How does monetary policy affect income and wealth inequality? An agent-based stock-flow consistent analysis

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Abstract: We study the effects of monetary policy on income and wealth inequality in an agent-based stock-flow consistent model. The model analyses the behaviour and the financial position of heterogeneous households as part of a dynamic macroeconomic system in which the financial decisions of firms and banks have distributional effects. The balance sheet structure of households is calibrated using the micro data of the Survey for Consumer Finances (SCF). We pay attention to four distribution channels of monetary policy: the interest income channel, the macroeconomic activity channel, the portfolio reallocation channel and the indebtedness channel. We find that the strength of the distributional effects of monetary policy depends on various behavioural and institutional factors, including the sensitivity of investment to profitability, the responsiveness of wages to unemployment, the household emulation motive, banks' credit provision behaviour and the responsiveness of the propensity to consume to changes in the interest rates. Prior knowledge of these factors is necessary in order to identify whether a monetary policy shock is likely to have an economically significant impact on inequality.

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1. Introduction

Recent years have seen a growing interest in the impact of monetary policy on inequality. It is now widely accepted that, since households differ in their balance sheet structures and the proportion of income that they receive from different income sources, changes in the policy interest rate and central bank asset purchases unavoidably affect the distribution of personal income and wealth. Although monetary policy might not be the most significant contributor to overall inequality, its effects on income and wealth distribution cannot be neglected and need to be the subject of detailed scrutiny.

The recent empirical literature on the distributional effects of monetary policy on inequality has focused on the various channels through which a change in the policy interest rate or the central bank asset purchases affect income and wealth inequality.[1] Although most studies show that expansionary (contractionary) conventional policy tends to reduce (increase) income inequality (see Coibion et al., 2017; Mumtaz and Theophilopoulou, 2017; Furceri et al., 2018; Guerello, 2018; Ampudia et al., 2018), there is no consensus on whether these effects are economically significant. In addition, there is no consensus about (i) the size and the direction of the effects of conventional monetary policy on wealth inequality and (ii) the distributional impact of quantitative easing (see e.g. Saiki and Frost, 2014; Domaski et al., 2016; Montecino and Epstein, 2017; Mumtaz and Thephilopoulou, 2017; O'Farrell and Rawdanowicz, 2016; Ampudia et al., 2018; Casiraghi et al., 2018; Guerello, 2018; Koedijk, 2018). This comes as no surprise: the magnitude of the distribution channels of monetary policy depends on a number of factors which influence the impact of these channels across countries and time periods. For example, it has been shown that the effect of monetary policy on inequality depends on the initial wealth distribution and the composition of household financial assets (O'Farrell and Rawdanowicz, 2017; Guerello, 2018), the initial wage share (Furceri et al., 2018) and the marginal propensity to consume (Ampudia et al., 2018).

[1] For some early studies that analysed the distributional impact of monetary policy see Niggle (1989), Arestis and Howells (1994), Argitis and Pitelis (2001), Hein (2006) and Hein and Schoder (2011).

Despite these recent developments in the empirical literature, there is currently no theoretical model that incorporates the key distribution channels of monetary policy simultaneously and is capable of analysing in a systematic way the exact conditions under which monetary policy has economically significant effects on inequality. This paper develops such a model by combining the agent-based (AB) and the stock-flow consistent (SFC) approaches to macroeconomic modelling. The SFC approach is characterised by the explicit incorporation of accounting principles into dynamic macro modelling and the emphasis that it places on the dynamic interplay between monetary stocks and flows (see Godley and Lavoie, 2007a). The AB approach is suitable for exploring how macroeconomic phenomena emerge out of the interactions between heterogeneous agents. It has been recently argued that the combination of agent-based and stock-flow consistent approaches is a fruitful avenue for the reconstruction of macroeconomics, moving beyond the conventional representative agents framework (see e.g. van der Hoog and Dawid, 2015; Caiani et al., 2016).

We have opted to develop an AB-SFC model primarily for two reasons. First, an AB-SFC model combines a high-level household heterogeneity with respect to balance sheet structures and income sources with a macro framework that incorporates explicitly the dynamic impact of monetary policy on macroeconomic activity and the assets/liabilities of households. This allows us to incorporate relatively easily the distribution channels of monetary policy, which include both first-round and second-round effects. Second, in AB-SFC models the balance sheets expand though the endogenous creation of money by the banking sector.[2] This permits an accurate analysis of the implications of monetary policy[3] and the process of asset/liability accumulation. As explained by Jakab and Kumhof (2015), the endogenous creation of money is absent in the conventional Dynamic Stochastic General Equilibrium (DSGE) models, restricting the ability of these models to analyse the role of financial factors successfully.

There are a few recent theoretical New Keynesian models of heterogeneous agents that have analysed some links between monetary policy and inequality (see e.g. Auclert, 2017 and Kaplan et al., 2018). However, in these models the dynamic interplay between the financial net worth of households and the balance sheet structure of firms and banks is missing. In addition, the financial system does not play a key role and the dynamics of household debt are not explicitly

[2] This feature is absent in the conventional Dynamic Stochastic General Equilibrium (DSGE) models (see Benes et al., 2014).
[3] For the role of money endogeneity in the conduct of monetary policy see Arestis and Sawyer (2006) and McLeay et al. (2014).

considered. Hence, these models cannot be easily used for an integrated analysis of the key distribution channels of monetary policy, as is the case with the model of this paper.

In our model households differ in skills, employment status, income sources, wealth accumulation and portfolio choices. As in Russo et al. (2016), Cardaci and Saraceno (2016) and Palagi et al. (2017), households accumulate debt and banks impose credit rationing on demanded loans. Monetary policy does not only affect directly their income sources and wealth, but it also has various indirect effects related to its impact on macroeconomic activity. Our simulation analysis shows that the strength of the distributional effects of monetary policy depend on various behavioural and institutional factors, including the sensitivity of investment to profitability, the responsiveness of wages to unemployment, the household emulation motive, banks' credit provision behaviour and the responsiveness of the propensity to consume to changes in the interest rates. Prior knowledge of these factors is necessary in order to identify whether a monetary policy shock is likely to have an economically significant impact on inequality.

These results have two main implications. First, future empirical studies need to explore the extent to which these factors can explain the different distributional effects of monetary policy across countries and time periods. Second, if monetary authorities are interested in the distributional effects of monetary policy, they need to have a thorough understanding of these factors in order to anticipate whether a monetary policy shock will affect substantially the level of income and wealth inequality.

An additional contribution of the paper is that, in contrast to previous macro AB models, it is calibrated using both micro and macro data. Of particular importance is the methodology that we develop in order to fit the distribution of households' net wealth and income to the distribution that is estimated based on the data of the Survey of Consumer Finances (SCF). This methodology can be employed in future AB models in order to bring them closer to the data.

The rest of the paper proceeds as follows. Section 2 presents the model. Section 3 describes the distribution channels of monetary policy that are captured by our model. Section 4 discusses the calibration and the validation of the model. Section 5 shows the results of our simulations about the effects of monetary policy on the distribution of personal income and wealth. Section 6 summarises and concludes.

2. The model

The economy of the model evolves over a time span $t = 0,1...T$ and is composed of N_H households, a firm sector, a commercial banking sector, an unemployment fund and a central bank. Households receive wage income when they provide labour services to firms and unemployment benefits when they are unemployed. They also receive the distributed profits of firms and banks if they hold equities. Their wealth is accumulated in the form of deposits and equities. Moreover, some households take on debt in order to sustain their previous consumption or to follow the consumption norms of their society.

Households differ in their skills which affect the wage income that they receive. They also differ in the initial wealth that they hold and the initial debt that they have accumulated. All households are assumed to have the same size and composition. The head of the household is the only income provider. Hence, personal income distribution coincides with household income distribution.

Firms run investment projects using both internal funds (retained profits) and external finance (equities and loans). As in Dafermos and Papatheodorou (2015), the unemployment fund, which is financed by the employees' and employers' contribution, provides unemployment benefits. The central bank determines the base interest rate (which is an exogenous variable in our model) and provides advances to commercial banks (on demand).

Table 1 shows the balance sheets of the economy's sectors. Symbols with a plus sign represent assets and symbols with a negative sign indicate liabilities. Table 2 depicts the transactions between the sectors. For firms, commercial banks and the central bank, a distinction is made between current and capital transactions. Symbols with a plus sign denote inflows. Symbols with a negative sign depict outflows. The columns of the matrix reflect the budget constraints of the sectors.

Table 1: Balance sheet matrix

	Households	Firms	Unemployment fund	Commercial banks	Central bank	Total
Deposits	$+M_H$		$+M_F$	$-M$		0
Equities	$+e \cdot p_e$	$-e \cdot p_e$				0
Household loans	$-L_H$			$+L_H$		0
Firm loans		$-L_F$		$+L_F$		0
Capital		$+K$				$+K$
Advances				$-A$	$+A$	0
High-powered money				$+HPM$	$-HPM$	0
Total (net worth)	$+V_H$	$+V_F$	$+M_F$	0	$+K_{CB}$	$+K$

Table 2: Transactions flow matrix

	Households	Firms		Unemployment fund	Commercial banks		Central bank		Total
		Current	Capital		Current	Capital	Current	Capital	
Consumption	$-C$	$+C$							0
Investment		$+I$	$-I$						0
Wages	$+W$	$-W$							0
Unemployment benefits	$+UB$			$-UB$					0
Firms' profits	$+DP$	$-TP$	$+RP$						0
Commercial banks' profits	$+BP$				$-BP$				0
Central bank's profits							$-CBP$	$+CBP$	0
Contributions	$-\tau_W \cdot W$	$-\tau_F \cdot W$		$+CO$					0
Interest on deposits	$+r_M \cdot M_{H-1}$			$+r_M \cdot M_{F-1}$	$-r_M \cdot M_{-1}$				0
Interest on household loans	$-r_{LH} \cdot L_{H-1}$				$+r_{LH} \cdot L_{H-1}$				0
Interest on firm loans		$-r_{LF} \cdot L_{F-1}$			$+r_{LF} \cdot L_{F-1}$				0
Interest on advances					$-r_B \cdot A_{-1}$		$+r_B \cdot A_{-1}$		0
Change in deposits	$-\Delta M_H$			$-\Delta M_F$		$+\Delta M$			0
Change in equities	$-\Delta E \cdot p_e$		$+\Delta E \cdot p_e$						0
Change in household loans	$+\Delta L_H$					$-\Delta L_H$			0
Change in firm loans			$+\Delta L_F$			$-\Delta L_F$			0
Change in advances						$+\Delta A$		$-\Delta A$	0
Change in high-powered money						$-\Delta HPM$		$+\Delta HPM$	0
Total	0	0	0	0	0	0	0	0	0

2.1 Timeline of events

In each period the main events that take place are the following:

1. Central bank sets the base interest rate.
2. Households decide about the proportion of income and wealth that they wish to consume. If their desired consumption cannot be achieved based on their budget constraint, they might demand bank loans. Banks supply a proportion of the demanded loans based on the income profile of potential borrowers.
3. Households allocate their gross wealth between deposits and equities taking into account the relative rates of return.
4. Wages are determined via a bargaining procedure where workers' bargaining power is affected by the rate of unemployment.
5. Firms decide about their investment plans. Part of their investment expenditures are financed via equity emission and bank loans. They also distribute their profits to firms.
6. The price of equities is determined through the interaction of the demand and the supply of equities.
7. Firms produce consumption and investment goods. Based on the production of goods, the unemployment rate is determined.
8. The unemployment fund provides unemployment benefits to those who are unemployed.
9. The central bank provides advances to commercial banks on demand.
10. Banks pay interest on deposits and advances and distribute their profits to households.

2.2 Households

Each household $i = 1...N_H$ is characterised as low-skilled ($s_i = 1$), medium-skilled ($s_i = 2$) or high-skilled ($s_i = 3$) based on the educational qualifications of the head of the household. In the initial period, $t = 0$, each household receives a specific amount of gross wealth (vg_{i0}), consisted of equities and stocks, an initial amount of debt and an initial wage or unemployment benefit, depending on whether it is unemployed or not. As will be explained in section 4, these initial values are set such that the initial distribution of wealth and income is in line with the real data. The same holds for the allocation of skills.

The evolution of the wage of each household is affected by two factors: (i) the growth rate of labour productivity at the economy level and (ii) the change in the unemployment rate which is a proxy for the bargaining power of workers. When the rate of unemployment remains unaltered, the growth rate of wages is on average equal to the growth rate of labour productivity. If the unemployment rate increases, the bargaining power of workers is low and the growth rate of minimum wage lags behind labour productivity growth. The opposite holds when the unemployment rate declines. This is captured by the following equation:

$$w_{it} = w_{it-1}\left(1+(1+ND_W)g_{\lambda t-1}-\varphi_i\left(\frac{ur_t-ur_{t-1}}{ur_{t-1}}\right)\right) \quad (1)$$

where g_λ is the labour productivity growth, ur is the total rate of unemployment and ND_W is a random number picked from a normal distribution with a mean equal to 0 and a standard deviation given by σ_W.[4]

In line with the empirical evidence (see e.g. Heathcole et al., 2010), φ_i is assumed to be higher for low-skilled households and lower for medium- and high-skilled households. In particular:

$$\varphi_i = \begin{cases} \varphi_{i0} & if \quad s_i = 1 \\ 0.5\varphi_{i0} & if \quad s_i = 2 \\ 0.25\varphi_{i0} & if \quad s_i = 3 \end{cases} \quad (2)$$

where φ_{i0} is a positive parameter. This implies that a contractionary monetary policy shock that increases unemployment tends to increase wage inequality.

Households can be employed or unemployed. Each period the total number of unemployed households (N_{Ut}) is determined by the demand for labour by firms (see Section 2.3). Based on this aggregate level of unemployment, the households that are unemployed are randomly determined assuming that the rate of unemployment is higher in the groups of households with lower skills. When a household is unemployed, we have that $unem_{it} = 1$. Otherwise, $unem_{it} = 0$.

Unemployed households receive unemployment benefits. The unemployment benefit rate (ub_{it}) is proportional to the median wage in the economy ($wmedian_t$). Hence, we have:

[4] See Dosi et al. (2010) for a similar formula.

$$ub_{it} = \begin{cases} \xi wmedian_t & if \quad unem_{it} = 1 \\ 0 & if \quad unem_{it} = 0 \end{cases} \tag{3}$$

where $\xi < 1$.

Each household has to decide about the allocation of wealth between deposits and equities. The value of equities is a proportion, pr_{it}, of the gross wealth of households:

$$eq_{it} = pr_{it} vg_{it} \tag{4}$$

This proportion increases whenever there is a change in the divergence between the rate of return on equities (re_t) and the interest rate on deposits (r_M). Formally:

$$pr_{it} = pr_{it-1} + \omega[(re_{t-1} - r_{M_{t-1}}) - (re_{t-2} - r_{M_{t-1}})] + ND_E \tag{5}$$

where ω is a positive parameter, ND_E is a random number taken from a normal distribution with a zero mean and standard deviation σ_E.

Deposits (m_{it}) are determined as a residual:

$$m_{it} = vg_{it} - eq_{it} \tag{6}$$

where vg_{it} is the gross wealth.

The interest income received by each household (int_{Rit}) is equal to:

$$int_{Rit} = r_M m_{it-1} \tag{7}$$

Households also receive the distributed profits of firms and banks. The total distributed profits of firms are denoted by DP_t and are allocated to households based on the number of stocks (e_{it}) that each of them holds:

$$dp_{it} = \frac{e_{it}}{\sum_{i=1}^{N_H} e_{it}} DP_t \tag{8}$$

where dp_{it} denotes the distributed profits of firms received by each household.

For simplicity, we have assumed in the model that banks do not issue equities. However, it is postulated that bank profits BP_t are distributed based on firm stocks:

$$bp_{it} = \frac{e_{it}}{\sum_{i=1}^{N_H} e_{it}} BP_t \tag{9}$$

where bp_{it} denotes the bank profits received by each household.

The capital gains are equal to:

$$cg_{it} = (p_{et} - p_{et-1}) e_{it-1} \tag{10}$$

where p_{et} is the price of equities. The number of equities held by each household are determined by the following formula:

$$e_{it} = \frac{eq_{it}}{p_{et}} \tag{11}$$

Households need to pay interest (int_{Pit}) on their accumulated debt (l_{it}):

$$int_{Pit} = r_{LH} l_{it-1} \tag{12}$$

where r_{LH} is the interest rate on household loans.

The total disposable income of each household reads:

$$yd_{it} = (1-\tau_W) w_{it} + ub_{it} + int_{Rit} - int_{Pit} + dp_{it} + bp_{it} \tag{13}$$

where τ_W is the rate of employee contributions.

The desired consumption of households is determined on the basis of (i) their disposable income and accumulated wealth, (ii) their past consumption and (iii) the consumption of their income reference group. Past consumption affects current desired consumption due to internal habit formation: households tend to follow their previous consumption patterns (see Russo et al., 2016). Also, households tend to follow the consumption patterns determined by richer households. This relies on the 'keeping up with the Joneses' argument according to which households desire to emulate the consumption standards of those that are richer than them (see, e.g. Cynamon and Fazzari, 2008; Barba and Pivetti, 2009; Rajan, 2010).[5] In line with Belabed et al. (2018) and Frank et al. (2014), we assume that households use as a reference the median consumption of the next higher decile in the income distribution. Overall, we have:

$$c_{Dit} = (1-\rho_1-\rho_2)(c_{1it} yd_{it-1} + c_2 vg_{it-1}) + \rho_1 c_{it-1} + \rho_2 c_{REFit-1} \quad (14)$$

where c_{Dit} is the desired consumption of each household, c_{it} is the consumption of the household in the previous period, c_{1it} is the propensity to consume out of disposable income, c_2 is the propensity to consume out of wealth (assumed for simplicity to be the same for all households), c_{REFit} is the median consumption of the income reference group and $0 < \rho_1, \rho_2 < 1$ are weights.[6]

If households cannot achieve their desired consumption using their disposable income and accumulated wealth, they demand new loans from banks (nl_{Dit}). In particular, we have:

$$nl_{Dit} = max\{0, c_{Dit} + repl_{it-1} - yd_{it} + vg_{it-1}\} \quad (15)$$

where rep is the repayment ratio.

However, due to the existence of credit rationing, only a specific proportion of the demanded new loans is provided by banks. This proportion is a negative function of the debt service ratio of households (dsr_{it}). Hence, the actual new loans (nl_{it}) are given by:

[5] This idea can be traced back to Veblen (1991) and Duesenberry (1949).
[6] For the top income decile, the reference consumption is the consumption of the previous period.

$$nl_{it} = (\gamma_0 - \gamma_1 dsr_{it})\, nl_{Dit} \tag{16}$$

The debt service ratio is defined as:

$$dsr_{it} = \frac{(r_{LH} + rep)\, l_{it-1}}{ydg_{it}} \tag{17}$$

where ydg_{it} is the gross disposable income of households given by:

$$ydg_{it} = yd_{it} - int_{Pit} \tag{18}$$

Overall, the effective consumption of households is given by:

$$c_{it} = \min\{c_{Dit}, yd_{it-1} + vg_{it-1} + nl_{it} - repl_{it-1}\} \tag{19}$$

This equation implies that credit rationing might not allow households to achieve their desired consumption.

The stock of loans is equal to:

$$l_{it} = l_{it-1} + nl_{it} - repl_{it-1} \tag{20}$$

It is important to point out that our overall formulation of household debt workers allows us to make an explicit link between inequality and indebtedness. Recent literature has placed a lot of emphasis on this link.[7]

The marginal propensity to consume (c_{1it}) out of income is assumed to be lower the higher is the disposable income. We also assume that the propensity to consume is a negative function of the deposit interest rate, since a higher deposit interest rate induces households to save more in order to earn from interest income.[8] A direct implication is that expansionary monetary policy increases the propensity to consume, placing downward pressures on aggregate consumption. Overall, we have:

[7] See, for example, Rajan (2010) and Kumhof et al. (2015).
[8] See Godley and Lavoie (2007b) and Greenwood-Nimmo (2013) for a similar assumption.

$$c_{1it} = \begin{cases} 1 & if \quad yd_{it-1} < y\min_t \\ 1-\theta_1 r_M - (1-\theta_2)(yd_{it-1}/yd_{90t-1}) & if \quad y\min_t \le yd_{it-1} \le yd_{90t-1} \\ \theta_2 - \theta_1 r_M & if \quad yd_{it-1} > yd_{90t-1} \end{cases} \tag{21}$$

where yd_{90} is the disposable income at the 90th percentile. Equation (21) implies that the propensity to consume is equal to 1 for households whose income is below a minimum value, $y\min$. The consumption patterns of these households are invariant to a change in the interest rate. Thus, they broadly correspond to the so-called 'hand-to-mouth' households in Kaplan et al. (2018). The households that are at the top decile have the minimum propensity to consume.

According to the budget constraint of households, their net wealth reads:

$$vn_{it} = vn_{it-1} + yd_{it} - c_{it} + cg_{it} \tag{22}$$

Households' gross wealth is given by:

$$vg_{it} = vn_{it} + l_{it} \tag{23}$$

At the aggregate level we have:

$$C_t = \sum_{i=1}^{N_H} c_{it} \tag{24}$$

$$W_t = \sum_{i=1}^{N_H} w_{it} \tag{25}$$

$$M_{Ht} = \sum_{i=1}^{N_H} m_{it} \tag{26}$$

$$EQ_t = \sum_{i=1}^{N_H} eq_{it} \tag{27}$$

$$L_{Ht} = \sum_{i=1}^{N_H} l_{it} \tag{28}$$

$$UB_t = \sum_{i=1}^{N_H} ub_{it} \tag{29}$$

where C_t is the total consumption of households, W_t is the total wage bill paid by firms, M_{Ht} is the total value of deposits held by households, EQ_t is the total value of household gross wealth held in the form of equities, L_{Ht} is the total value of household loans and UB_t is the total value of unemployment benefits.

2.3 Firms

The output (Y_t) produced by firms is equal to the sum of consumption and investment goods:

$$Y_t = C_t + I_t \tag{30}$$

where I_t stands for investment. Firms' total profits (TP_t) are computed as the difference between revenues and costs (the latter include wages and interest paid on accumulated debt):

$$TP_t = Y_t - (1+\tau_F)W_t - r_{LF}L_{Ft-1} \tag{31}$$

where τ_F is the rate of employer contributions, r_{LF} is the interest rate on firm loans and L_{Ft} is the stock of accumulated loans. A proportion (s_F) of these profits is retained:

$$RP_t = s_F TP_t \tag{32}$$

where RP_t denotes the retained profits of firms.

The rest profits (DP_t) are distributed to households:

$$DP_t = TP_t - RP_t \tag{33}$$

The wage share is equal to the wage bill divided by output:

$$s_{Wt} = \frac{W_t}{Y_t} \tag{34}$$

The total employment (N_{Et}) is determined as:

$$N_{Et} = \frac{Y_t}{\lambda_t} \tag{35}$$

where λ_t denotes labour productivity. We have that:

$$\lambda_t = \lambda_{t-1}(1 + g_{\lambda t}) \tag{36}$$

Following the Kaldor-Verdoorn law (see Lavoie, 2014, ch. 6), the growth rate of labour productivity ($g_{\lambda t}$) is a positive function of the growth rate of output (g_{Yt}):

$$g_{\lambda t} = \sigma_0 + \sigma_1 g_{Yt-1} \tag{37}$$

The number of unemployed households is:

$$N_{Ut} = N_H - N_{Et} \tag{38}$$

Hence, the rate of unemployment is given by:

$$ur_t = \frac{N_{Ut}}{N_H} \tag{39}$$

Using a Kaleckian specification, the investment of firms relies on the rate of retained profits and the rate of capacity utilisation:

$$I_t = [d_0 + d_1(RP_{t-1}/K_{t-1}) + d_2 u_{t-1}]K_{-1} \tag{40}$$

where K_t is the capital stock and u_t is the rate of capacity utilisation which is defined as:

$$u_t = Y_t / Y_t^* \tag{41}$$

where Y_t^* is the potential output given by $Y_t^* = vK_t$ (v expresses the potential output-to-capital ratio and is technologically fixed). Since we have assumed away capital depreciation, capital stock is given by:

$$K_t = K_{t-1} + I_t \tag{42}$$

A proportion, x, of firms' investment is financed via equity emissions:

$$E_t = E_{t-1} + x(I_t / p_{et}) \tag{43}$$

where E_t is total the number of equities.

The rest is financed via bank loans:

$$L_{Ft} = L_{Ft-1} - RP_t - (E_t - E_{t-1})p_{et} \tag{44}$$

The price of equities is given by:

$$p_{et} = \frac{EQ_t}{E_t} \tag{45}$$

Note that the rate of return is the same for all households and is equal to:

$$re_{et} = \frac{DP_t}{E_t} + \frac{p_{et} - p_{et-1}}{p_{et-1}} \tag{46}$$

2.4 Unemployment fund

The unemployment fund receives the contributions of employees and employers. The total contributions (CO_t) are:

$$CO_t = (\tau_W + \tau_F)W_t \tag{47}$$

The unemployment fund accumulate deposits (M_{Ft}). Its budget constraint is given by:

$$M_{Ft} = M_{Ft-1} + CO_t - UB_t + r_M M_{Ft-1} \tag{48}$$

2.5 Commercial banks

Commercial banks receive interest on firm and household loans. They pay interest on total deposits (M_t) and central bank advances (A_t). Thus, their profits (BP_t) are given by equation (49):

$$BP_t = r_{LF} L_{Ft-1} + r_{LH} L_{Ht-1} - r_M \cdot M_{t-1} - r_B \cdot A_{t-1} \tag{49}$$

where r_B is the base interest rate that is determined by the policy of the central bank.

The total deposits are equal to the deposits of households plus the deposits of the unemployment fund:

$$M_t = M_{Ht} + M_{Ft} \tag{50}$$

A proportion of the deposits of banks is held in the form of high-powered money (HPM_t):

$$HPM_t = \zeta M_t \tag{51}$$

where ζ is the required reserve ratio. Equation (52) reflects the budget constraint of commercial banks where central banks' advances play the role of the residual variable:

$$A_t = L_{Ft} + L_{Ht} + HPM_t - M_t \tag{52}$$

The interest rate on firm loans is equal to the base interest rate (r_B) plus a spread ($\chi_1 > 0$):

$$r_{LF} = r_B + \chi_1 \tag{53}$$

Similarly, the interest rate on household debt is determined by applying a spread over the base interest rate ($\chi_2 > 0$):

$$r_{LH} = r_B + \chi_2 \tag{54}$$

Note that $\chi_1 < \chi_2$.

The interest rate on deposits is lower than the base interest by $\chi_3 > 0$:

$$r_M = r_B - \chi_3 \tag{55}$$

2.6 Central bank

The profits of the central bank (CBP_t) are equal to the interest that they receive on advances:

$$CBP_t = r_B A_{t-1} \tag{56}$$

It is assumed that all central bank profits are retained and increase thereby the capital of the central bank (K_{CBt}):

$$K_{CBt} = K_{CBt-1} + CBP_t \tag{57}$$

The budget constraint of the central bank implies that:

$$A_t = HPM_t + K_{CBt} \tag{58}$$

Equation (58) is the 'redundant' identity: it is logically implied by all the other identities of the model.

3. Distribution channels of monetary policy

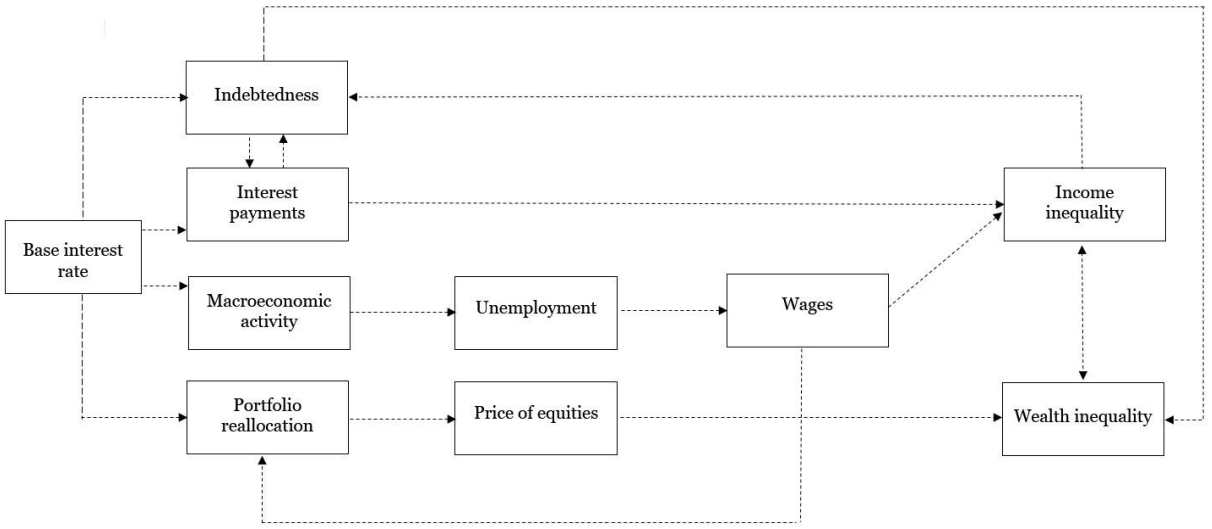
Fig. 1 provides a pictorial representation of the channels through which a change in the base interest rate affects the distribution of personal income and wealth in our model. The *interest payments channel* is straightforward (see also Bank of England, 2012 and McKinsey Global Institute, 2013). An increase in the policy interest rate pushes up (a) the interest income received by households that have accumulated deposits, (b) the interest payments of indebted households, (c) the profits of banks (which are distributed to households) and (d) the interest payments of firms. Since richer households hold higher wealth and have accumulated less debt relative to poorer households, the first three

effects tend to increase income inequality, while the last one tends to decrease income inequality by decreasing the distributed profits of firms.

The *macroeconomic activity channel* refers to the second-round effects of monetary policy. An increase in the base interest rate increases the return on saving. This reduces the propensities to consume of households, placing downward pressures on aggregate consumption. Also, a higher lending interest rate induces firms to invest less. The overall result is a decline in macroeconomic activity that increases the unemployment rate, which in turn decreases the wage income because (a) the wage rate becomes lower and (b) the number of unemployed workers increases. These developments tend to increase income inequality.

The magnitude of the macroeconomic activity channel depends on a number of factors. At a first place, the impact of an increase in the interest rate on economic activity is expected to be stronger the higher is the responsiveness of investment to the profit rate of firms (d_1) and the higher is the sensitivity of the propensity to consume to the interest rate on deposits (θ_1). At a second place, the wage share will be affected more if the bargaining power of workers is very sensitive to changes in the unemployment rate (φ_j).

Fig. 1: Distributional channels of monetary policy in the model



The *portfolio reallocation channel* reflects the fact that a change in the base interest rate modifies the relative rate of return on deposits and equities. An increase in the base interest rate increases the deposit interest rate and tends to reduce the rate of return on equities (since firms' interest payments

increase and, thus, distributed profits decrease). This induces households to reallocate their expected wealth towards deposits and away from equities. For a given number of supplied equities, this causes a decline in the equity prices, decreasing the inequality in the distribution of wealth. The portfolio reallocation channel will generally be stronger the higher is the sensitivity of portfolio allocation to changes in assets' rates of return (ω). Crucially, the portfolio choice of households is also affected by the *macroeconomic activity channel*: any change in wages can affect the rate of return on equities (via its impact on the distributed profits of firms), influencing thereby the portfolio reallocation channel.

The *indebtedness channel* refers primarily to two effects. First, an increase in the base interest rate places downward pressures on the disposable income of indebted households, increasing their need to rely on new debt if they wish to continue emulating the consumption of higher income households. This effect is stronger the higher is the importance of emulation for households' consumption (which is captured by parameter ρ_2). Second, higher interest payments tend to increase the debt service ratio and, thus, credit rationing, leading to lower indebtedness. This effect is stronger when credit availability is highly responsive to the debt service ratio (this is captured by parameter γ_1). If (a) outweighs (b), the indebtedness of households increases. Generally speaking, higher indebtedness is conducive to a more disperse distribution of personal income and wealth. It also noteworthy that a rise in inequality has feedback effects since it leads to an increase in indebtedness due to the 'keeping up with the Joneses' effect.

As shown in Fig. 1, income and wealth inequality dynamically interact. Since a rise in the income of households increases, ceteris paribus, their net wealth, a more unequal distribution of income leads to a more unequal distribution of wealth (the so-called 'snowball effect'). Furthermore, since a higher amount of accumulated wealth implies more income from wealth-related income sources, higher wealth inequality leads to higher income inequality.

4. Calibration and validation

The initial values of the net wealth and wages of households have been calibrated using the SCF conducted in 2016. The calibration has taken place in two steps. We first estimated the gross wealth of all households in the sample of the survey by summing up the value of their stocks and deposits. Recall that in our model these are the only two assets held by households. Since in our simulations the number of households is 100, we calculated the percentiles of gross wealth using the population weights and we set the initial value of gross wealth for each household equal to the mean wealth in

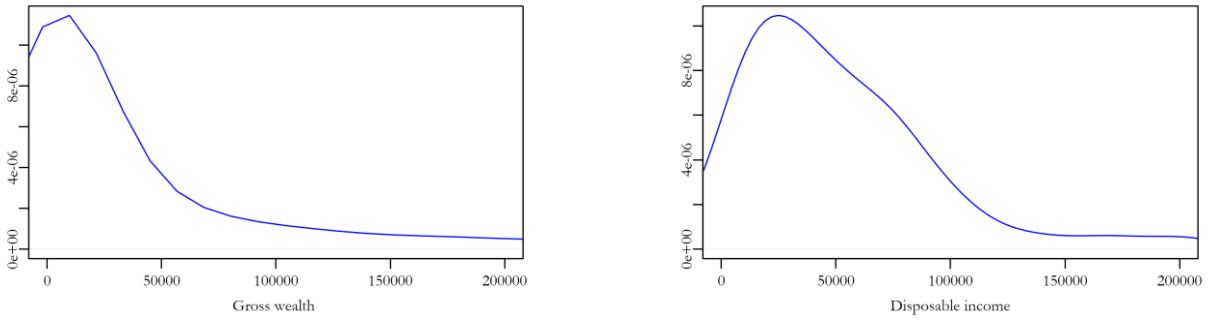
each percentile. In other words, the gross wealth of household *i* in our model was set equal to the mean wealth of the *i*th percentile. This allowed us to get a Gini coefficient of gross wealth equal to the Gini coefficient in the data (see Table 3).

Table 3: Comparison of the initial values of the inequality indices in the model with the values in the data

	Model	**Data**
Gini, gross wealth	0.89	0.89
Gini, net wealth	0.98	0.86
Gini, disposable income	0.64	0.60
Gini, wage income	0.47	0.55

In the second step we estimated the mean debt and mean wages for each wealth percentile. Since in our model debt does not include mortgages, we have used only the non-housing loans. The disposable income of households was endogenously determined based on the related equations of the model. As reported in Table 3, this procedure produced a Gini coefficient of disposable income, net wealth and wages which is broadly consistent with the Gini in the data. Fig. 2 shows the shape of the distribution of gross wealth and disposable income in the model.

Fig. 2: Distribution of initial gross wealth and disposable income in the model



The distinction between low-skilled, medium-skilled and high-skilled households has been made based on the education category of the head of the household provided by SCF. The procedure that we followed resulted in having 26% of households as low-skilled, 39% as medium-skilled and 37% as high-skilled. The unemployment benefit rate has been calibrated by diving the total government expenditures on unemployment benefits of the US government by the unemployed people. The level of income below which households have a marginal propensity to consume equal to 1 was set to 60% of the median household disposable income. As a result, 34% of the households in the model

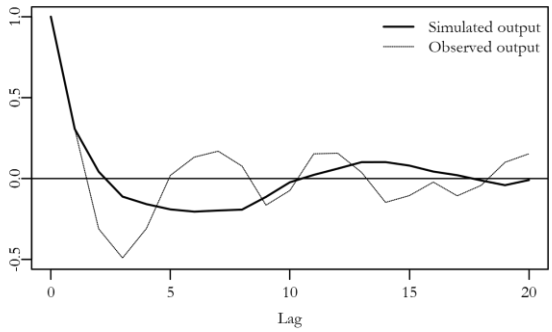
have a marginal propensity to consume equal to 1, which is broadly in line with the fact that, according to SCF, 30% of US households spend all their income. The proportion of gross wealth that is held in the form or equities by each household was calibrated by dividing the value of stocks by the total value of gross wealth in each wealth percentile.

The initial unemployment rate, the initial growth rate, the initial wage share, the initial capital-to-output ratio, the initial capacity utilisation rate and the initial firm debt-to-output ratio have been set based on their average values in the US economy over the period 2013-2017. A number of parameters, including d_0, v, s_F and x, have been calibrated such that the path of the economy in the baseline scenario of our simulations is, on average, in line with these initial values. More details about the calibration of the model are provided in Appendix A and Appendix B.

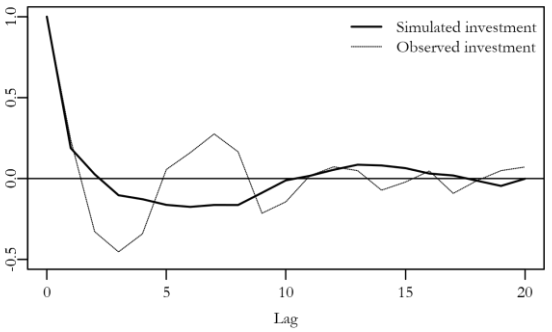
We have validated the model by comparing the auto-correlation and cross-correlation structure of the cyclical component of output, consumption and investment in the model with the respective structure in the real data. We have used the data for the US economy provided by FRED over the period 1960-2017. The cyclical component has been isolated utilising the HP filter. Fig. 3 shows the results. Overall, the time series properties of our simulated data are close to the properties of the real data. An exception is probably the peak behaviour of the cross-correlation of investment with output: in the simulated data the peak is slightly different from the peak observed in the real data.

Fig. 3: Cross-correlation and auto-correlation structures of simulated and real data

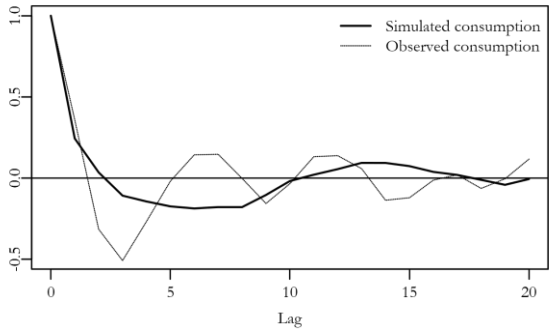
(a) Auto-correlation: output



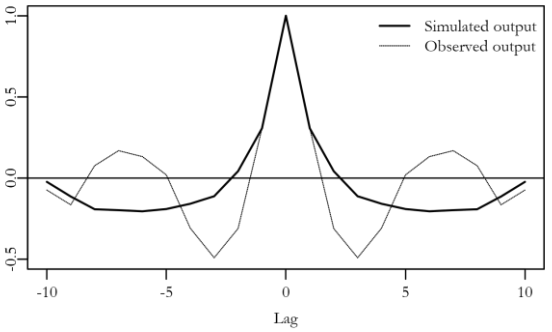
(b) Auto-correlation: investment



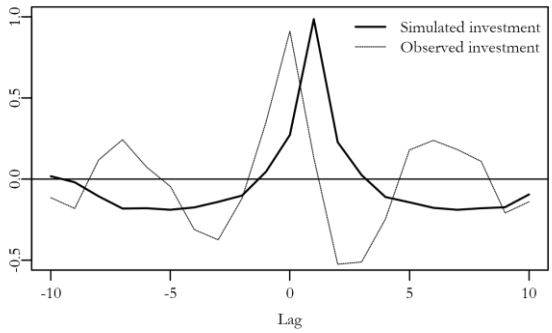
(c) Auto-correlation: consumption



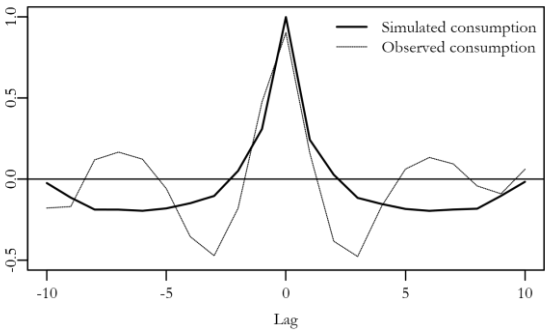
(d) Cross-correlation: output



(e) Cross-correlation: investment



(f) Cross-correlation: consumption



5. Simulation results

We have allowed the model to operate sequentially and we have performed 100 Monte Carlo simulations. As alluded to above, in our baseline scenario the economy evolves in line with the recent trends in the US economy. At $t = 30$ we imposed a contractionary monetary policy shock: central bank increases the base interest rate from 2% to 3%; the interest rate remains equal to 3% thereafter. Table 4 shows the across-run averages of inequality indices and key macroeconomic variables at $t = 50$ as a ratio of their values in the case in which the interest rate remains equal to 2%. Fig. 4 provides more details about the dynamic effects on the contractionary monetary policy shock.

Table 4: Across-run averages of inequality indices and key macroeconomic variables as a ratio of their values in the case of no monetary policy shock

	Gini, disposable income	Gini, net wealth	Gini, wage income	Atkinson$_{\varepsilon=2}$, disposable income	Squared coefficient of variation, disposable income	Growth rate	Unemp. rate	Wage share	Equity prices	Debt-to-income ratio
Baseline case	1.02	1.05	1.02	1.10	1.06	0.61	1.18	0.99	0.87	1.17
Case I: higher θ_1 + higher d_1 + higher φ_0	1.05	1.07	1.05	1.22	1.11	0.24	1.32	0.96	0.78	1.32
Case II: Higher ω	1.02	1.06	1.02	1.07	1.04	0.56	1.22	0.98	0.85	1.23
Case III: Higher ρ_2 + lower γ_1	1.03	1.04	1.03	0.96	1.09	0.64	1.26	0.98	0.87	1.17
Case IV: Case I+Case II+Case II	1.08	1.09	1.06	1.24	1.18	0.58	1.43	0.93	0.79	1.36

Note: θ_1: *sensitivity of the propensity to consume to the interest rate;* d_1: *responsiveness of the investment rate to the profit rate;* ρ_2: *weight of the emulation motive in the consumption of households;* ω *: responsiveness of the portfolio choice to a change in the relative rates of returns on deposits and equities;* γ_1 *: sensitivity of credit availability to the debt service ratio;* φ_0: *sensitivity of wages to changes in unemployment rate*

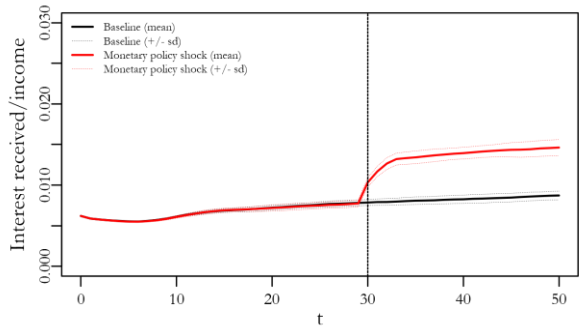
Let us first focus on the baseline case.[9] Starting from the *interest payments channel*, we observe that the shock causes an increase in the interest income received by households as a share of total household income (Fig. 4a). Moreover, the share of interest expenses becomes higher (Fig. 4b) and bank profits go up (Fig. 4c).[10] These developments tend to increase inequality. However, the shock places at the same time downward pressures on inequality since it generates a slight increase in the interest payments of firms (Fig. 4d): this decreases the distributed profits which are primarily received by wealthy households.

[9] All the parameter values that have been used for this case can be found in Appendix B.

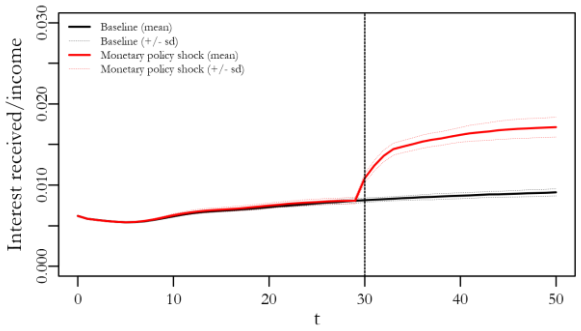
[10] There is initially a small decline in the profits of banks which has to do with the fact that the higher policy interest rate is passed gradually on to the lending interest rates.

Fig. 4: Evolution of key variables, Monte Carlo simulations, Baseline and Case IV (*sd* stands for standard deviation)

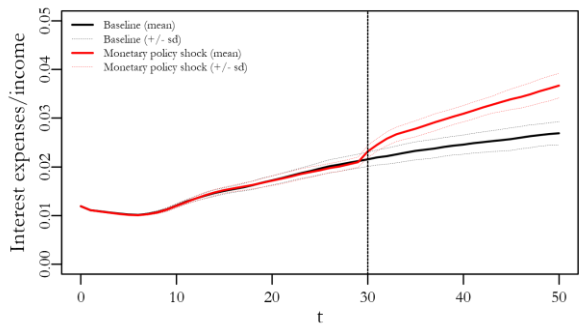
(a) Interest received as a proportion of household income (Baseline)



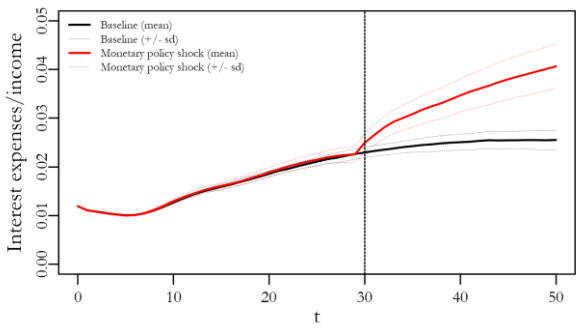
(a') Interest received as a proportion of household income (Case IV)



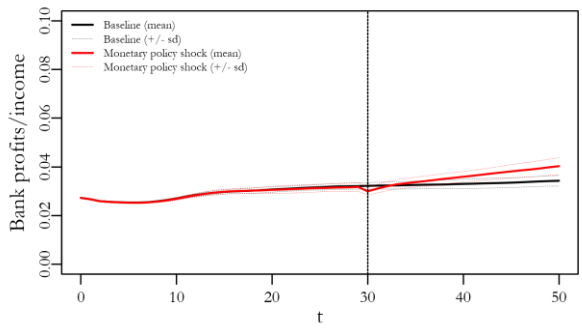
(b) Interest paid as a proportion of household income (Baseline)



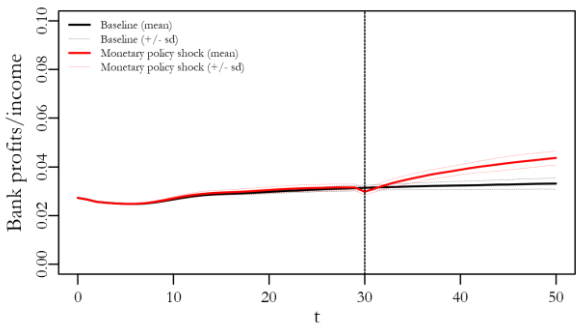
(b') Interest paid as a proportion of household income (Case IV)



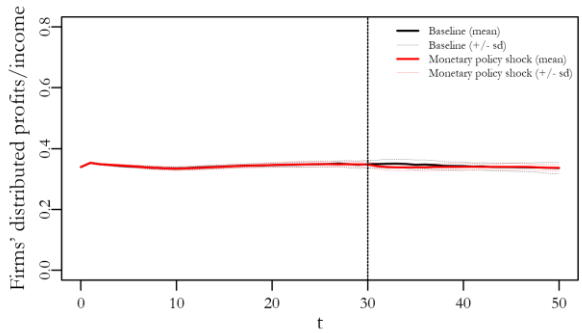
(c) Bank profits as a proportion of household income (Baseline)



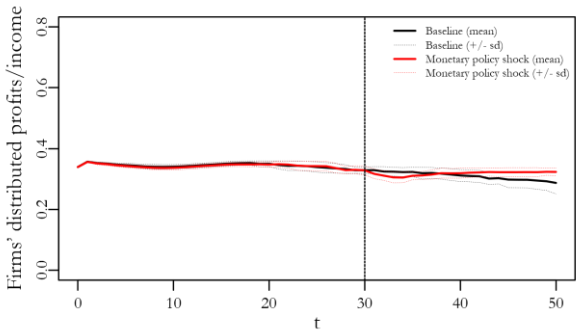
(c') Bank profits as a proportion of household income (Case IV)



(d) Distributed firm profits as a proportion of household income (Baseline)



(d') Distributed firm profits as a proportion of household income (Case IV)



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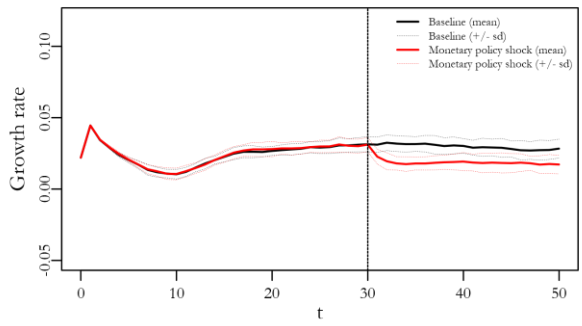
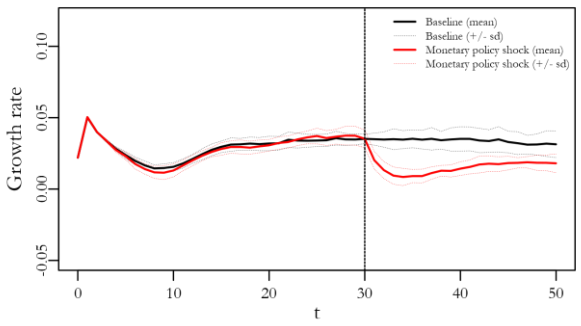
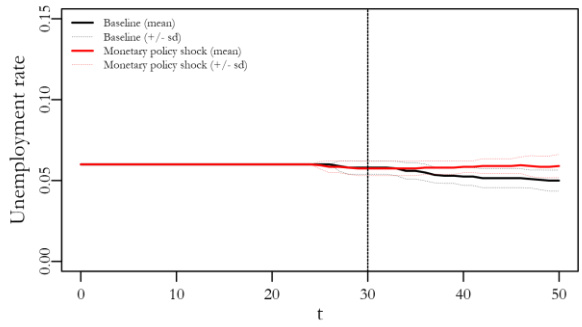
(e) Economic growth (Baseline)



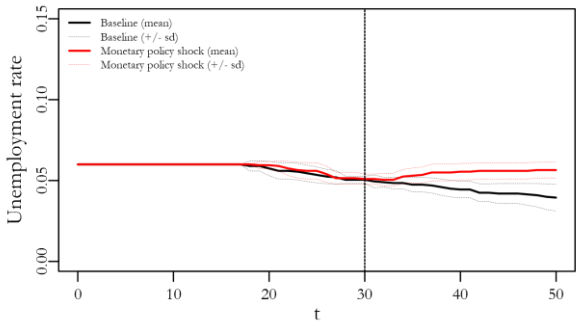
(e') Economic growth (Case IV)



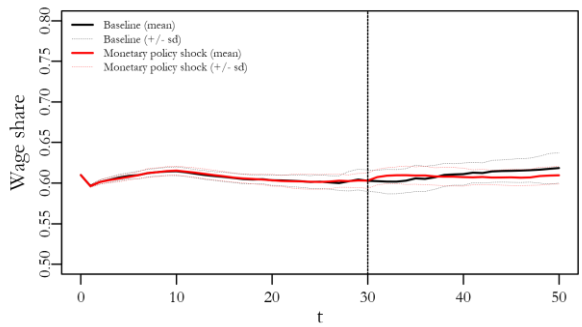
(f) Unemployment rate (Baseline)



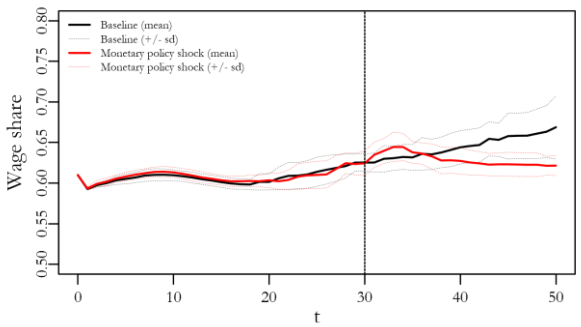
(f') Unemployment rate (Case IV)



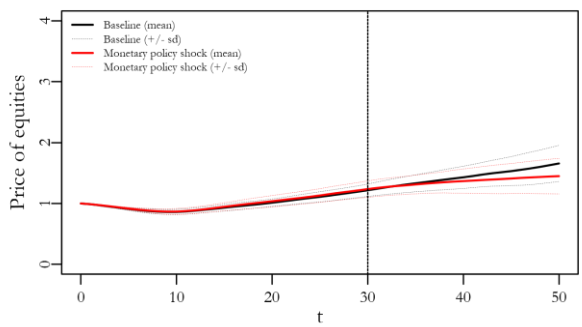
(g) Wage share (Baseline)



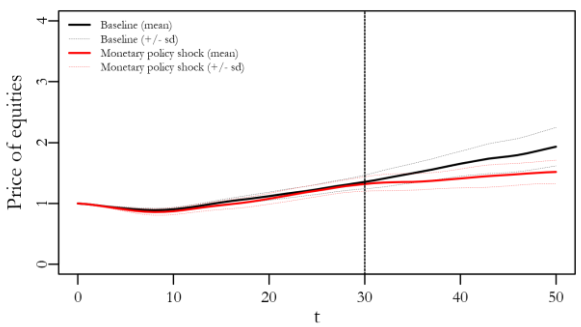
(g') Wage share (Case IV)



(h) Equity prices (Baseline)



(h') Equity prices (Case IV)



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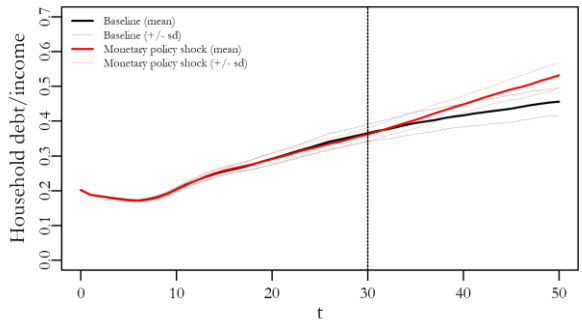
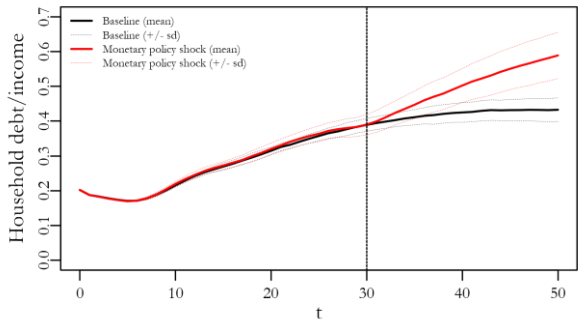
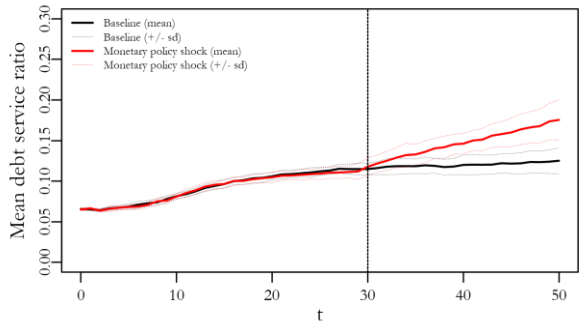
(i) Household debt as a proportion of household income (Baseline)



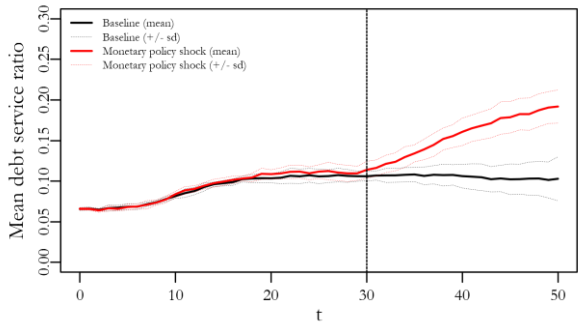
(i') Household debt as a proportion of household income (Case IV)



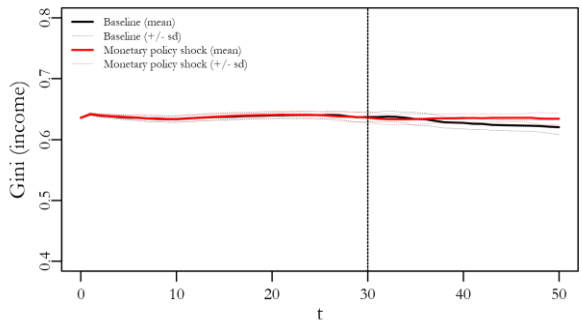
(j) Mean debt service ratio (Baseline)



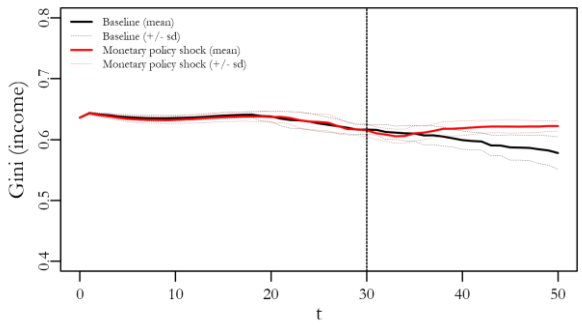
(j') Mean debt service ratio (Case IV)



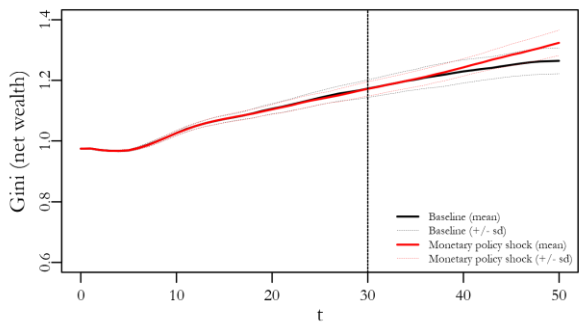
(k) Gini index, disposable income of households (Baseline)



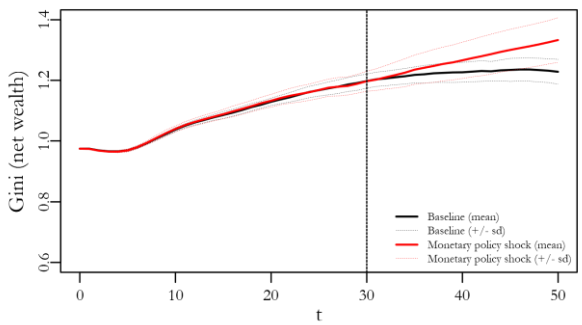
(k') Gini index, disposable income of households (Case IV)



(l) Gini index, net wealth of households (Baseline)



(l') Gini index, net wealth of households (Case IV)



The increase in the interest rate decreases both consumption and investment, causing lower economic growth (Fig. 4e) and higher unemployment (Fig. 4f) compared to the case in which there is no shock. As a result, the bargaining power of workers declines and after a few periods the wage share becomes lower (Fig. 4g). Lower wages increase profitability, inducing thereby an increase in income inequality. The increase in inequality is also reinforced by the larger number of unemployment people. These developments are linked with the *macroeconomic activity channel*.

Fig. 4h captures the *portfolio reallocation channel*. Since the rate of return on equities declines relative to the higher deposit interest rate, households reallocate wealth away from equities. This lower demand for equities makes the price of equities lower compared to the case of no monetary policy shock, pushing down wealth inequality. Regarding the *indebtedness channel*, Fig. 4i shows that gradually the indebtedness of households becomes higher. This happens because the higher borrowing cost reduces the disposable income of households. As a result, households need to increase their debt in order to keep their consumption at a level consistent with their past consumption norms and the consumption behavior of their reference group.

Particular attention should be paid to the effects of the monetary policy shock on wealth inequality. Despite the fact that the price of equities is reduced - a development that is conducive to lower wealth inequality - wealth inequality overall increases primarily because of the lower wage share and higher indebtedness.

Overall, an increase in the interest rate leads to higher inequality in our model. This is in line with the findings of the recent empirical literature. However, the effect on inequality is relatively small: the Gini coefficient of disposable income is only 2% higher compared to the case of unchanged monetary policy stance. And even when inequality is measured by the Atkinson$_{(\varepsilon=2)}$ index, which is more responsive to changes that take place at the bottom of the distribution, inequality does not increase by more than 10%. Hence, the key question is whether the effect of the monetary policy shock on inequality would be more pronounced under different parameter values linked with the distribution channels of monetary policy.

In Case I we change the parameters related to the *macroeconomic activity channel* such that this channel becomes stronger. As Table 4 shows, the higher sensitivity of consumption and investment to the interest rate leads to lower economic growth and higher unemployment. Since the responsiveness of wages to unemployment is also higher, the wage share becomes lower compared to the baseline case.

Thus, the increase in inequality is reinforced. The effects on inequality are also reinforced in Case II where the responsiveness of the portfolio choice of households to the rates of return on financial assets is higher in comparison with the baseline case. As reported in Table 4, the price of equities becomes lower. However, wealth inequality increases because a lower equity price reduces the wealth-related consumption of richer households, leading to lower growth. Finally, in Case III, the emulation motive of households is stronger and banks' credit availability is less responsive to a higher debt service ratio. Interestingly, in this case economic growth is higher than in the baseline case because of higher debt-financed consumption. Therefore, although indebtedness increases, the positive impact of higher consumption and credit availability on economic growth leaves inequality almost unchanged.

What are the effects on inequality when Cases I, II and III and combined? As shown in Table 4 and Fig. 4, both income and wealth inequality are significantly higher than in the baseline case. This result is primarily driven by the *macroeconomic activity channel*. However, it is interesting that when this channel is combined with the *portfolio reallocation channel* and the *indebtedness channel*, the distributional effects on the monetary policy shock are magnified even more.

6. Conclusion

Our agent-based stock-flow consistent model shows that there are a number institutional and behavioural factors that determine the magnitude of the distributional effects of monetary policy. These factors are not only linked with the consumption patterns and the portfolio choice of the household sector. The way that firms' investment responds to changes in profits and the way that banks modify credit availability as a response to a change in the financial position of households also play a crucial role. In addition, a monetary policy shock is more likely to cause a sizeable change in inequality when labour market institutions render wages highly responsive to changes in unemployment rates.

Our results have two important implications. First, the econometric literature on monetary policy and inequality needs to place more emphasis on exploring the empirical relevance of the factors analysed in this paper and their role in determining the magnitude of monetary policy distributional effects. Second, our analysis illustrates that the distributional impact of monetary policy shocks differs across countries and time periods which are characterised by different institutional and behavioural factors. Hence, if monetary policy authorities are interested in anticipating the inequality

effects of their interventions, they need to have a deep understanding of the factors mentioned above.

Our model can be extended in a number of ways in order to shed further light on the distributional effects of monetary policy. First, a bond market could be introduced in order to explore the distributional effects of quantitative easing. Second, inflation could be incorporated in order to analyse the distributional effects that monetary policy has via inflation. These effects are particularly important in countries in which inflation affects poor and rich in a different way. Third, since monetary policy has an impact on housing prices, the model could be extended in order to include a housing market and mortgages. The key strength of our framework is that it provides a flexible platform whereby these extensions can be introduced in a relatively straightforward way.

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Appendix A: Initial values for endogenous variables (baseline case)

Symbol	Description	Value	Remarks/sources
		Agent-based variables	
$bp_{it\ (i=1\ldots100)}$	Banks' distributed profits (US$)	2538 (mean value)	Determined endogenously via the equations of the model
$c_{it\ (i=1\ldots100)}$	Consumption (US$)	90662 (mean value)	Determined based on the disposable income and gross wealth of households
$c_{1it\ (i=1\ldots100)}$	Marginal propensity to consume out of disposable income	0.87 (mean value)	Determined endogenously via the equations of the model
$c_{Dit\ (i=1\ldots100)}$	Desired consumption (US$)	-	The model starts estimating the value of desired consumption in the second period
$c_{REFit\ (i=1\ldots100)}$	Consumption of the reference group (US$)	-	The model starts estimating the value of the consumtpion of the reference group n in the second period
$cg_{it\ (i=1\ldots100)}$	Capital gains on equities (US$)	-	The model starts estimating the value of capital gains in the second period
$dp_{it\ (i=1\ldots100)}$	Firm's distributed profits (US$)	31562 (mean value)	Determined endogenously via the equations of the model
$dsr_{it\ (i=1\ldots100)}$	Debt service ratio	0.07 (mean value)	Determined endogenously via the equations of the model
$e_{it\ (i=1\ldots100)}$	Number of equities	174448 (mean value)	Determined endogenously via the equations of the model
$eq_{it\ (i=1\ldots100)}$	Total value of equities (US$)	174448 (mean value)	Calibrated based on the variable *stocks* in SCF
$int_{Pit\ (i=1\ldots100)}$	Interest expenses (US$)	1084 (mean value)	Determined endogenously via the equations of the model
$int_{Rit\ (i=1\ldots100)}$	Interest payments (US$)	564 (mean value)	Determined endogenously via the equations of the model
$l_{it\ (i=1\ldots100)}$	Non-housing debt (US$)	18780 (mean value)	Calibrated based on the value of non-housing household loans in SCF, estimated as: *debt -ploans1* -
$m_{it\ (i=1\ldots100)}$	Deposits (US$)	38456 (mean value)	Calibrated based on the variable *liq* in SCF
$nl_{it\ (i=1\ldots100)}$	New loans (US$)	-	The model starts estimating the value of new loans in the second period
$nl_{Dit\ (i=1\ldots100)}$	Desired new loans (US$)	-	The model starts estimating the value of desired new loans in the second period
$pr_{it\ (i=1\ldots100)}$	Proportion of wealth held in equities	0.35 (mean value)	Calibrated based on the variables *stocks* and *liq* in SCF
$ub_{it\ (i=1\ldots100)}$	Unemployment benefit rate (US$)	4254	Estimated based on US data for the number of unemployed people and the government spending on unemployment insurance (data source: FRED)
$unem_{it\ (i=1\ldots100)}$	Unemployment status	Equal to 1 for 6% of the households	The unemployed households have been identified randomly
$vg_{it\ (i=1\ldots100)}$	Gross wealth equal to the sum of the value of equities and deposits (US$)	212904 (mean value)	Calibrated based on the variables *stocks* and *liq* in SCF
$vn_{it\ (i=1\ldots100)}$	Net wealth equal to the difference between gross wealth and debt (US$)	194124 (mean value)	Equal to vg_{it} - l_{1j}
$w_{it\ (i=1\ldots100)}$	Wage income (US$)	59396 (mean value)	Calibrated based on the variable *wageinc* in SCF
$yd_{it\ (i=1\ldots100)}$	Disposable income (US$)	93053 (mean value)	Determined endogenously via the equations of the model
$yd_{90it\ (i=1\ldots100)}$	Disposable income of the 90th percentile (US$)	144409 (mean value)	Determined endogenously via the equations of the model
$ydg_{it\ (i=1\ldots100)}$	Gross disposable income (US$)	94138 (mean value)	Determined endogenously via the equations of the model

(continued from the previous page)

Symbol	Description	Value	Remarks/sources
	Aggregate variables		
A	Advances (US$)	3619433	Determined endogenously via the equations of the model
BP	Banks' profits (US$)	253820	Determined endogenously via the equations of the model
C	Total consumption expenditures (US$)	9066268	Estimated as the difference between output and investment
CG	Capital gains on equities	-	The model starts estimating the value of capital gains in the second period
CBP	Profits of the central bank (US$)	70830	Determined endogenously via the equations of the model
CO	Sum of employee and employer contributions (US$)	35637	Determined endogenously via the equations of the
DP	Distributed profits of firms (US$)	3156225	Determined endogenously via the equations of the model
E	Number of equities	17444803	Determined endogenously via the equations of the model
EQ	Value of equities (US$)	17444803	Estimated as the sum of the value of all equities
g_Y	Growth rate of output	0.02	Mean US economic growth over the period 2013-2017 (data source: FRED)
g_λ	Productivity growth rate	0.02	Equal to the growth rate of output
HPM	High-powered money (US$)	329039	Determined endogenously via the equations of the model
I	Investment (US$)	670729	Estimated such that the model generates the baseline scenario
K	Capital stock of firms (US$)	31158389	Determined based on the value of the capital-to-output ratio in the US over the period 2016-2017 (data source: PENN World 9.1)
K_{CB}	Capital of the central bank (US$)	3290393	Determined endogenously via the equations of the model
L_H	Loans to hosueholds (US$)	1878046	Estimated as the sum of the loans of all hosueholds
L_F	Loans to firms (US$)	5550088	Determined basd on the the US corporate loans-to-GDP ratio over the period 2013-2017 (data source: BIS)
M	Total deposits (US$)	4137741	Sum of the deposits of households and the unemployment fund
M_F	Deposits of the unemployment fund (US$)	292110	Determined endogenously via the equations of the model
M_H	Deposits of households (US$)	3845631	Estimated as the sum of the deposits of all hosueholds
p_e	Price of equities	1	Normalised to 1 in the intial period
RP	Firms' retained profits (US$)	346424	Determined endogenously via the equations of the model
s_W	Wage share	0.61	Mean US unemployment rate over the period 2013-2017 (data source: AMECO)
TP	Firms' total profits (US$)	3502649	Determined endogenously via the equations of the model
u	Rate of capacity utilisation	0.77	Mean US capacity utilisation rate over the period 2013-2017 (data source: FRED)
UB	Rate of capacity utilisation	25524	Estimated as the sum of all unemployment benefits provided to households
ur	Unemployment rate	0.06	Mean US unemployment rate over the period 2013-2017 (data source: FRED)
W	Wage bill (US$)	5939568	Estimated as the sum of the wages of all households
Y	Output (US$)	9736996	Estimated based on the formula $Y=W/s_W$
Y^*	Full-capacity output (US$)	12645450	Determined endogenously via the equations of the model
$ymin$	Disposable income below which the marginal propensity to consume is equal to 1	27550	Estimated such that about 30% of households have a marginal propensity to consume equal to 1
λ	Labour productivity (US$)	103585	Determined endogenously via the equations of the model

Appendix B: Values for parameters and exogenous variables (baseline case)

Symbol	Description	Value	Remarks/sources
	Agent-based parameters/ exogenous variables		
$\varphi_{i\ (i=1\ldots100)}$	Responsiveness of wages to changes in the unemployment rate	Depends on the level on skills	Selected from a reasonable range of values; modified in the simulation analysis
$\varphi_{i0\ (i=1\ldots100)}$	Responsiveness of low-skilled wages to changes in the unemployment rate	0.5	Selected from a reasonable range of values; modified in the simulation analysis
	Aggregate parameters/ exogenous variables		
c_2	Marginal propensity to consume out of gross wealth	0.10	Calibrated such that the model generates the baseline scenario
d_0	Autonomous component in the investment function	0.002	Calibrated such that the model generates the baseline scenario
d_1	Sensitivity of investment rate to profitability	0.1	Selected from a reasonable range of values; modified in the simulation analysis
d_2	Sensitiivty of investment rate to capacity utilisation	0.03	Selected from a reasonable range of values
r_B	Policy interest rate	0.02	Equal to the current Fed funds rate
rep	Repayment ratio on household loans	0.05	Selected from a reasonable range of values
r_{LH}	Rate of interest on firms' loans	0.06	Determined as a spread over the policy interest rate
r_{LF}	Rate of interest on households' loans	0.05	Determined as a spread over the policy interest rate
r_M	Rate of interest on deposits	0.02	Equal to the policy interest rate minus a spread
s_F	Rate of firms' retained profits to total profits (retention rate)	0.10	Calibrated such that the model generates the baseline scenario
v	Full potential output to capital ratio	0.41	Calibrated such that the model generates the baseline scenario
χ_1	Spread of the interest rate of firms's loans	0.03	Estimated based on the US interest rate on corporate loans over the period 2013-2017 (source: FRED)
χ_2	Spread of the interest rate of households' loans	0.04	Estimated based on the US interest rate on consumer loans over the period 2013-2017 (source: FRED)
χ_3	Spread of the deposit interest rate	0.01	Estimated based on the US interest rate on deposits over the period 2016-2017 (source: FRED)
γ_0	Autonomous parameter in the credit availability of banks	0.7	Calibrated such that the model generates the baseline scenario
γ_1	Responsiveness of credit availability to the debt service ratio	0.05	Selected from a reasonable range of values; modified in the simulation analysis
ζ	Required reserve ratio	0.08	Selected from a reasonable range of values
θ_1	Responsiveness of the propensity to consume to the interest rate on deposits	2	Selected from a reasonable range of values; modified in the simulation analysis
θ_2	Autonomous propensity to consume	0.68	Calibrated such that the model generates the baseline scenario
ξ	Ratio of unemployment benefit to the median wage	0.09	Calibrated using the spending on unemployment
ϱ_1	Weight in the desired consumption of households related to past consumption	0.1	Calibrated such that the model generates the baseline scenario
ϱ_2	Weight in the desired consumption of households related to the consumption of the reference group	0.2	Selected from a reasonable range of values; modified in the simulation analysis
σ_0	Autonomous growth rate of labour productivity	0.001	Calibrated such that the model generates the baseline scenario
σ_1	Responsiveness of the growth rate of labour producitvity to the growth rate of output	0.95	Calibrated such that the model generates the baseline scenario
τ_F	Rate of employer contributions	0.003	Calibrated such that the model generates the baseline scenario
τ_W	Rate of employee contributions	0.003	Calibrated such that the model generates the baseline scenario
x	Proportion of investment expenditures financed via equity emission	0.31	Calibrated such that the model generates the baseline scenario
ω	Responsivess of the portfolio choice of hosueholds to the relative rates of return	0.1	Selected from a reasonable range of values; modified in the simulation analysis