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 using an agent-based stock-flow consistent model. The model consists of heterogeneous households that differ in skills, employment status, income sources, wealth accumulation and portfolio choices. We identify four distributional transmission channels of monetary policy: (i) the interest income channel that refers to the direct effects of monetary policy stance on the interest income and interest expenses of households and non-financial firms; (ii) the macroeconomic activity channel which encapsulates the second-round distributional effects of monetary policy via its impact on macroeconomic activity and, thus, on unemployment; (iii) the portfolio reallocation channel that refers to the equity price effects of the portfolio reallocation that stems from a change in the base interest rate; and (iv) the indebtedness channel which is associated with the dynamic interaction between interest expenses, consumption norms and inequality. The simulation analysis shows that expansionary monetary policy increases income inequality in the short run: this happens primarily due to the reduction in the interest payments of non-financial firms that increases the dividend income of richer households. However, gradually the macroeconomic activity channel prevails causing a reduction in unemployment that tends to reduce income inequality. Expansionary monetary policy increases wealth inequality basically due to the portfolio reallocation channel and the indebtedness channel.

Keywords: monetary policy, income and wealth inequality, agent-based macroeconomics, stock-flow consistent modelling

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1. Introduction

Over the last decades the research on monetary policy has largely concentrated on the impact of monetary authorities' decisions on inflation and the fine-tuning of the macroeconomy. Much less attention has been paid to the distributional effects of monetary policy. These effects are non-trivial. Since households differ in their balance sheet structures and the proportion of income that they receive from the various income sources, changes in the policy interest rate and purchases of assets from monetary authorities 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.

There are a few studies that have explored the distributional implications of monetary policy. Argitis and Pitelis (2001), Hein (2006) and Hein and Schoder (2011) have concentrated on the impact of conventional monetary policy on functional income distribution. Niggle (1989), Arestis and Howells (1994), Coibion et al. (2012), Bank of England (2012), McKinsey Global Institute (2013), Saiki and Frost (2014), O'Farrell et al. (2016) and Domanski et al. (2016) have investigated empirically various channels through which conventional or unconventional monetary policy influence the distribution of personal income and wealth.

However, there is still a lack of a theoretical framework that analyses the complex distributional effects of monetary policy in an integrated way. This paper develops such a framework by combining the stock-flow consistent (SFC) approach developed by Godley and Lavoie (2007a) with the agent-based (AB) analysis that has been used extensively over the last years for the combined examination of macro and micro issues (see e.g. Dosi et al., 2015 and Russo et al., 2016 and the references therein). The SFC approach is characterised by the explicit incorporation of accounting principles into dynamic macro modelling and the emphasis that is placed on the dynamic interplay between monetary stocks and flows. The AB approach is suitable for exploring how macroeconomic phenomena emerge out of the interactions between heterogeneous agents that are characterised by bounded rationality. 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[1] (see e.g. Michell, 2014; van der Hoog and Dawid, 2015; Caiani et al., 2016). The AB-SFC framework serves perfectly the purposes of this paper since the analysis of the distributional effects of monetary policy requires a model that combines a high-level household heterogeneity with respect to balance sheet structures and income sources with a consistent macro framework that incorporates explicitly the dynamic impact of monetary policy on macroeconomic activity and the assets/liabilities of households. Crucially, the fact that in SFC models the balance sheets expand though the endogenous creation of money by the banking sector permits an accurate analysis of the implications of monetary policy.[2]

In the model developed in this paper households differ in skills, employment status, income sources, wealth accumulation and portfolio choices. 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. In the simulations conducted emphasis is placed on the distributional effects of expansionary monetary policy which are materialised via a reduction in the policy interest rate. The structure of our model borrows elements from the SFC model developed by Dafermos and Papatheodorou (2015), who have analysed the links between functional and personal income distribution, with certain features of the AB model of Russo et al. (2016), who have studied the links between inequality, consumer credit and financial fragility.

We have opted to abstract from the distributional effects of monetary policy that stem from its impact on inflation. Moreover, we do not examine the distributional effects of quantitative easing. Since the analysis of these effects would overly increase the size of the current paper, we have left these issues for future research. However, it should be emphasised that the model of this paper could be easily extended in order to include these additional distributional implications of monetary policy.

[1] In this framework representative agents maximise profit or intertemporal utility functions having perfect knowledge of the probability distributions of all variables in the model. De Grauwe (2010), Wren-Lewis (2011), Stiglitz (2011) and Dosi et al. (2015), among others, have called this approach into question, pinpointing its empirical and methodological shortcomings.

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

We proceed as follows. Section 2 presents the model. Section 3 describes the distributional transmission channels of monetary policy that are captured by our model. Section 4 shows the results of our simulations about the effects of monetary policy on the distribution of personal income and wealth. Section 5 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.[3] The household structure that we have assumed is broadly in line with the empirical fact that richer households receive a lower proportion of their income in the form of wages and a higher proportion in the form of capital income (see, for example, Diaz-Giménez et al., 2011; Federal Reserve Bulletin, 2012).

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). 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

[3] The model abstracts from mortgages and the housing market. Although these are particularly relevant for monetary policy, their incorporation would complicate the current model substantially. Therefore, this extension is allowed for future work.

between the sectors. In the case of firms and commercial banks, 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 represent the budget constraints of the sectors.

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 educational qualifications and has an initial wealth at $t = 0$ equal to vg_{i0}. The allocation of initial wealth is determined by using a log normal distribution with a mean μ_{LN}

and a standard deviation σ_{LN}. There is a minimum wage rate in the economy, $wmin_t$, which every year is adjusted based on labour productivity growth and the total unemployment rate. Algebraically:

$$wmin_t = wmin_{t-1}\left(1 + g_{\lambda t-1} - \phi\left(\frac{ur_t - ur_{t-1}}{ur_{t-1}}\right)\right) \quad (1)$$

where g_λ is the labour productivity growth and ur is the total rate of unemployment.[4] When the rate of unemployment remains unaltered, the growth rate of the minimum wage is exactly 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.

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, $unem_{it} = 0$.

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

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

The wage received by employed households is determined by multiplying $wmin_t$ by a wage premium π_i. Since unemployed households do not receive wage income, we have:

$$w_{it} = \begin{cases} \pi_i w\min_t & if \quad unem_{it} = 0 \\ 0 & if \quad unem_{it} = 1 \end{cases} \tag{2}$$

The wage premium, which reflects individual skills and various idiosyncratic features, is determined by the following formula:

$$\pi_i = 1 + FN_i + \chi(s_i - 1) \tag{3}$$

where FN_i is a random number picked from a folded normal distribution with a mean μ_{FN} and a standard deviation σ_{FN}.

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

$$ub_{it} = \begin{cases} \xi wmin_t & if \quad unem_{it} = 1 \\ 0 & if \quad unem_{it} = 0 \end{cases} \tag{4}$$

where $\xi < 1$.

Each household has to decide about the allocation of wealth between deposits and equities. If the gross wealth of a household (vg_{it}) is below a minimum level, $minv$, then households keep all their wealth in the form of deposits. Otherwise, they keep a proportion of their wealth, pr_{it}, as equities (eq_{it}):

$$eq_{it} = pr_{it} vg_{it} \tag{5}$$

This proportion increases as wealth becomes higher and as the rate of return on equities (re_t) increases relative to the interest rate on deposits (r_M). Formally:

$$pr_{it} = \begin{cases} 0 & if \quad vg_{it-1} < minv \\ \lambda_{10} + \lambda_{11}(re_{t-1} - r_M) + (\lambda_{20} - \lambda_{10})(vg_{it-1}/v_{90t-1}) & if \quad minv \le vg_{it-1} \le v_{90t-1} \\ \lambda_{20} + \lambda_{21}(re_{t-1} - r_M) & if \quad vg_{it-1} > v_{90t-1} \end{cases} \tag{6}$$

where v_{90} is the gross wealth at the 90th percentile.

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

$$m_{it} = vg_{it} - eq_{it} \tag{7}$$

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

$$int_{Rit} = r_M m_{it-1} \tag{8}$$

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:

$$dp_{it} = \frac{e_{it}}{\sum_{i=1}^{N_H} e_{it}} DP_t \tag{9}$$

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:

$$bp_{it} = \frac{e_{it}}{\sum_{i=1}^{N_H} e_{it}} BP_t \tag{10}$$

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

The capital gains are equal to:

$$cg_{it} = (p_{et} - p_{et-1})e_{it-1} \tag{11}$$

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

$$e_{it} = \frac{eq_{it}}{p_{et}} \tag{12}$$

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

$$int_{Pit} = r_{LH} l_{it-1} \tag{13}$$

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

The total disposable income of each household reads:

$$yd_{it} = (1-\tau_W)w_{it} + ub_{it} + int_{Rit} - int_{Pit} + dp_{it} + bp_{it} \tag{14}$$

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. (2013) 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:

$$c_{Dit} = (1-\rho_1-\rho_2)(c_{1it}\,yd_{it-1} + c_{2it}\,vn_{it-1}) + \rho_1 c_{it-1} + \rho_2 c_{REFit-1} \quad (15)$$

where vn_{it} is the net wealth, 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_{2it} is the propensity to consume out of wealth, 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:

$$nl_{Dit} = max\{0, c_{Dit} + repl_{it-1} - yd_{it} + vg_{it-1}\} \quad (16)$$

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 burden of debt of households (bur_{it}). Hence, the actual new loans (nl_{it}) are given by:

$$nl_{it} = (\psi_0 - \psi_1 bur_{it})\,nl_{Dit} \quad (17)$$

The burden of debt is defined as follows:

$$bur_{it} = \frac{(r_{LH} + rep)l_{it-1}}{ydg_{it}} \quad (18)$$

[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.

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

$$ydg_{it} = yd_{it} - int_{Pit} \tag{19}$$

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 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:

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

where yd_{90} is the disposable income at the 90th percentile.

A similar formula is used for the propensity to consume out of wealth:

$$c_{2it} = \begin{cases} \phi_0 & if \quad yd_{it-1} < minyd \\ 1-\phi_1 r_M + (1-\phi_2)(yd_{it-1}/yd_{90t-1}) & if \quad minyd \le yd_{it-1} \le yd_{90t-1} \\ \phi_2 - \phi_1 r_M & if \quad yd_{it-1} > yd_{90t-1} \end{cases} \tag{22}$$

[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.

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

$$vn_{it} = vn_{it-1} + yd_{it} - c_{it} + cg_{it} \tag{23}$$

Households' gross wealth is given by:

$$vg_{it} = vn_{it} + l_{it} \tag{24}$$

At the aggregate level we have:

$$C_t = \sum_{i=1}^{N_H} c_{it} \tag{25}$$

$$W_t = \sum_{i=1}^{N_H} w_{it} \tag{26}$$

$$M_{Ht} = \sum_{i=1}^{N_H} m_{it} \tag{27}$$

$$EQ_t = \sum_{i=1}^{N_H} eq_{it} \tag{28}$$

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

2.3 Firms

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

$$Y_t = C_t + I_t \tag{29}$$

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):

$$TP_t = Y_t - (1+\tau_F)W_t - r_{LF}L_{Ft-1} \tag{30}$$

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:

$$RP_t = s_F TP_t \tag{31}$$

where RP_t denotes the retained profits of firms.

The rest profits (DP_t) are distributed to households:

$$DP_t = TP_t - RP_t \tag{32}$$

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

$$N_{Et} = \frac{Y_t}{\lambda_t} \tag{33}$$

where λ_t denotes labour productivity. We have that:

$$\lambda_t = \lambda_{t-1}(1+g_{\lambda t}) \tag{34}$$

Following the Verdoon-Kaldor 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}):

$$g_{\lambda t} = \sigma_0 + \sigma_1 g_{Yt-1} \tag{35}$$

The number of unemployed households is:

$$N_{Ut} = N_{Ht} - N_{Et} \tag{36}$$

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

$$I_t = d_0 + d_1\left(RP_{t-1}/K_{t-1}\right) + d_2 u_{t-1} \tag{37}$$

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

$$u_t = Y_t / Y_t^* \tag{38}$$

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:

$$K_t = K_{t-1} + I_t \tag{39}$$

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

$$E_t = E_{t-1} + x\left(I_t / p_{et}\right) \tag{40}$$

where E_t is total the number of equities.

The rest is financed via bank loans:

$$L_{Ft} = L_{Ft-1} - RP_t - (E_t - E_{t-1})p_{et} \tag{41}$$

The price of equities is given by:

$$p_{et} = \frac{EQ_t}{E_t} \tag{42}$$

2.4 Unemployment fund

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

$$CO_t = (\tau_W + \tau_F)W_t \tag{43}$$

The total unemployment benefits provided by the unemployment fund (UB_t) are equal to:

$$UB_t = ub_t(N_{Et} + N_{Ut}) \tag{44}$$

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

$$M_{Ft} = M_{Ft-1} + CO_t - UB_t + r_M M_{Ft-1} \tag{45}$$

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 (46):

$$BP_t = r_{LF} L_{Ft-1} + r_{LH} L_{Ht-1} - r_M \cdot M_{t-1} - r_B \cdot A_{t-1} \tag{46}$$

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:

$$M_t = M_{Ht} + M_{Ft} \tag{47}$$

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

$$HPM_t = \zeta M_t \tag{48}$$

where ζ is the required reserve ratio. Equation (49) reflects the budget constraint of commercial banks where central banks' advances play the role of the residual variable:

$$A_t = L_{Ft} + L_{Ht} + HPM_t - M_t \tag{49}$$

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

$$r_{LF} = r_B + \chi_1 \tag{50}$$

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

$$r_{LH} = r_B + \chi_2 \tag{51}$$

Note that $\chi_1 < \chi_2$.

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

$$r_M = r_B - \chi_3 \tag{52}$$

2.6 Central bank

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

$$CBP_t = r_B A_{t-1} \tag{53}$$

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

$$K_{CBt} = K_{CBt-1} + CBP_t \tag{54}$$

The budget constraint of the central bank implies that:

$$A_t = HPM_t + K_{CBt} \tag{55}$$

Equation (55) is the 'redundant' identity: it is logically implied by all the other identities of the model.

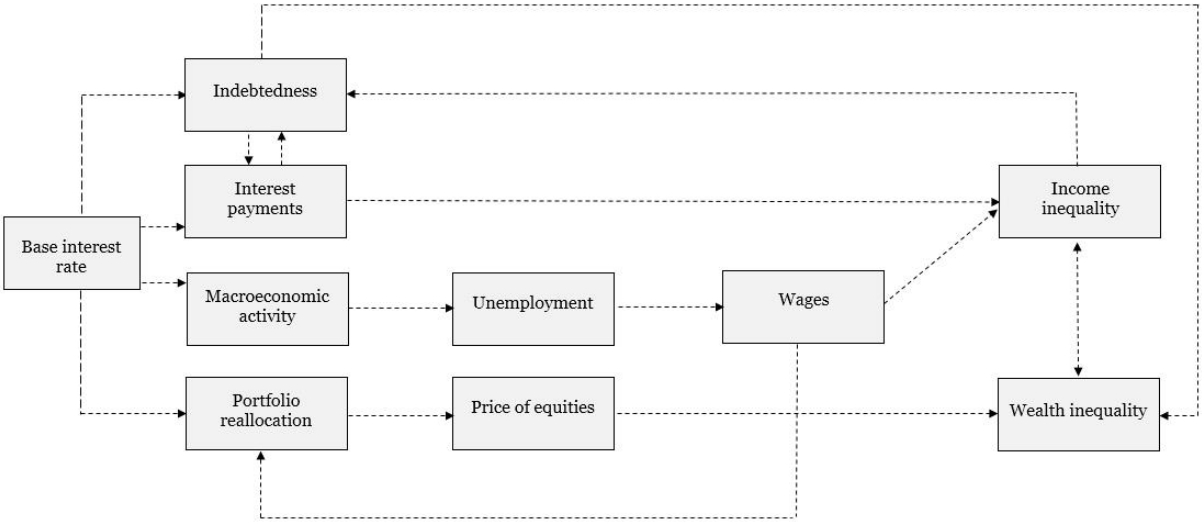
3. Distributional transmission channels of monetary policy

Figure 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). A decline in the policy interest rate pushes down (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 reduce income inequality, while the last one tends to increase income inequality by increasing the distributed profits of firms.

The *macroeconomic activity channel* refers to the second-round effects of monetary policy. A decline in the base interest rate reduces the return on saving. This increases their propensities to consume, placing upward pressures on aggregate consumption. Also, a lower lending interest rate induces firms to invest more. The overall result is an increase in macroeconomic activity that reduces the unemployment rate, placing upward pressures on wage income because (a) the wage rate becomes

higher and (b) the number of unemployed workers declines. These developments tend to reduce income inequality.

Figure 1: Distributional transmission channels of monetary policy



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. A decline in the base interest rate reduces the deposit interest rate and tends to increase the rate of return on equities (since firms' interest payments decline and, thus, distributed profits increase). This induces households to reallocate their expected wealth towards equity. For a given number of supplied equities, this causes a rise in the equity prices, increasing the inequality in the distribution of wealth. However, it is remarkable that any change in wages (due to the macroeconomic activity channel) can affect the rate of return on equities, influencing thereby the portfolio reallocation channel.

The *indebtedness channel* refers primarily to two effects: (a) a decline in the base interest rate places upward pressures on the disposable income of indebted households, reducing their need to rely on new debt; (b) lower interest payments tend to reduce the burden of debt and, thus, credit rationing, leading to higher indebtedness. If (b) outweighs (a), 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 leads to an increase in indebtedness due to the 'keeping up with the Joneses' effect.

Of particular importance is the fact that, as shown in Figure 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. Simulation results (incomplete section)

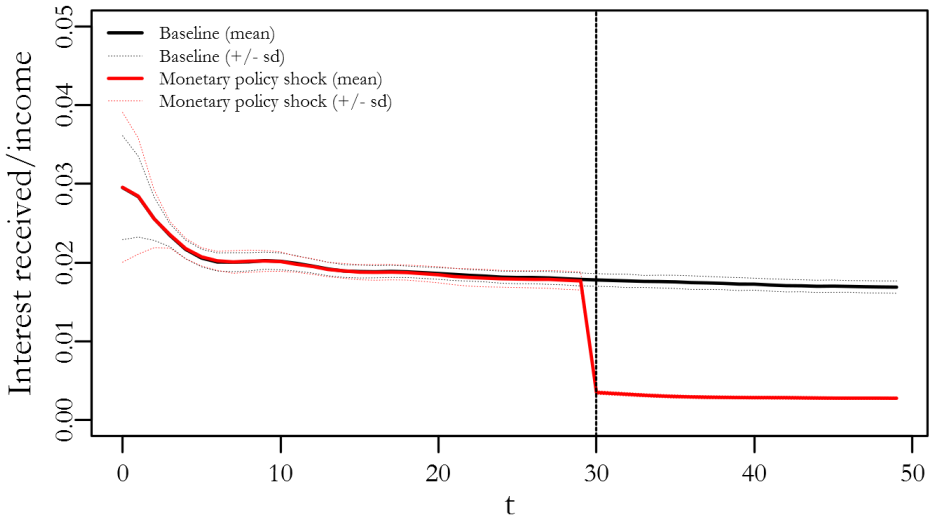
Due to its analytical complexity, the model is solved using computer simulations and Monte Carlo analysis. In the simulations the model is allowed to operate sequentially. At $t = 30$ we impose an expansionary monetary policy shock: central bank reduces the base interest rate from 3% to 1%. The simulation results will be discussed with reference to the distributional transmission channels discussed in section 3.

Figure 2 presents the results. The graphs in this figure show the across-run averages over 100 replications and their standard deviation bands ($N_H = 200$). In order to measure income inequality we use two different indices: the Gini coefficient and the S80/S20 index. Welath inequality is measured by the Gini coefficient.

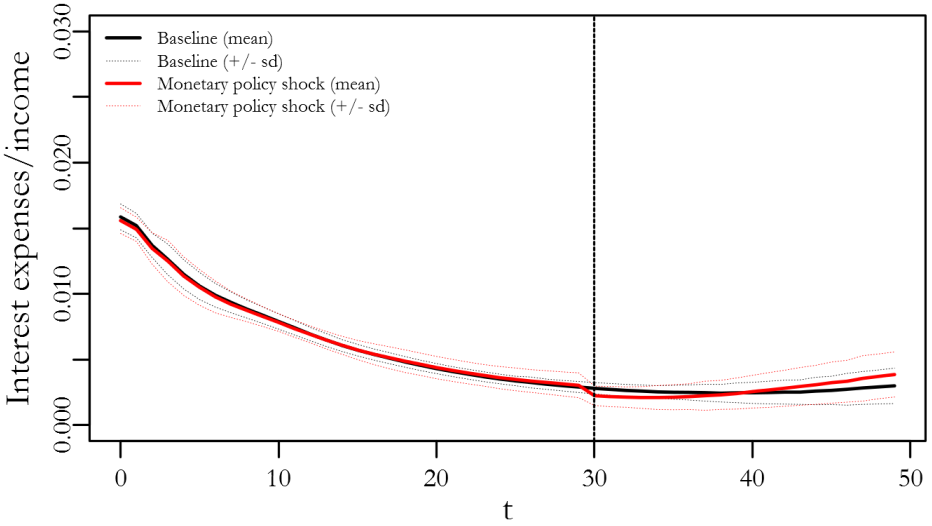
Starting from the *interest payments channel*, we observe that the shock causes a decline in the interest income received by households as a share of total household income (Fig. 2a). Moreover, the share of interest expenses becomes slightly lower (Fig. 2b) and bank profits go down (Fig. 2c). These developments tend to reduce inequality. However, the shock places at the same time upward pressures on inequality since it generates a decline in the interest payments of firms (Fig. 2d): this increases the distributed profits which are primarily received by wealthy households.

Fig. 2: Evolution of key variables, Monte Carlo analysis, 100 simulations (sd stands for standard deviation)

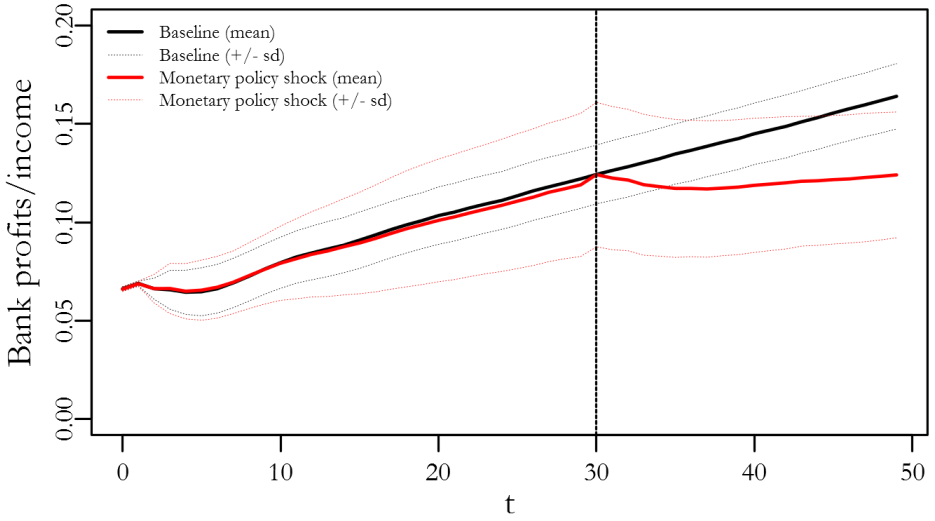
(a) Interest received as a proportion of household income



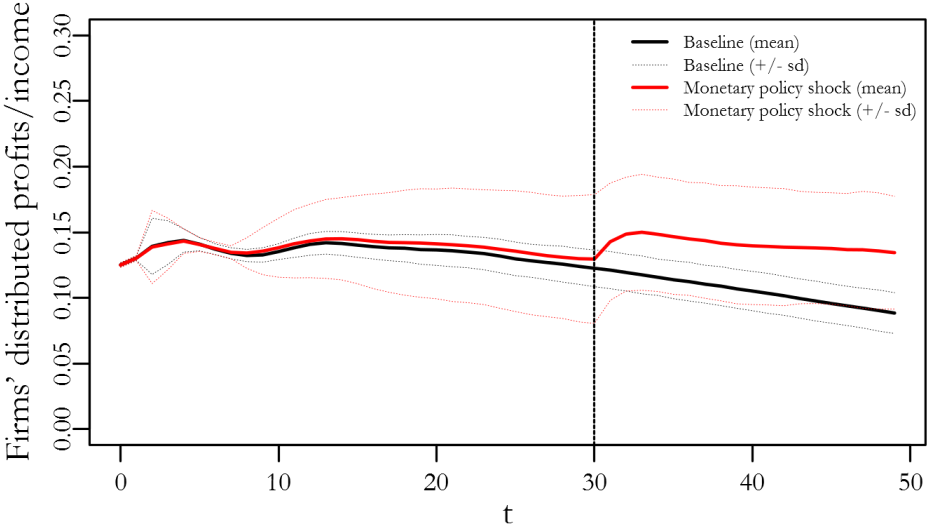
(b) Interest expenses as a proportion of household income



(c) Bank profits as a proportion of household income



(d) Distributed profits as a proportion of household income



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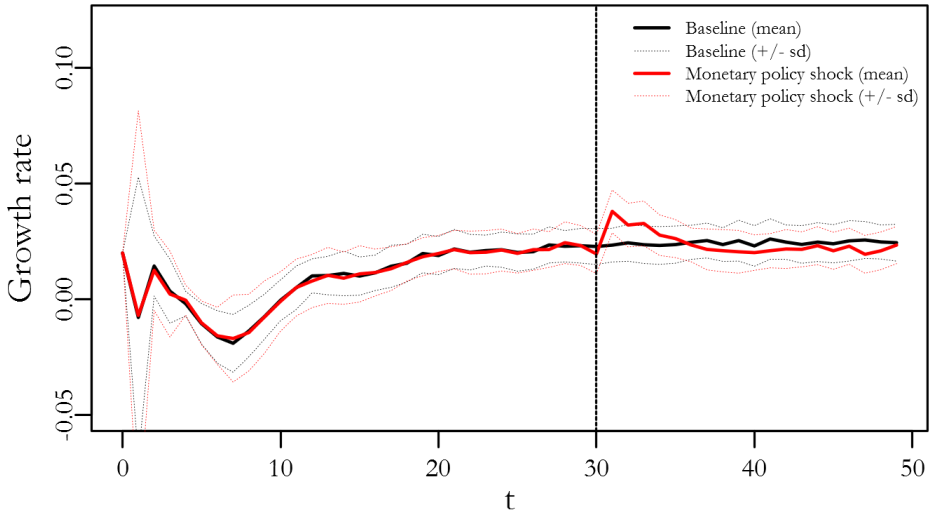
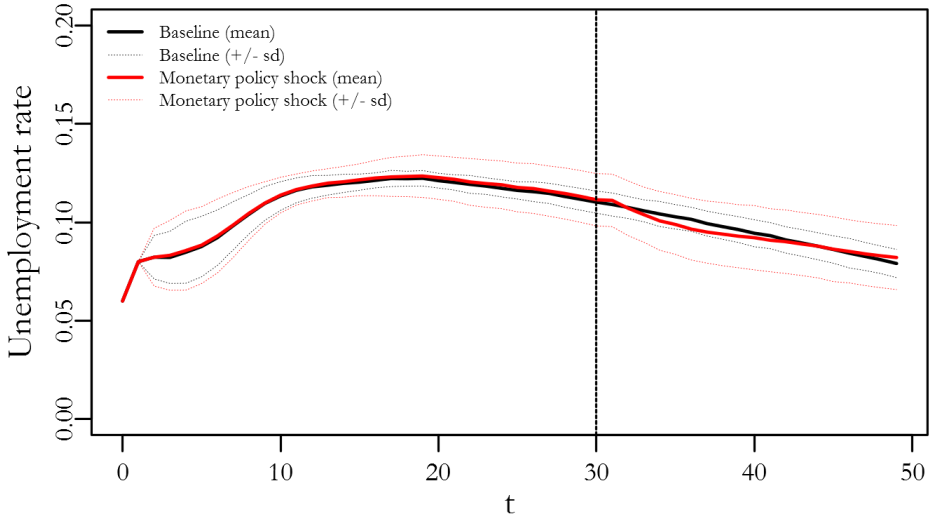
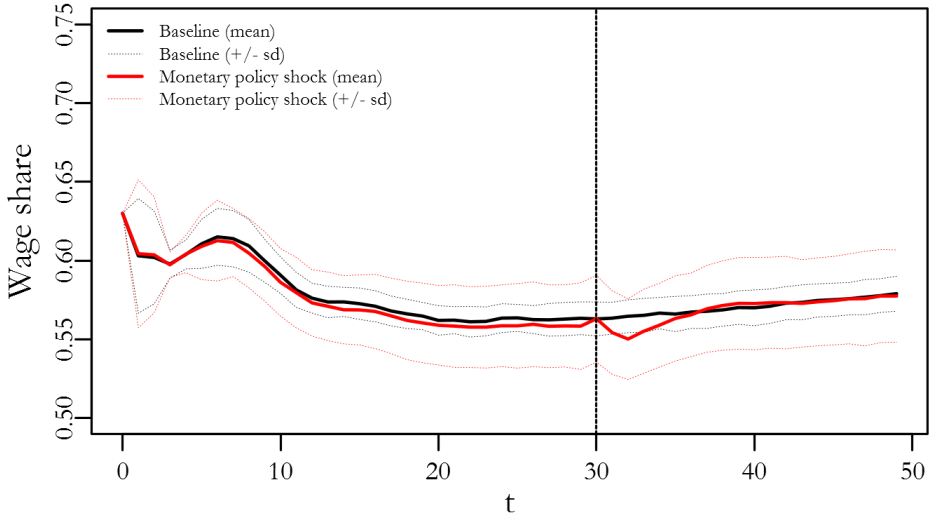
(e) Growth rate of output



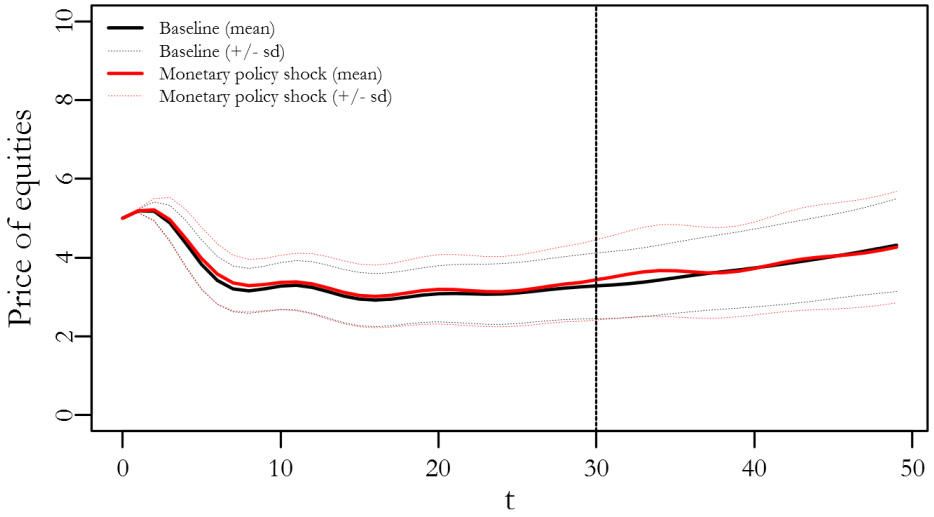
(f) Unemployment rate



(g) Wage share



(h) Price of equities



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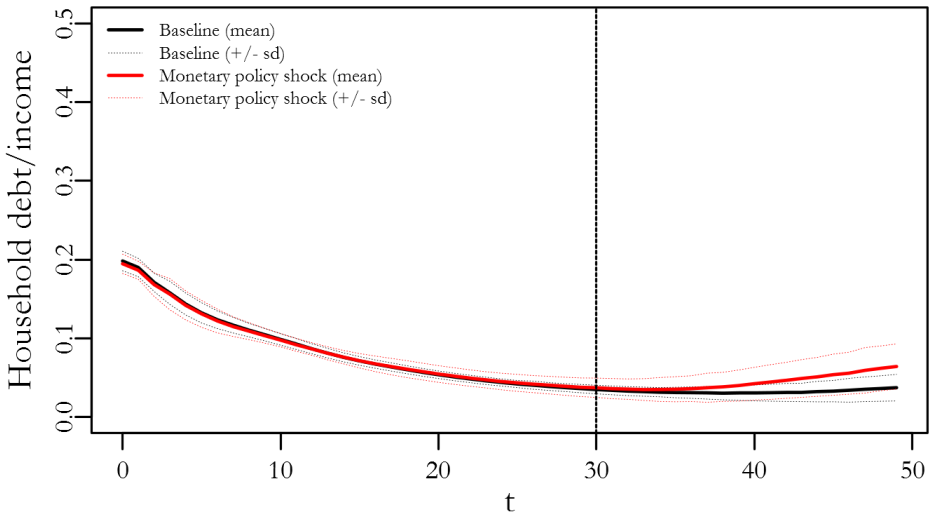
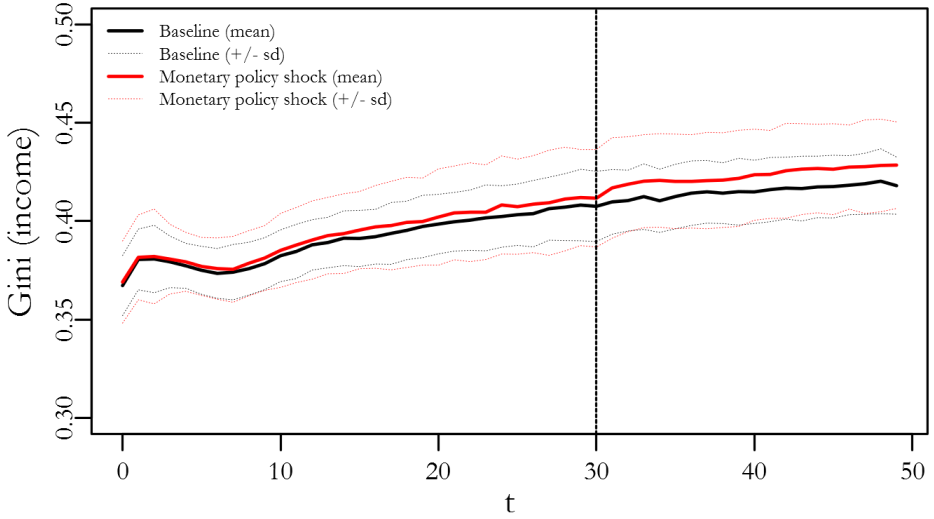
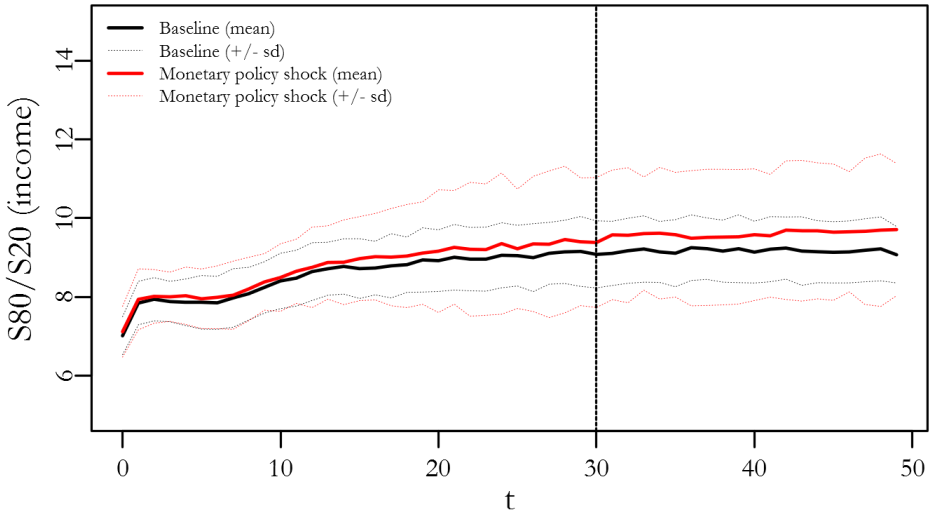
(i) Household debt as a proportion of disposable income



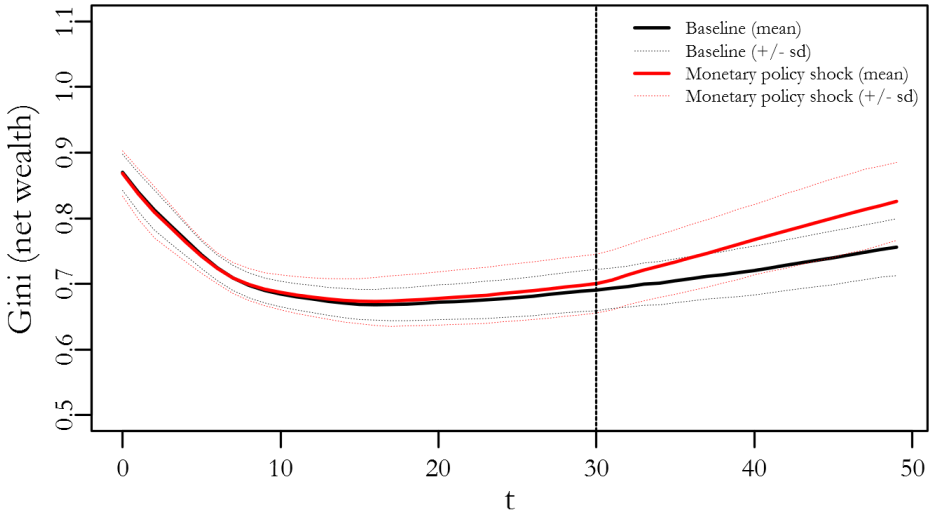
(j) Gini index for the disposable income of households



(k) S80/S20 for the disposable income of households



(l) Gini for the net wealth of households



The decline in the interest rate increases both consumption and investment, causing higher economic growth (Fig. 2e) and lower unemployment (Fig. 2f). As a result, the bargaining power of workers increases and after a few periods the wage share becomes higher than in the baseline scenario (Fig. 2g). Higher wages reduce profitability, inducing thereby a decline in income inequality. The decline in inequality is also reinforced by the reduction in the number of unemployment people. Accordingly, the *macroeconomic activity channel* tends to reduce inequality.

Fig. 2h captures the *portfolio reallocation channel*. Since the rate of return on equities increases relative to the deposit interest rate, households reallocate wealth towards equities. This higher demand for equities makes the price of equities higher compared to the baseline scenario, pushing up wealth inequality. Regarding the *indebtedness channel*, Fig. 2i shows that gradually the indebtedness of households increases compared to the baseline scenario. This happens because the lower borrowing cost reduces credit rationing. Higher indebtedness tends to increase income inequality.

Overall, as shown in Fig. 2j, inequality initially increases basically due to the increase in the distributed profits of firms. However, as time elapses, the macroeconomic activity channel materialises. Higher economic activity, combined with the other developments linked with the interest payments channel, tends to reduce inequality slightly. Regarding wealth inequality, Fig. 2l illustrates that the Gini coefficient for net wealth is higher than in the baseline scenario. This is primarily related with the rise in the price of equities and the gradual increase in household debt caused by expansionary monetary policy.

5. Concluding remarks

The fact that households are heterogeneous with respect to their balance sheets and income sources implies the monetary policy plays a non-neutral role in the distribution of personal income and wealth. This paper examined this role by developing a novel agent-based stock-flow consistent model. The model allowed us to identify four channels through which conventional monetary policy can affect the distribution of personal income and wealth: (i) the interest payments channel; (ii) the macroeconomic activity channel; (iii) the portfolio reallocation channel; and (iv) the indebtedness channel. The simulation analysis shows that expansionary monetary policy increases income inequality in the short run: this happens primarily due to the reduction in

the interest payments of non-financial firms that increases the dividend income of richer households. However, gradually the macroeconomic activity channel prevails causing a reduction in unemployment that tends to reduce income inequality. Expansionary monetary policy increases wealth inequality basically due to the portfolio reallocation channel and the indebtedness channel.

The model of this paper can provide a benchmark platform for the analysis of the distributional implications of monetary policy. The model can be easily extended in order to examine the distributional effects of monetary policy-induced changes in inflation as well as the impact of unconventional monetary policy on inequality. The theoretical platform developed in this paper can also be used as a guideline for the empirical investigation of the various channels through which monetary policy affects the distribution of personal income and wealth.

References

Arestis, P. and Howells, P. G. A. 1994. Monetary policy and income distribution in the UK, Review of Radical Political Economics, 7 (2), 150-163.

Arestis, P. and Sawyer, M. 2006. The role and nature of monetary policy when money is endogenous, Cambridge Journal of Economics, 30 (6), 847-860.

Argitis, G. and Pitelis, C. 2001. Monetary policy and the distribution of income: evidence for the United States and the United Kingdom, Journal of Post Keynesian Economics, 23 (4), 617-638.

Bank of England. 2012. 'The Distributional Effects of Asset Purchases', Quarterly Bulletin 2012 Q3, Bank of England.

Barba, A. and Pivetti, M. 2009. Rising household debt: its causes and macroeconomic implications-a long-period analysis, Cambridge Journal of Economics, 33 (1), 113-137.

Belabed, C.A., Theobald, T. and van Treeck, T. 2013. Income Distribution and Current Account Imbalances, IMK Working Paper no. 126.

Benes, J., Kumhof, M. and Laxton, D. 2014. Financial Crises in DSGE Models: A Prototype Model, IMF Working Paper no. 14/57.

Caiani, A., Godin, A., Caversazi, E., Gallegati, M., Kinsella, S. and Stiglitz, J. E. 2016. Agent based-stock flow consistent macroeconomics: towards a benchmark model, Journal of Economic Dynamics and Control, forthcoming.

Coibion, O., Gorodnichenko, Y., Kueng, L. and Silvia, J. 2012. 'Innocent Bystanders? Monetary Policy and Inequality in the US', NBER Working Papers no. 18170.

Cynamon, B. Z. and Fazzari, S. M. 2008. Household debt in the consumer age: source of growth-risk of collapse, Capitalism and Society, 3 (2), 1-30.

Dafermos, Y. and Papatheodorou, C. 2015. Linking functional with personal income distribution: a stock-flow consistent approach, International Review of Applied Economics, 29 (6), 787-8-15.

De Grauwe, P. 2010. The scientific foundation of dynamic stochastic general (DSGE) models, Public Choice, 144 (3-4), 413-443.

Diaz-Giménez, J., Glover, A. and Ríos-Rull, J-V. 2011. Facts on the Distributions of Earnings, Income, and Wealth in the United States: 2007 Update, Federal Reserve Bank of Minneapolis Quarterly Review, 34 (1).

Domanski, D., Scatigna, M. and Zabai, A. 2016. Wealth inequality and monetary policy, BIS Quarterly Review, March.

Dosi, G., Fagiolo, G. and Roventini, A. 2010. Schumpeter meeting Keynes : a policy-frendly model of endogenous growth and business cycles, Journal of Economic Dynamics and Control, 34, 1748-1767.

Dosi, G., Fagiolo, G., Napoletano, M., Roventini, A. and Treibich, T. 2015. Fiscal and monetary policies in complex evolving economies, Journal of Economic Dynamics and Control, 52, 166-189.

Duesenberry, J. S. 1949. Income, Saving and the Theory of Consumer Behavior, Cambridge, Massachusetts, Harvard University Press.

Federal Reserve Bulletin. 2012. 'Changes in U.S. Family Finances from 2007 to 2010: Evidence from the Survey of Consumer Finances', Board of Governors of the Federal Reserve System, 98 (2).

Frank, R. H., Levine, A. S. and Dijk, O. 2014. Expenditure cascades, Review of Behavioral Economics, 2014 (1), 55–73.

Godley, W. and Lavoie, M. 2007a. Monetary Economics: an Integrated Approach to Credit, Money, Income, Production and Wealth, Basingstoke, Palgrave Macmillan

Godley, W. and Lavoie, M. 2007a. Fiscal policy in a stock-flow consistent (SFC) model, Journal of Post Keynesian Economics, 30 (1), 79-101.

Greenwood-Nimmo, M. 2014. Inflation targeting monetary and fiscal policies in a two-country stock-flow-consistent model, Cambridge Journal of Economics, 38 (4), 839-867.

Hein, E. 2006. Wage bargaining and monetary policy in a Kaleckian monetary distribution and growth model: trying to make sense of the NAIRU, European Journal of Economics and Economic Policies: Intervention, 3 (2), 305-329.

Hein, E. and Schoder, C. 2011. Interest rates, distribution and capital accumulation–a Post-Kaleckian perspective on the US and Germany, International Review of Applied Economics, 25 (6), 693-723.

Kumhof, M., Rancière, R., and Winant, P. 2015. Inequality, leverage, and crisis. American Economic Review, 105 (3), 1217-1245.

Lavoie, M., 2014. Post-Keynesian Economics: New Foundations. Edward Elgar, Cheltenham, UK and Northampton, MA, USA.

McKinsey Global Institute. 2013. QE and ultra-low interest rates: Distributional effects and risks, Discussion Paper November 2013.

McLeay, M., Amar, R., and Ryland, T. 2014. 'Money Creation in the Modern Economy', Bank of England Quarterly Bulletin Q1, 14-27.

Michell, J. 2014. A Steindlian Account of the Distribution of Corporate Profits and Leverage: A Stock-flow Consistent Macroeconomic Model with Agent-based Microfoundations, PKSG Working Paper, no. 1412.

Niggle, C. J. 1989. Monetary policy and changes in income distribution, Journal of Economic Issues, 23 (3), 809-822.

O'Farrell, R., Rawdanowicz, L. and Inaba, K.-I. 2016. Monetary policy and inequality, OECD Economics Department Working Papers, 1281, OECD Publishing, Paris.

Rajan, R. G. 2010. Fault Lines-How Hidden Fractures Still Threaten the World Economy, Princeton, NJ, Princeton University Press.

Russo, A., Riccetti, L., Gallegati, M. 2016. Increasing inequality, consumer credit and financial fragility in an agent based macroeconomic model, Journal of Evolutionary Economics, 26 (1), 25-47.

Saiki, A. and Frost, J. 2014. Does unconventional monetary policy affect inequality? Evidence from Japan, Applied Economics, 46 (36), 4445-4454.

Stiglitz, J. 2011. Rethinking macroeconomics: what failed, and how to repair it, Journal of the European Economic Association, 9 (4), 591-645.

Van der Hoog, S. and Dawid, H., 2015. Bubbles, Crashes and the Financial Cycle: Insights from a Stock-flow Consistent Agent-based Macroeconomic Model, Bielefeld University, Working Papers in Economics and Management, 01-2015, May 2015.

Veblen, T. 1991 [1899]. The Theory of the Leisure Class, Augustus M. Kelley, Fairfield.

Wren-Lewis, S. 2011. Internal consistency, price rigidity and the microfoundations of macroeconomics, Journal of Economic Methodology, 18 (2), 129-146.