g}$. Furthermore, since we calibrate transfers to patient households $\bar{T}^p$ to 0 in steady state, the budget constraint pins down a level of steady-state government debt $\bar{B}$.

Outside of the steady state, expenditure rises and revenue falls in recessions, so the government deficit increases, which has a potential stabilising effect. We impose that the lump-sum transfer to patient households and government purchases adjust to close deficits out of the steady state because they are the tools least interfering with other stabilisers. The dynamics of government purchases and transfers to patient households follow linear rules as in Leeper et al. (2010).

$$\log(g_t) = \log(\bar{g}) - \gamma^G \log \frac{B_t \; p_t}{\bar{B}} \quad (16)$$

$$T_t^p = \bar{T}^p - \gamma^T \log \frac{B_t \; p_t}{\bar{B}} \quad (17)$$

The parameters γ^T and γ^G measure the speed at which the deficits from recessions are paid over time.

3.7 Shocks and business cycles

In the baseline model, monetary policy follows a simple inflation-based Taylor rule

$$i_t = \bar{i} + \phi \log(p_t) - \varepsilon_t \quad (18)$$

The economy is subject to three aggregate shocks: technology, $\log(a_t)$, monetary policy, ε_t and markups, $\log(\mu_t)$, which all follow independent AR(1) processes.

On the other hand, the idiosyncratic shocks to households, $e_t(i)$ and $s_t(i)$ are first-order Markov processes, with the labour-force status transition matrix depending on a linear combination of aggregate shocks to make unemployment vary with the business cycle.

4 Calibration

Table 4 displays parameters calibrated to match features of UK fiscal policy before and after the financial crisis of 2008. We calibrate as many parameters as possible targeting the fiscal outlays and receipts in Table 1. We target fiscal outlays with tax rates parameters using the method proposed by Mendoza et al. (1994). The tax rate on consumption τ^c is calculated as

$$\tau^c = \frac{Tax_C}{C - Tax_C}$$

Where Tax_C is receipts from sales and excise taxes and C is private sector consumption. The denominator allows for the inclusion of sales taxes in consumption in national accounts. The tax rate on property τ^p targets the average revenue from the Council Tax as follows

$$\tau^p = \frac{Tax_P}{V_P}$$

Where Tax_P is revenue from Council Tax and V_P is the estimated value of residential property stock. The rationale for this equation is the status of the Council Tax as a levy on the value of property, although it is only an approximation since its rate does not increase linearly with property value. τ^K is set equal to the statutory rate of corporate income tax, while the capital costs deduction rate υ targets the average revenue from the corporate income tax, taking τ^K as given and following the equation

$$Tax_K = \tau^K * \Pi_K - \upsilon * Inv$$

Where Tax_K represents corporate income tax receipts, Π_K corporate profits and Inv capital expenditure, all as a fraction of GDP.
Parameters referring to outlays in Panel B target the right-hand side of table 1, but we scale expenditures by a factor that ensures the government balances its budget in the steady state using the following procedure. We take the sum of all outlays included in the model and find the scaling factor that sets it equal to the sum of all revenues included in the model, excluding public deficit. The results are 1.103 for 2004-07 and 1.1 for 2015-18. The parameters on unemployment and safety net benefits combine average outlays on benefits from Table 1 with steady-state output per worker and fractions of households belonging to each occupational category reported in Table 2.

$\bar{T}^u$ is the solution of

$$\frac{Exp_U}{Y} = \bar{T}^u * \frac{U}{E} * \frac{\bar{E}}{\bar{Y}}$$

Where $\frac{Exp_U}{Y}$ is the average expenditure on unemployment benefits, $\frac{\bar{E}}{\bar{Y}}$ is steady-state output per worker and $\frac{U}{E}$ is the ratio of unemployed to employed workers derived from Table 2.
$\bar{T}^s$ satisfies

$$\frac{Exp_S}{Y} = \bar{T}^s * \frac{S}{E} * \frac{\bar{E}}{\bar{Y}}$$

Table 2: Steady State Employment Status

Employment Status	Population %
Employed	0.692
Unemployed	0.021
Needy	0.087

Where $\frac{Exp_S}{Y}$ represents average outlays on safety-net benefits and $\frac{S}{E}$ the ratio of needy to employed households derived from Table 2.
We calibrate the maximum ratio of unemployment benefits to average income $\bar{s}^u/\bar{T}^u$ to match the maximum Jobseeker's Allowance payment mandated by UK law, using data from the Institute for Fiscal Studies. The ratio of steady-state debt to output $\bar{B}/\bar{Y}$ targets average interest expenses according to

$$\frac{Exp_i}{Y} = \bar{i} * \frac{\bar{B}}{\bar{Y}}$$

Where $\bar{i}$ is the steady-state interest rate.
We obtain the ratio of steady-state government purchases to output by via the following relationship between production and GDP in the model

$$\bar{Y} = \frac{GDP}{\mu}$$

Where $\bar{Y}$ is steady-state production and $\frac{1}{\mu}$ equals fixed costs of production at the steady-state. Therefore, the ratio of steady-state purchases to output equals the government expenditure figure in Table 1 multiplied by $\frac{1}{\mu}$.
The fiscal adjustment parameters γ^T and γ^G target the standard deviations of deficit/GDP and government spending, respectively. These parameters are calibrated to quarterly HP-filtered data over the 1960-2011 period, in order to better match the volatility of aggregate macroeconomic variables by including a larger sample of recessions.
Finally, we calibrate the personal income tax function $\bar{\tau}^x(x)$ by building a marginal income tax schedule for a typical household as a function of income relative to the average for each year in our 2004-07 and 2015-18 samples, and then averaging over the years in each sample. We include National Insurance contributions as well as Personal Income taxes, as explained in section 2, and it takes into account tax credits in order to obtain an effective income tax schedule that represents the net payment for every level of income. Since the model does not feature life-cycle considerations and fertility choices, in building the income tax schedule we considered only Working Tax Credit elements as awarded to a typical household.

Table 3: UK Fiscal Parameters

Symbol	Parameter	Value (2004-2007)	Value (2015-2018)	Target (Source)
Panel A. Tax bases and rates				
τ^c	Tax rate on consumption	0.1444	0.1498	Avg. revenue from sales taxes (Table 1)
τ^p	Tax rate on property	0.00523	0.00470	Avg. revenue from property taxes (Table 1)
τ^k	Tax rate on corporate income	0.3	0.2	Statutory rate
v	Deduction of capital costs	0.21	0.13	Avg. revenue from corporate income tax (Table 1)
Panel B. Government outlays and debt				
$\bar{T}^u$	Unemployment benefits	0.076	0.052	Avg. outlays on unemp. benefits (Table 1)
$\bar{s}^u/\bar{T}^u$	Max. UI benefit / avg. income	0.157	0.158	Maximum Jobseeker's Allowance payment in UK law
$\bar{T}^s$	Safety-net transfers	0.802	0.817	Avg. outlays on safety-net benefits (Table 1)
G/Y	Steady-state purchases / output	0.1897	0.1874	Avg. outlays on purchases (Table 1)
γ^T	Fiscal adjustment speed (tax)	-1.6	-1.6	St. dev. of deficit/GDP = 0.031 (ONS Public Sector)
γ^G	Fiscal adjustment speed (spending)	-1.28	-1.28	St. dev. of spending = 0.0301 (QNA)
B/Y	Steady-state debt / output	0.73	0.84	Avg. interest expenses (Table 1)

This figure includes the extra element for couples, but it excludes all Child Tax Credit. The results are shown in Figure 1, which highlights how, in both regimes, the marginal effective income tax rate is strongly increasing in the range between 0.2 and 1 because of the progressive decrease in tax credits. Contrarily, as households stop receiving Working Tax Credit altogether the tax rate strongly decreases, while only in the post-crisis regime the marginal tax rate increases sharply again, up to 62%, as the Personal Allowance tapers away for incomes higher than £100,000.

This feature, together with the introduction of the Additional Rate at 45% for incomes higher than £150,000, makes the effective income tax markedly more progressive in the post-crisis fiscal regime and suggests that its countercyclical effect before the financial crisis might have been limited.

We then approximate the schedule with a third-degree polynomial to facilitate the numerical analysis, and spline it with a flat line above the income level after which the schedule becomes decreasing, as the income tax function in the model is non-decreasing. Lastly, we add an intercept to target the average income tax rate, calculated with the Mendoza et al. (1994) method according to the following equation

$$\tau^x = \frac{Tax_x}{W + OSPUE + PEI}$$

Where Tax_x is the average revenue from Personal Income Tax and National Insurance Contributions, W is average wage income $OSPUE$ is the operating surplus of private unincorporated enterprises and PEI is households' property and entrepreneurial income. Therefore, the income tax function in the model targets both the structure of the effective income tax schedule, via its shape, and the average revenue from income taxes, via the intercept.

All other parameters, mainly preferences, technology and the business cycle, are kept fixed from McKay and Reis (2013) in order to isolate the effect of the fiscal regime.

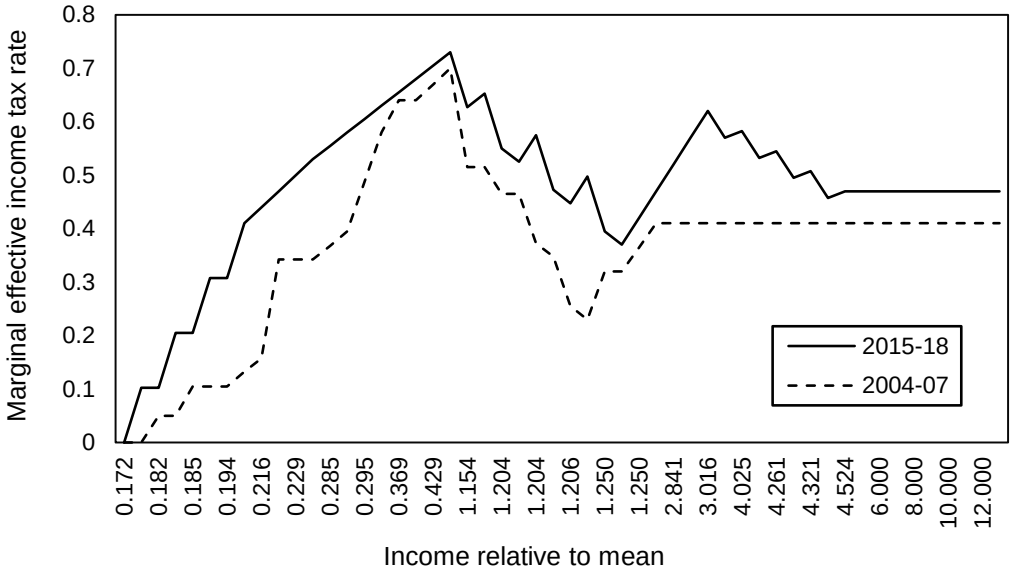

Figure 1: Effective Income Tax Schedules

Table 4: Fixed US Parameters

Symbol	Parameter	Value	Target (Source)
Panel A. Technology and preferences			
β	Discount factor of patient households	0.989	Consumption-income ratio = 0.689 (NIPA)
β^h	Discount factor of impatient households	0.979	Wealth of top 20% by wealth
α	Coefficient on labour in production	0.296	Capital income share = 0.36 (NIPA)
ξ	Fixed costs of production	0.575	Corporate profits / GDP = 9.13% (NIPA)
μ	Desired gross markup	1.1	Avg. U.S. markup (Basu, Fernald, 1997)
Panel B. Income and wealth distribution			
ν	Non-participants / stock owners	4	
$\bar{s}$	Skill level of stock owners	3.72	Income of top 20% by wealth (SCF)
Panel C. Business-cycle parameters			
θ	Calvo price stickiness	0.286	Avg. price spell duration = 3.5 (Klenow, Malin, 2011)
ψ_1	Labor supply	21.6	Avg. hours worked = 0.31 (Cooley, Prescott, 1995)
ψ_2	Labor supply	2	Frisch elasticity = 1/2 (Chetty, 2011)
δ	Depreciation rate	0.0114	Annual depreciation expenses / GDP = 0.046 (NIPA)
ζ	Adjustment costs for investment	6	St. dev. of I = 0.053 (NIPA)
ρ_z	Autocorrelation productivity shock	0.75	Autocorrel. of log GDP = 0.864 (NIPA)
σ_z	St. dev. of productivity shock	0.00294	St. dev. of log GDP = 1.539 (NIPA)
ρ_m	Autocorrelation monetary shock	0.62	Largest AR for inflation = 0.85 (Pivetta, Reis, 2006)
σ_m	St. dev. of monetary shock	0.00353	Share of output variance due to shock = 0.25
ρ_p	Autocorrelation markup shock	0.85	
σ_p	St. dev. of markup shock	0.0251	Share of output variance due to shock = 0.25
ϕ_p	Interest-rate rule on inflation	1.55	St. dev. of inflation = 0.638 (NIPA)

5 Positive Properties

Before turning to experiments aimed at investigating the effectiveness of automatic stabilisers, we present some of the positive properties displayed by the model, both at the steady state and in response to shocks. Since the equilibrium behaviour analysed in this section is very similar, both quantitatively and qualitatively, under both regimes, we only report figures and tables for the 2015-18 period for the sake of brevity.

Figure 2 shows the optimal savings rule for the three types of impatient households. They save only when they are employed, as shown by the function for employed households being the only one above the 45 degree line in the figure. Conversely, households consume assets to finance consumption when they are not working. When their wealth falls to zero, the unemployed and needy use up all their safety-net and unemployment transfers, as evident in the flat segment on the horizontal axis in their savings functions.

Figure 4 displays the ergodic wealth distribution for impatient households. Notice that needy households hold nearly no assets, so they rely almost entirely on safety-net transfers for their consumption. As we will see in section 6.2, this plays a crucial role in differentiating the effect of transfers on the business cycle in the United Kingdom and the United States, as the former spend a far larger share of GDP on safety-net transfers, which benefit disproportionately poorer households.

We also present a counterfactual wealth distribution in which we significantly reduce all stabilisers, as we will do in the experiment in section 6.4. Households now save more because losing their job now implies a larger fall in disposable income. This behaviour has crucial implications as it suggests an important role of the social insurance channel and hence of policies like transfers.

These features are present in McKay and Reis (2013) as well, which reassures that the calibration we are using does not alter the core mechanisms at work in the model.

5.1 Business Cycles

We now analyse some dynamic properties of the model to establish whether it can reproduce key features of standard models in the literature and business cycle data.

Figure 4 reports the impulse responses of key variables in the model to three aggregate shocks of one standard deviation. The model reproduces well the positive correlation of output, hours and consumption and the hump-shaped response of output.

Figure 5 shows the reaction of output to three fiscal shocks: an increase in government purchases, a cut in the personal income tax, and a redistribution of wealth from patient households to the long-term unemployed. For the first two shocks, the parameter changes unexpectedly at date 1 only and we follow the dynamics of the aggregate variables in the economy as it converges back to the previous ergodic distribution. Conversely, for the third one, we redistribute wealth at date 1 and simulate the model starting from the new distribution.In all three cases, we report the response of output normalised by the size

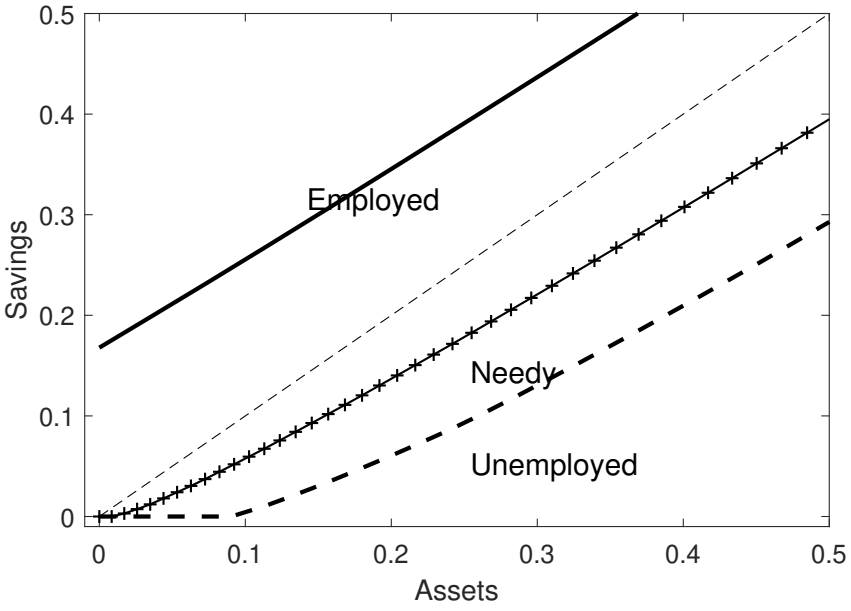

Figure 2: Optimal savings policies, 2015-18

of the policy change in terms of its impact on public deficit. This approach allows us to calculate simple fiscal multipliers as the ratio of change in output to the change in deficit in the first year of the experiment, providing a first answer to the question of fiscal policy effectiveness in this setting.

The multipliers for the new regime are 0.84 for government purchases, 0.15 for taxes and 0.21 for redistribution, while they are 0.82 for purchases, 0.21 for taxes and 0.22 for redistribution in the old regime. The higher multiplier on taxation in the United Kingdom under the new regime is due to the steeper income tax schedule, which causes a stronger labour supply effect on rich employed households and so a greater impact on output. These figures are higher than the typical results from new-Keynesian synthesis models, but in line with the analysis of American fiscal policy in McKay and Reis (2013).Larger fiscal multipliers can be explained by both aggregate demand and aggregate supply factors. The former are due to household heterogeneity, and in particular to the presence of unemployed and needy households with higher marginal propensities to consume, which amplifies aggregate demand. The latter are attributable to employed households increasing their labour supply markedly when marginal tax rates fall or when their after-tax wealth decreases in response to bearing a larger share of the financing for the fiscal expansion.

Table 5 shows the distribution of marginal propensities to consume (MPC) over employment status and wealth percentiles. They range from 0.02 to 0.49, broadly in line with

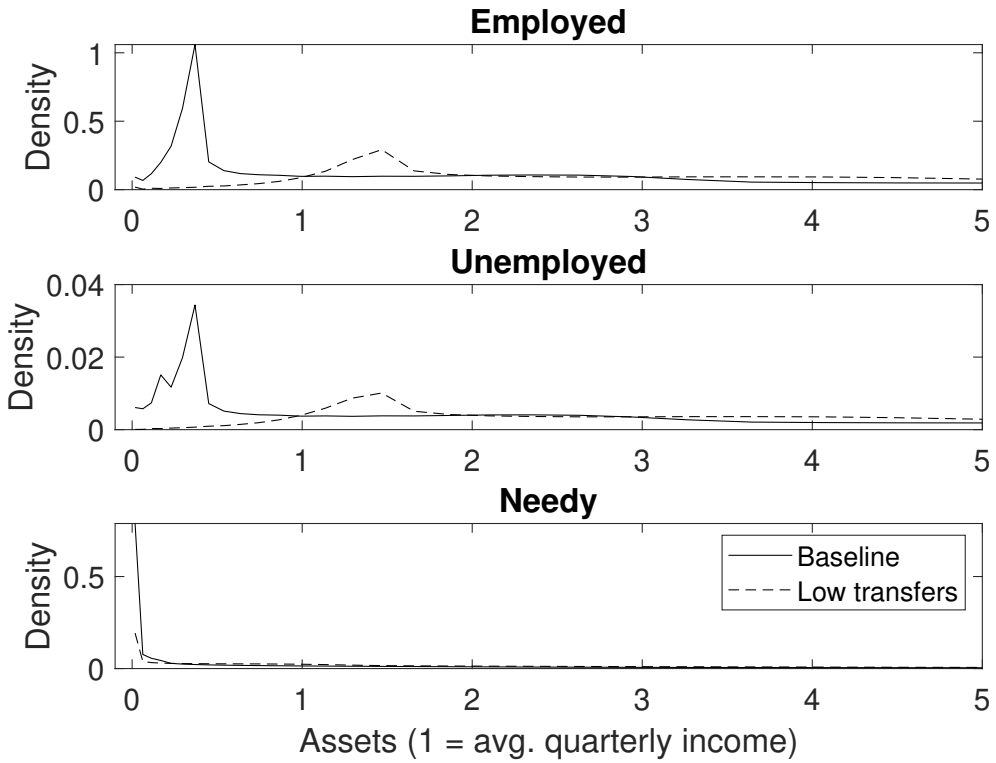

Figure 3: Smoothed ergodic wealth distribution (density), 2015-18

empirical estimates, (Bracke and Sethi (2017)). Notice that needy and low-skilled unemployed households display the highest marginal propensities to consume, which opens the possibility of strong effects of stabilisers through the redistribution because moving resources from agents with higher to lower MPCs would trigger large effects on aggregate demand. Comparing table 5 to figure 3 reveals that households with high MPCs belong to groups that resort to precautionary savings when stabilisers are cut. This feature suggests that the social insurance channel might play a large role too.

Table 5: Marginal propensity to consume

		Wealth percentile		
Skill group	Employment	10th	25th	50th
Low	Employed	0.10	0.08	0.07
Medium	Employed	0.04	0.03	0.03
High	Employed	0.03	0.03	0.02
Low	Unemployed	0.47	0.33	0.21
Medium	Unemployed	0.10	0.06	0.05
High	Unemployed	0.06	0.04	0.03
Low	Needy	0.48	0.48	0.48
Medium	Needy	0.49	0.49	0.10
High	Needy	0.49	0.13	0.07

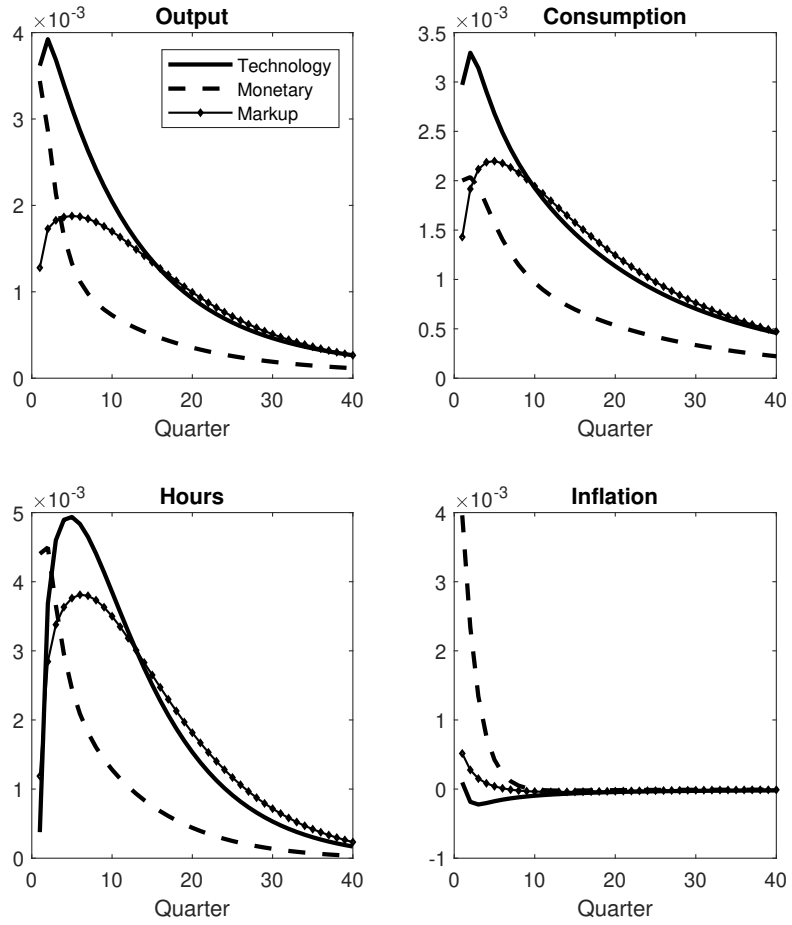

Figure 4: Impulse responses to the aggregate shocks, 2015-18

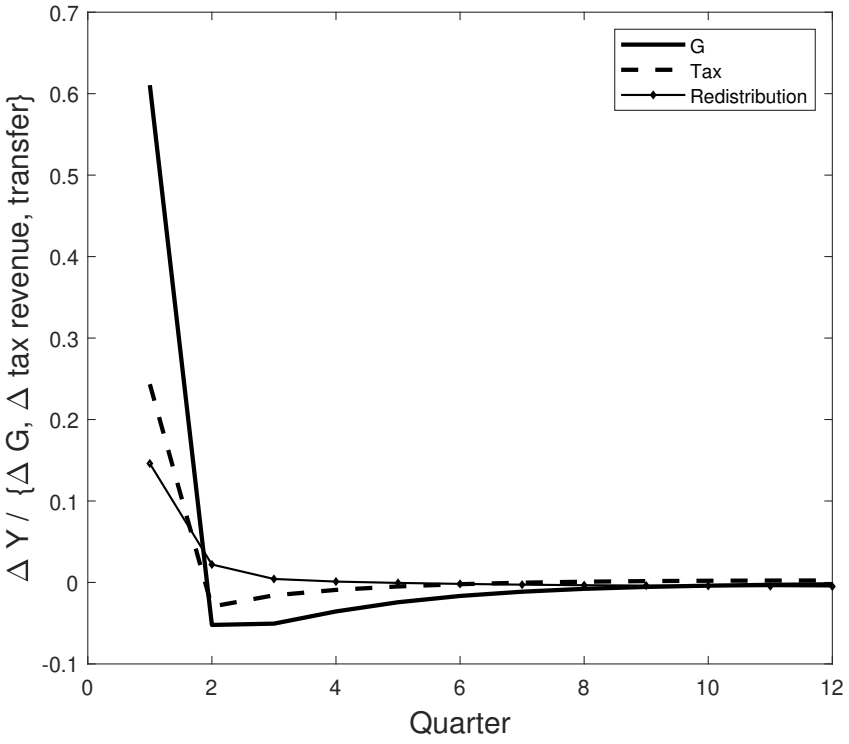

Figure 5: Impulse responses to the aggregate shocks, 2015-18

6 Results

In this section, we present the results of experiments aimed at establishing the effect of all the automatic stabilisers in the model on the volatility of business cycle variables and on the welfare of households. The tables below report changes from cutting stabilisers, so in the case of welfare and averages, a negative value implies a positive effect of the stabiliser, while in the case of variances, a positive value implies a positive effect.

6.1 Proportional Taxes

Table 6 reports the results from cutting the three proportional taxes, τ^c, τ^p and τ^k by 10% each. In the full model, lowering proportional taxes lowers the variance of output and hours by a negligible amount, while it has a slightly stronger effect on consumption in either fiscal regime. This result implies that proportional taxes fails to stabilise the business cycle, as they display a fixed rate regardless of economic conditions, they do not affect marginal incentives to work nor do they have a different impact on disposable income in expansions or recessions. On the other hand, as expected average aggregate economic activity is higher across all models when proportional taxes are cut as they lower returns from working. In the representative agent case we can observe a slight increase in volatility as a result of the tax cut, but its very small size still suggests a negligible effect of proportional taxes on the business cycle.
The impact of proportional taxes is very similar across the two regimes, as expected given the almost identical size of proportional tax revenue before and after the crisis.
In table 7, we lower the intercept of the income tax schedule, corresponding to a lower average income tax rate. Since this experiment does not change the shape of the income tax function, it does not affect any of the theoretical channels and, as expected, it acts like a proportional tax cut by slightly lowering business cycle volatility across all cases. Cutting the average tax income also results in a smaller increase in economic activity than lowering proportional taxes, but this is due to the smaller change in average income tax revenue caused by the experiment.

Table 6: The effect of proportional taxes on the business cycle.

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
2004-07						
output	-0.0066	0.0229	0.0001	0.0233	-0.0109	0.0227
hours	-0.0012	0.0021	0.0054	0.0045	-0.0029	0.0015
consumption	-0.0359	0.0198	-0.0312	0.0202	-0.0089	0.0194
2015-18						
output	-0.0074	0.0187	-0.0005	0.0185	-0.0085	0.0185
hours	-0.0031	0.0023	0.0033	0.0047	-0.0030	0.0020
consumption	-0.0307	0.0161	-0.0240	0.0159	-0.0054	0.0159

Proportional change caused by cutting the stabilizer.

Table 7: The effect of the level of income tax rates on the business cycle.

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
2004-07						
output	-0.0099	0.0075	-0.0051	0.0078	-0.0269	0.0071
hours	-0.0105	0.0040	-0.0048	0.0078	-0.0093	0.0031
consumption	-0.0134	0.0087	-0.0039	0.0091	-0.0342	0.0082
2015-18						
output	-0.0128	0.0068	-0.0041	0.0067	-0.0157	0.0066
hours	-0.0084	0.0035	-0.0034	0.0067	-0.0062	0.0029
consumption	-0.0138	0.0078	-0.0037	0.0077	-0.0112	0.0075

Proportional change caused by cutting the stabilizer.

6.2 Transfers

We evaluate the effect of the two transfers in the model, unemployment benefits and safety-net transfers, by cutting both by 50%, which corresponds to 0.375% of GDP. The decrease in government expenditure is compensated by a lump-sum transfer to capital owners to prevent affecting the stabilising property of the fiscal regime.

Cutting transfers makes output and consumption more volatile under both fiscal regimes in the full model, while hours are more stable without stabilisers in the pre-crisis sample, but less stable in the new regime. However, the quantitative impact on hours is very small in either case, so we can consider the two regimes as practically identical, as expected from the outlays on transfers reported in Table 1. To investigate further the drivers of the stabilisation, we turn to the two special cases in which some channels are shut off. In the model with representative agents, where only the marginal incentives and disposable income channels are active, transfers have a negligible effect on the volatility of all three variables. The impact on consumption is particularly striking, as its volatility increases by 17% in the full model, while it barely changes in the representative agent model. This suggests that the redistribution channel has a major role to play.

Transfers shift resources from employed households to the unemployed and needy. Since the latter have higher marginal propensities to consume and more households qualify for transfers during recessions, this redistribution causes consumption to increase during slumps, acting as a brake to volatility. At the same time, we would expect transfers to affect the labour supply as they are financed by taxing patient households, who respond to their lower wealth by working more during recessions, hence stabilising hours worked.

The intuition is confirmed by the hand-to-mouth case, in which the social insurance channel is inactive while the redistribution channel still operates. The effect on consumption of lowering transfers now is very close to that in the full model, while hours become volatile. The latter feature is consistent with the increase in labour supply of patient household noted above.

Conversely, transfers have a very small effect on the average level of activity in the economy, not distinguishable from zero for the level of approximation of this tables in the representative agent case.

Interestingly, transfers seem to have a very large and positive effect on the volatility of consumption in the United Kingdom, while they make it more volatile in the United States according to McKay and Reis (2013). This difference is attributable to significantly higher expenditure on a vast range of safety-net programmes in the United Kingdom, which makes the effect on consumption through the redistribution channel more prominent as needy households rely mostly on safety-net transfers to finance consumption and have the highest marginal propensity to consume in the model.

Table 8: The effect of transfers on the business cycle.

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
2004-07						
output	0.0645	-0.0061	-0.0009	0.0000	0.0479	-0.0112
hours	-0.0098	0.0082	-0.0008	0.0000	0.0406	-0.0046
consumption	0.1657	-0.0070	-0.0021	0.0000	0.1606	-0.0129
2015-18						
output	0.0675	-0.0076	-0.0007	0.0000	0.0728	-0.0114
hours	0.0099	0.0035	-0.0006	0.0000	0.0468	-0.0048
consumption	0.2058	-0.0087	-0.0016	0.0000	0.2476	-0.0130

Proportional change caused by cutting the stabilizer.

6.3 Progressive Income Taxes

In the experiment presented in Table 9, we replace the progressive personal income tax with a flat tax collecting the same amount in steady state.

Shifting to a proportional income tax raises the average level of output, hours and consumption in all three models and across the two regimes because more taxes are now collected from poorer households, which implies that high-income households face a lower marginal tax rate. Therefore, they save more, the average capital stock is higher, and average output rises together with hours worked and consumption. On the other hand, the impact on volatility is remarkably different across the two periods. Under the old regime, adopting a flat tax leads to a significantly less volatile business cycle. The core mechanism driving this result is related to the presence of monetary policy shocks and fixed prices.

With a progressive tax, the after-tax return on saving $(1-\tau^x(x_{t+1}i_t))$ is lower and less sensitive to variation in the nominal interest rate with respect to the flat-tax case. Since the nominal interest rate is driven by inflation through the monetary policy rule, a progressive income tax makes the after-tax real rate respond less strongly to inflation. Furthermore, with a progressive tax, the marginal tax rate increases in booms, which further lowers the after-tax real interest rate. As a result, progressive taxes lead to lower real interest rates after expansionary monetary policy shocks, making the responses of output and hours more volatile.

Another contribution to the higher volatility is a relatively flat tax schedule in the old regime, which implies a small difference in the marginal income tax rate of employed households between booms and recessions and weakens the redistribution channel, already less effective than in the case of transfers because it benefits relatively poorer employed households rather than the needy and unemployed.

Table 9: The effect of progressive taxes on the business cycle.

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
2004-07						
output	-0.0404	0.0476	-0.0253	0.0367	-0.1307	0.0464
hours	-0.0410	0.0290	-0.0153	0.0367	-0.0501	0.0249
consumption	-0.0685	0.0552	0.0043	0.0425	-0.1411	0.0537
2015-18						
output	0.0455	0.0043	0.0107	0.0149	0.0174	0.0032
hours	0.0238	0.0020	0.0144	0.0149	0.0061	0.0033
consumption	0.0347	0.0049	0.0338	0.0171	-0.0039	0.0037

Proportional change caused by cutting the stabilizer.

The new fiscal regime displays a much more progressive income tax, which implies that patient households face steeper changes in their marginal tax rate between booms and recessions. This in turn causes a significant incentive to intertemporal substitution of work effort, leading to more variable hours worked, output and aggregate consumption when the progressive income tax is replaced by a flat tax. The intuition that the stronger marginal incentives channel lies behind the more effective progressive income tax in the new regime is confirmed by the special cases: in the representative-agent and hand-to-mouth economies, the precautionary savings channels is absent, but a flat income tax still raises the variance of output and hours worked, although the effect is less quantitatively important. In the case of consumption, however the social insurance channel effect of the income tax schedule appears to have a crucial role in the new regime as volatility decreases with a flat tax in the hand-to-mouth case in which this channel is inactive.

6.4 All Stabilisers

Table 10 presents results from combining all the previous experiments: we replace the progressive income tax with a flat tax, cut proportional taxes by 10% and reduce unemployment and safety-net transfers by 50%. We also decrease the fiscal adjustment coefficients γ^T and γ^G so that the variance of budget deficits falls by 10%.

Overall, both the pre- and post-crisis fiscal regimes are very effective at reducing the volatility of output and hours, with effects of similar magnitude, while hours worked become slightly less volatile when stabilisers are cut under the old regime. Since the income tax was less progressive pre-crisis, the weaker incentive to redistribute working hours in the face of changing tax rates for employed households can account for the lack of stabilisation.

Table 10: The effect of all stabilizers on the business cycle.

	Full model		Representative agent		Hand-to-mouth	
	variance	average	variance	average	variance	average
2004-07						
output	0.0141	0.0654	-0.0405	0.0636	-0.0962	0.0593
hours	-0.0540	0.0370	-0.0662	0.0441	-0.0206	0.0222
consumption	0.8638	0.0689	1.2887	0.0669	0.1040	0.0619
2015-18						
output	0.0711	0.0078	-0.0320	0.0058	0.0443	0.0046
hours	0.0009	0.0096	-0.0428	-0.0079	0.0308	0.0008
consumption	0.7067	0.0038	0.9188	0.0014	0.3260	0.0001

Proportional change caused by cutting the stabilizer.

The most remarkable result is the very large increase in the volatility of consumption resulting from the weakening of automatic stabilisers, more than 100% in the 2004-07 period. The most important mechanism behind this result is the social insurance channel, as demonstrated by the much weaker impact on consumption in the hand-to-mouth case, in which there are no precautionary savings. Interestingly, the effect on consumption is stronger under the old regime, indicating a secondary stabilising role for the income tax as it is more progressive in the post-crisis regime. Therefore, the main source of stabilisation is plausibly transfers acting through social insurance. Since households face idiosyncratic employment risk, they engage in precautionary savings and so reduce consumption. The presence of a generous safety net provides insurance and allows households to consume more across the business cycle by reducing the need for precautionary savings.

In contrast, McKay and Reis (2013) finds that automatic stabilisers in the United States are much less effective at stabilising consumption, while they make output and hours worked more volatile. The difference can be explained by the much higher expenditure on safety-net benefits in the United Kingdom, paired with a more progressive income tax schedule acting mainly through the redistribution and marginal incentive channels. Furthermore, in the US the maximum unemployment benefit is higher as a proportion of income, at 66% while in the UK the Jobseeker's Allowance pays a maximum of roughly 16% of income under both regimes. Therefore, the transfers system is more skewed towards unemployment benefits in the US, which weakens the strength of the redistribution channel as unemployment benefits are subject to income taxation in the model. Furthermore, needy households have higher marginal propensity to consume, so higher spending on safety-net transfers has a stronger stabilising effect on consumption.

6.5 Fiscal Adjustment

We now turn to the matter of government debt financing, to explore the effect of both the speed of fiscal adjustment after recessions and of the means to finance it on the business cycle.

The second column in Table 11 presents the results of setting $\gamma^G = 0$, so that only the lump-sum tax adjusts to finance deficits. The stabilising effect of the fiscal regime on consumption is now much lower, and this is due to government purchases being now independent of the business cycle. In the baseline economy, the reduction in government consumption after a recession crowds in private consumption, but this effect disappears if $\gamma^G = 0$.

In the third column, we set $\gamma^G = 0$ and raise γ^T towards infinity, so that the government balances its budget in every period. The outcome is quantitatively very similar to column 2, which suggests that the timing of budget financing matters little despite Ricardian equivalence not holding in this economy.

In the experiment presented in column 4, we replace the fiscal adjustment rule for lump-sum taxes with a similar rule that acts on proportional tax rates and the intercept of the income tax schedule, targeting average income tax revenue. We choose the adjustment speed so that any change in public debt yields the same revenue as in the baseline rule. The result is a large destabilising effect on output and hours, and a significantly reduced stabilisation on consumption.

These effects are driven by three mechanisms. Firstly, the property and corporate income taxes raise during a recession, which pushes investment down. Furthermore, the sales tax rises to finance public debt, disincentivising households from consuming and working in the recession. Lastly, the average income tax rate rises as well, and is expected to decrease once the slump is over, discouraging labour supply. Consequently, when stabilisers are cut these distortionary adjustment to taxation weaken, making the economy less volatile. Note that consumption is still significantly stabilised by the fiscal regime because the crowding-in effect of government consumption is still present in this case.

Table 11: The effect of budget deficits on variances.

	Baseline	No spending response	No spending response and balanced budget	Distortionary taxes adjust
2004-07				
output	0.0141	0.0055	0.0070	-0.2602
hours	-0.0540	-0.0380	-0.0373	-0.0892
consumption	0.8638	0.0546	0.0568	0.3642
2015-18				
output	0.0711	0.0971	0.0976	-0.0569
hours	0.0009	0.0280	0.0282	-0.0168
consumption	0.7067	0.1895	0.1903	0.5927

Proportional change caused by cutting all stabilizers.

6.6 Monetary Policy and Automatic Stabilisers

In section 6.3, we showed that monetary policy plays an important role in the effectiveness of stabilisers, providing a further channel of action. Our results so far have demonstrated that automatic stabilisers in the United Kingdom are rather effective stabilising the business cycle, especially regarding consumption. Now we analyse the effect of cutting all stabilisers under different policy rule to gauge the relative importance of the monetary policy and fiscal channels.

The second column in Table 12 reports results from a model with flexible prices, serving as a useful benchmark because it neutralises the role of monetary policy entirely. From this first experiment we can already conclude that monetary policy seems to have a crucial role for output and labour supply stabilisation, as only the effects of fiscal stabilisers on consumption remain strong in the flexible prices case.

The model in column 3 has price rigidities and employs the following monetary policy rule, which Schmitt-Grohe (2007) show to be close to optimal in a standard neoclassical synthesis model

$$\log\left(\frac{i_t}{i_{t-1}}\right) = 0.77\log\left(\frac{i_{t-1}}{i_{t-2}}\right) + 0.75\log(\pi_{t-1}) + 0.02\log\left(\frac{y_{t-1}}{y_{t-2}}\right)$$

We use this rule because it depends on observables, avoiding the problem of defining the output gap in an economy with price rigidities and a full set of fiscal instruments. Under the Schmitt-Grohe and Uribe rule, stabilisers have a very similar effect on output, hours and inflation to the flexible-price case, while they have a larger impact on consumption. These results indicate that a quasi-optimal monetary policy is effective in stabilising the business cycle, but automatic stabilisers still have some room to operate through aggregate

consumption, further highlighting the importance of instruments like transfers that act mainly on this variable.
The last segment of the table compares results from the baseline model, which uses a standard inflation-based Taylor rule, to Taylor rules that follow the general form

$$\mathbb{E}_t \left[1 - \tau^x(x_{t+1})\right] i_t = \bar{i} + \phi_p \Delta \log(p_t) + \phi_y \Delta \log(y_t) - \varepsilon_t$$

and differ in aggressiveness with respect to output and inflation ϕ_p and ϕ_y. We use the after-tax interest rate because the progressive income tax interacts with monetary policy to determine the effective response of real interest rate to inflation through the mechanism explained in section 6.3.
The aggressive policy rule sets $\phi_p = 1.75$, while the baseline model uses $\phi_p = 1.55$, both with $\phi_y = 0$. The output rule keeps $\phi_p = 1.55$ from the baseline, but uses $\phi_y = 0.125$. Lastly, in the accommodative rule $\phi_p = 1.03$ and $\phi_y = 0$, making the after-tax real interest rate relatively insensitive to changes in inflation.
Under the output and aggressive monetary policies, results are quite similar to the baseline across the two regimes. On the other hand, the accommodative monetary policy renders automatic stabilisers more effective in dampening output volatility in both time periods, while it makes hours significantly more stable too under the 2015-18 fiscal regime. In the old regime, hours are still less volatile when stabilisers are cut, but the effect is quantitatively smaller.
These effects happen because the accommodative policy amplifies the fluctuations in output and labour supply due to demand shocks, since monetary policy reacts less strongly to the ensuing inflation movements. As a consequence, there is more room for automatic stabilisers to dampen the volatility of output and hours. Note that the strong effect on consumption persists under the accommodative policy. This result confirms that the stabilisers do not act solely through the government purchase channel, but they also have an important direct effect. If government purchases were the only driver, consumption volatility should not be significantly affected by cutting stabilisers under the accommodative policy, as private consumption is sheltered from changes in government spending in this case. Under the new fiscal regime, automatic stabilisers seem to be more effective on output stabilisation under flexible prices too, suggesting that the effect of the progressive income tax works mainly through a fiscal channel rather than through its interaction with monetary policy.

Automatic Stabilisers at the Zero Lower Bound

We study the behaviour of automatic stabilisers at the zero lower bound (ZLB) as a limit case of accommodative monetary policy. Furthermore, as noted by McKay and Reis (2013), recent research (Woodford (2003)) has shown that fiscal policy can be particularly powerful when nominal interest rates do not respond to inflation, and that different fiscal instruments have widely different effect relative to each other and to the case in which the Taylor

Table 12: The effect of all stabilizers on the business cycle.

			Taylor rule			
	Flexible prices	S.G.-U.	Baseline	Output	Aggressive	Accommodative
2004-07						
output	-0.0246	-0.0160	0.0141	-0.0045	-0.0075	0.0598
hours	-0.0621	-0.0605	-0.0540	-0.0498	-0.0535	-0.0421
consumption	0.9157	1.0803	0.8638	0.9029	0.8745	0.9485
inflation	-0.3659	-0.2660	-0.2442	0.1002	0.0959	-0.2232
2015-18						
output	0.0544	0.0588	0.0711	0.0616	0.0594	0.1122
hours	-0.0046	-0.0122	0.0009	-0.0021	-0.0045	0.0075
consumption	0.8296	0.9492	0.7067	0.7830	0.7630	0.7483
inflation	-0.0241	-0.1670	0.0323	0.0639	0.0641	-0.1242

Proportional change caused by cutting the stabilizer.

principle holds (Eggertsson (2011)).

Solving our model at the zero lower bound presents several difficulties, which we avoid by making some simplifications. Firstly, we fix the capital stock by raising the capital adjustment cost towards infinity. Secondly, we raise the degree of price stickiness to $\theta = 0.15$, which does not change much the other results but helps ensure the existence of a determined equilibrium by dampening the explosive dynamics of inflation at the ZLB. Furthermore, instead of the ergodic distribution, we calculate a perfect foresight transition path starting from a stationary equilibrium with no aggregate shocks but with idiosyncratic shocks still present. In summary, we eliminate aggregate uncertainty and investment to be able to preserve the strong non-linearities at the ZLB.

We then perform the following experiment: at date 1, all agents learn that the rate of time preference of all households falls by 0.25% for 15 periods, implemented by raising β and $\hat{\beta}$ by a factor of 1.0025. Furthermore, the risk of becoming unemployed rises by 1.35% per quarter and he job-finding rate of needy households falls by 0.89% for 8 quarters, which causes a cumulative drop of 4% in employment.

Figures 6 and 7 show the response of aggregate output, aggregate consumption, the nominal interest rate and consumption of impatient households in the old and new regime, respectively. Note that the reactions are qualitatively and quantitatively very similar for both regimes, so we will analyse them together.

Without stabilisers, the zero lower bound binds for one period, while output and aggregate consumption fall by between 1% and 2% on impact. With stabilisers, the response of all these variables are stronger, with the zero lower bound in particular binding for slightly

longer. In contrast, consumption of impatient households returns to its steady-state value faster with automatic stabilisers, albeit decreasing more on impact. This suggests that the social insurance and redistribution channel, which we found to be particularly important for the volatility of consumption, are especially powerful at the zero lower bound.
Overall, the results suggest that stabilisers are less effective at dampening the business cycle at the zero lower bound, which is surprising given results in the literature suggesting that fiscal policy is more powerful at the zero lower bound.

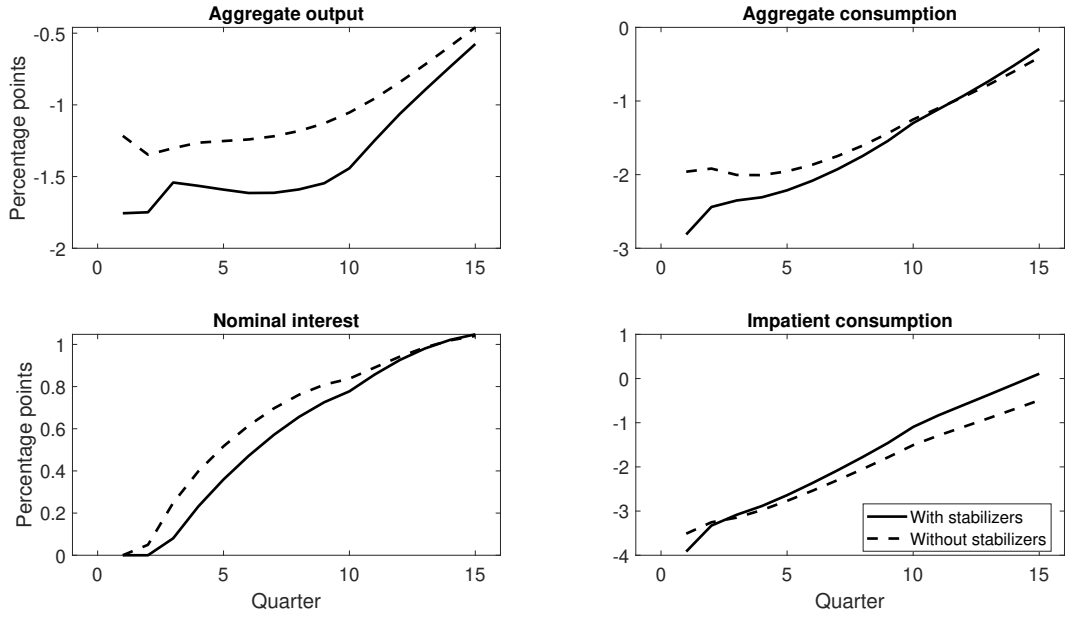

Figure 6: Zero lower bound episode with and without automatic stabilisers, 2004-07

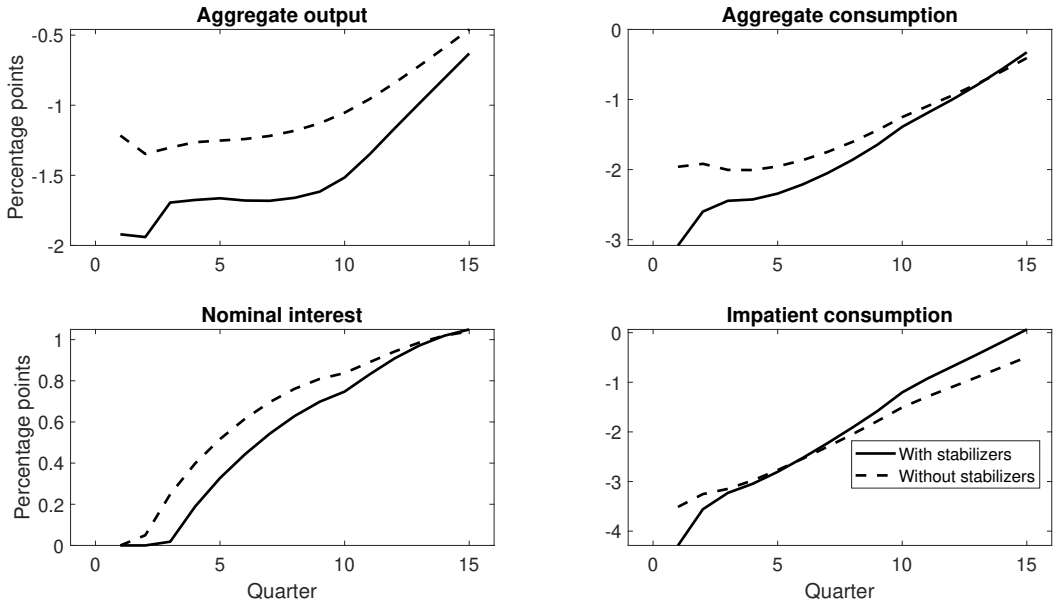

Figure 7: Zero lower bound episode with and without automatic stabilisers, 2015-18

6.7 Welfare Effects of Automatic Stabilisers

Tables 14 and 15 show the effect of cutting all stabilisers on the welfare of impatient households, broken down by employment and skill status and by wealth under the old and the new fiscal regimes, respectively. In both cases we take households with their current state variables and place them in the economy without stabilisers from the economy with stabilisers. We consider steady states, but the welfare of agent reflects anticipations of future shocks. We also calculate the effect of lowering all stabilisers on the welfare of patient households, which increases by 6.87% in the 2004-07 period, and by 15.49% in 2015-18.
Welfare is significantly lower for all impatient households in the new regime, while medium- and high- skill employed households enjoy higher welfare under the old regime when stabilisers are cut. This effect is due to the more progressive income tax under the new regime, which redistributes resources from patient households, who enjoy a higher income than impatient households for the same skill level and bond holdings as they also receive dividends, to impatient ones. On the other hand, the less progressive tax schedule in place in 2004-07 shifts this redistribution within the impatient households group, hurting the relatively richer among them. The higher welfare gains of patient households from cutting stabilisers in the new regime confirm the intuition that the effect of stabilisers for different types of households changed significantly with the more progressive income tax.
To solve the problem of aggregating different types of impatient households, we report two

versions of social welfare in table 13. We calculate a simple equally-weighted average of welfare changes across all employment-skill pairs and a utilitarian average weighing every group by their population. Under both regimes, cutting stabilisers reduces average welfare using both definitions, but in the 2004-07 period losses are substantially smaller because medium- and high-skill employed households actually benefit from lower automatic stabilisers. Note that the utilitarian welfare losses are smaller because employed households are the largest subgroup at the steady state.

In both periods, low-skill and low-wealth needy households suffer the most from cutting stabilisers, which confirms the importance of the redistribution channel. Needy households rely entirely on transfers for current consumption, so they are especially vulnerable to reducing stabilisers in the United Kingdom fiscal regime, which relies disproportionately on safety-net benefits. It is noteworthy that welfare effects are particularly large across the board even at the steady state. There are two reasons for this phenomenon: stabilisers, transfers in particular, provide a significant amount of social insurance, which benefits impatient households who cannot insure; moreover, the fiscal regime alters after-tax average income across different types of households, hence redistributing resources even without shocks.

Table 13: Social welfare of impatient households

Fiscal regime	Equally-weighted	Utilitarian
2004-07	-0.013	-0.002
2015-18	-0.135	-0.126

Proportional change caused by cutting all stabilisers.

Table 14: Welfare of impatient household by status, 2004-07

employment	skill	w10	w25	w50	w75	w90	w100
Employed	Low	-0.001	-0.001	-0.001	-0.002	-0.007	-0.037
Employed	Medium	0.015	0.015	0.014	0.013	0.012	-0.022
Employed	High	0.033	0.032	0.032	0.032	0.031	-0.002
Unemployed	Low	-0.068	-0.061	-0.061	-0.059	-0.057	-0.057
Unemployed	Medium	-0.040	-0.038	-0.037	-0.036	-0.035	-0.042
Unemployed	High	-0.017	-0.016	-0.014	-0.014	-0.014	-0.023
Needy	Low	-0.163	-0.157	-0.147	-0.138	-0.130	-0.097
Needy	Medium	-0.128	-0.124	-0.119	-0.113	-0.108	-0.081
Needy	High	-0.100	-0.097	-0.095	-0.092	-0.088	-0.062

Proportional change caused by cutting all stabilisers.

Table 15: Welfare of impatient household by status, 2015-18

employment	skill	w10	w25	w50	w75	w90	w100
Employed	Low	-0.129	-0.129	-0.129	-0.128	-0.124	-0.084
Employed	Medium	-0.118	-0.117	-0.117	-0.116	-0.115	-0.082
Employed	High	-0.104	-0.104	-0.103	-0.102	-0.102	-0.078
Unemployed	Low	-0.172	-0.168	-0.167	-0.166	-0.160	-0.103
Unemployed	Medium	-0.153	-0.151	-0.150	-0.149	-0.146	-0.099
Unemployed	High	-0.138	-0.136	-0.133	-0.132	-0.131	-0.094
Needy	Low	-0.238	-0.231	-0.219	-0.206	-0.195	-0.140
Needy	Medium	-0.215	-0.211	-0.205	-0.198	-0.191	-0.133
Needy	High	-0.200	-0.198	-0.195	-0.192	-0.189	-0.125

Proportional change caused by cutting all stabilisers.

7 Conclusion

Firstly, an interesting result of this exercise is the remarkable similarity of the fiscal regimes in the United Kingdom in 2004-07 and 2015-18 in terms of revenues and outlays on all the automatic stabilisers included in the model. The main difference concerns the income tax schedule, which is significantly more progressive in the post-crisis regime due to the tapering of Personal Allowance and the introduction of the Additional Rate. The experiments in Section 6 indicate that this difference has a large effect on the relative success of auto-

matic stabilisers under the two regimes. The more progressive income tax produces both a strong stabilising effect on consumption through redistribution and a significant dampening of volatility on output and hours through the marginal incentives channel.

We also find significant differences in the income tax schedule and transfer spending between the United Kingdom and the United States. The post-crisis income tax in the United Kingdom is more progressive than in the United States, leading to stronger stabilising effects. Furthermore, the United Kingdom spends five times as much as the United States on safety-net transfers in both periods, while its unemployment benefits are less generous as a fraction of income. The relative size of safety-net versus unemployment benefit spending has large repercussions for the effectiveness of automatic stabilisers: since the poorest households rely almost entirely on safety-net benefits for consumption and they have the highest marginal propensity to consume in the model, devoting a higher amount to this particular fiscal policy makes automatic stabilisers much more effective at stabilising aggregate consumption in the United Kingdom.

Another remarkable difference between the two periods lies in the welfare effects of stabilisers: due to the relatively flat income schedule in the pre-crisis regime, much of its weight is borne by relatively poorer employed households, who actually benefit from cutting stabilisers. In contrast, under the new regime income tax revenues are levied mainly from richer households, as the larger welfare gain of patient households and welfare loss of impatient employed households from lowering stabilisers confirm.

We also established that the monetary policy channel, while important for output and hours stabilisation, is not crucial for the effect of stabilisers on consumption, confirming that in the United Kingdom there is significant room for fiscal policy like transfers even when monetary policy is close to optimal.

The counterfactuals on hand-to-mouth and representative agent models suggest that the redistribution and social insurance channels are the main mechanisms behind the effectiveness of automatic stabilisers, particularly regarding the role of transfers for consumption stabilisation. This result, combined with the fact that low-income and low-wealth individuals, implies that poor households are the main beneficiaries of fiscal stabilisers in the United Kingdom.

The analysis performed in this study lends itself to further work. An immediate next step would involve calibrating preferences and business cycle parameters to explicitly match United Kingdom data. An interesting extension could entail modifying the model to better match some features that the United Kingdom does not share with the United States, for instance the larger role that international trade plays in the former, which would be represented well by extending the model to a small open economy framework. Finally, the results suggesting that automatic stabilisers are less effective at the zero lower bound are surprising as most of the studies conclude that fiscal policy is more powerful when monetary policy is constrained by the zero-lower bound. Therefore, further work should address the mechanisms at work in this limit case.

8 Data Appendix

Table 1
Income Tax and National Insurance Contributions Receipts: Office of National Statistics Public Sector Finances.
Corporate Income Tax Receipts: Office of National Statistics Public Sector Finances.
Council Tax Receipts: Office for Budget Responsibility Databank.
Sales and Excise Taxes Receipts: Office for Budget Responsibility Databank.
Jobseeker's Allowance Expenditure: Office for Budget Responsibility Databank.
Child Benefit Expenditure: Department for Work and Pensions.
Child Tax Credits Expenditure: Department for Work and Pensions. Estimate of 77% of total Tax Credit expenditure.
Incapacity Benefits Expenditure: Department for Work and Pensions.
Employment and Support Allowance Expenditure: Department for Work and Pensions. Only income-based portion.
Income Support Expenditure: Department for Work and Pensions.
Housing Benefits Expenditure: Department for Work and Pensions.
General Government Consumption: Office of National Statistics.
Central Government Debt Interest, net of AFP: Office for Budget Responsibility Databank. Used to derive net interest expenditure.
Public Sector Interest and Dividends Receipts: Office for Budget Responsibility Databank. Used to derive net interest expenditure.
Contributory Benefits Expenditure: Department for Work and Pensions. Excluding contributory portion of Jobseeker's Allowance.

Table 4 *Private Sector Consumption:* Office of National Statistics Quarterly National Accounts. Used to calibrate τ^C.
Value of Housing Stock: Office of National Statistics. Used to calibrate τ^P.
Gross Operating Surplus of Private Corporations: Office of National Statistics Quarterly National Accounts. Used to calibrate υ.
Gross Fixed Capital Formation: Office of National Statistics Quarterly National Accounts. Used to calibrate υ.

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