Monetary policy and inequality: an heterogenous agents' approach

Andrea Boitani[a] Lorenzo Di Domenico[a] Giorgio Ricchiuti [bc]

September 26, 2024

[a] *Università Cattolica del Sacro Cuore, Milano*;[b], *Università degli Studi di Firenze*; [c] *Complexity Lab in Economics (CLE), Università Cattolica del Sacro Cuore, Milano*;

Abstract

In this paper, we study the impact of contractionary monetary policies on income and wealth inequality. By developing an Agent Based – Stock Flow Consistent model, we show that both the sign and magnitude of monetary policy impacts depend on the heterogeneity characterizing income sources across the population, the composition of households wealth and portfolio preferences, the value of the labor share, and the size of unemployment benefits. Monetary policy can affect inequality through four main transmission channels: saving remuneration, asset prices, aggregate demand and cost-push channels. The paper delivers five main results: i) the impact of monetary policy on income inequality is non-linear and is a function of the degree of symmetry in the distribution of firms and bank shares, markup, and unemployment benefits; ii) the magnitude of the impact is not independent of the inequality measure considered; iii) the short-run effects on wealth inequality due to capital gains and losses (CGL) on long-term bonds are positively correlated with the degree of heterogeneity in the portfolio preferences of households. In the long-run, such effect vanishes. The short-run effect is null in the case of zero heterogeneity; iv) If the monetary shock has an asymmetric impact on portfolio decisions, monetary policy can have a long-lasting impact on wealth inequality through the CGLs in the stock market. In the presence of symmetric shocks, CGLs in the stock market have no effect, neither in the short nor in the long term; v) the higher the labor share, the greater the impact of monetary policy on inequality. Finally, we adopt the income factor decomposition to disentangle how income heterogeneity affect the transmission channels of monetary policies.

Keywords: Monetary policies; income inequality; Agent-Based models; Stock-Flow Consistent models
JEL codes: E4, E52, E53, D31, D63
Acknowledgment: We really thank the participants of the Wehia 2024 at the University of Bamberg (Germany) for their comments and suggestions. As usual, all errors are ours.

1 Introduction

In recent years, there has been a growing concern about the consequences that monetary policy (MP) shocks have on income and wealth inequality. Usually, political economy arguments specify that the distribution of income is affected by fiscal policy (Acemoglu and Robinson, 2008; Muinelo-Gallo and Roca-Sagalés, 2011; Neves and Silva, 2014). On the other hand, Central Banks should deal with purely technical matters, such as the control of price stability over the medium term. However, there are certain technical, non-judgmental interests for central bankers in the distribution of income and wealth that have led them to question how long the distributional side-effects should be tolerated, particularly during financial and economic crises or extended periods of zero-lower bound constraints (Guerello, 2018). Furthermore, as income distribution is a matter of political rather than technical decision-making, the possible link between monetary policy and inequality has recently led to an increase in public criticism of central banks' independence (Acemoglu and Johnson, 2012).

The empirical literature on the topic is growing; however, the results are quite ambiguous and sometimes contradictory. Empirical studies find both equalizing and dis-equalizing effects of restrictive monetary policies. Aye et al. (2019), Furceri et al. (2018), Galbraith et al. (2007), Mumtaz and Theophilopoulou (2017), and Saiki and Frost (2014, 2018) find that contractionary monetary policies increase income inequality. Conversely, Davtyan (2016) and Villarreal (2014) show that contractionary shocks have an equalizing effect. Hafemann et al. (2018), Herradi and Leroy (2021), and Inui et al. (2017) find that expansionary shocks worsen inequality, while Samarina and Nguyen (2024) and Taghizadeh-Hesary et al. (2020) show that expansionary shocks reduce inequality. Casiraghi et al. (2018) find that ECB unconventional monetary policy reduces labor income inequality. Coibion et al. (2017) find that contractionary monetary policy, instead, increases inequality in labor earnings. Di Bucchianico and Lofaro (2023) find that the dynamic of income inequality is strictly connected to labor share movements. Their SVAR analysis shows that contractionary monetary policies generate long-run adverse effects on the level of real wages. While the labor share initially rises because of the fall in GDP, the subsequent pronounced fall in real wages lets the labor share fall back to the pre-shock level. Montecino and Epstein (2015) for the U.S. find that an expansionary monetary policy, mainly in the form of Q.E., contributed to the rise in inequalities. Bulir (2001) provides evidence that the effect of monetary policy on income inequality, by affecting price stability, is nonlinear.

Furthermore, results differ according to the inequality measure considered. Most of the studies adopt the Gini coefficient (Aye et al., 2019; Bunn et al., 2018; Casiraghi et al., 2018; Coibion et al., 2017; Davtyan, 2016; Furceri et al., 2018). A smaller number of researchers adopt the Theil index (Galbraith et al., 2007; Guerello, 2018), Top 1 percent income share (Herradi and Leroy, 2021) and the interdecile ratios (Montecino and Epstein, 2015; Taghizadeh-Hesary et al., 2020).In this regard, Davtyan (2016) shows that the estimated effects of monetary policy depend on the degree of representativeness of the inequality measures. That is, the effects might differ if they do not represent the whole income share of the population, particularly the top one percent. Researches show that in the USA, the dynamic of income inequality is mainly driven by the variation in this upper end of the distribution (Atkinson et al., 2011; Harris et al., 2011; Kenworthy and Smeeding, 2014).

However, rather than contradictory, as argued by Dolado et al. (2021), such apparently divergent results can be explained in light of the fact that different distributions of households along relevant heterogeneity dimensions determine different effects of monetary policy on inequality. In this sense, the same monetary policy move can have distinct, and possibly counteracting, effects on inequality along different dimensions of heterogeneity. Because of this, it is a priori unclear how monetary policy will ultimately affect inequality. In this respect, 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., 2024).

On the institutional side, central banks have started devoting more attention to the heterogeneity of households (Carney, 2016; Draghi, 2016; Yellen, 2016) and inequality has become one of the topics that came up most in the European Central Bank summary reports (Bergbauer et al., 2022). Recent studies on the role of household heterogeneity in the transmission of macroeconomic shocks and policies have provided support for these developments. For instance, as argued by Debortoli and Galí (2017), taking into account agents' heterogeneity has been shown to be important in order to understand the transmission of monetary policy, including the relative contribution of direct and indirect effects(Kaplan et al., 2018), or its redistributive effects across income groups (Auclert, 2019). The majority of these studies acknowledges that the overall impact of monetary policies may have heterogeneous effects on individual households due to significant variations in the makeup of their portfolios (which include stocks, bonds, and real estate) and their sources of income (such as employment status and labour versus financial income). For instance, Lenza and Slacalek (2018), by estimating a Bayesian VAR model for the Euro-area, show that the transmission of the Quantitative Easing to individual households passes through three channels: income composition, portfolio composition and earnings heterogeneity. They find that the (obviously expansionary) QE in the euro area has diminished income inequality, mostly via the earnings heterogeneity channel and a sizeable reduction in the unemployment rate for the poorer part of the population. The Gini coefficient for gross household income drops from 43.1 to 42.9. Instead, CB's asset purchases have contributed to reducing wealth inequality, albeit to an almost negligible extent. Dossche et al. (2021) estimate the transmission channel from monetary policy to consumption, studying how it varies across individual households on the basis of the structure of their income and wealth, their marginal propensity to consume, and the type of income reaction to aggregate shocks. They show that the impact that the different interest rate paths have on households' net financial income (net interest rate exposure) is heterogeneous across households, depending on the composition of their asset and liability portfolios.

In light of these empirical evidences, in this paper, we develop an Agent Based - Stock Flow Consistent model (AB-SFC) (Caiani et al., 2016; Di Domenico, 2023) to study the relationship between monetary policies and income and wealth inequality. The main aim of the paper is to provide a theoretical explanation for the ambiguous empirical findings, overcoming the difficulties that arise in their apparently contradictory interpretations and shedding light on how different initial conditions in the endowments structure guide the final impact of MPs. On the one hand, AB models are naturally predisposed to encompass a multitude of heterogeneous agents, and they present themselves among the first options for analyzing distributional issues. They have been extensively used to study economic phenomena emerging from the heterogeneity characterizing economic agents (Riccetti et al., 2015; Dosi and Roventini, 2019; Fagiolo and Roventini, 2016). On the other hand, the SFC approach provides a sound macroeconomic and monetary framework within which the behavioural equations of the agents consistently operate with associated monetary flows, and the stringency between the different balance sheets is described.

The SFC framework allows for a rigorous representation of the monetary dimension of the production process, treating the real and financial sides of the economy in an integrated way (Nikiforos and Zezza, 2017). The use of money is not simply represented by a demand and supply function ex-post attached to a system determining real quantities, conversely all transactions are explicitly realized in monetary terms, and agents must equip themselves with currency before carrying out their "trades" in each period. The determination of real quantities goes hand in hand with the dynamic of money circulation. As a result, the process of money creation, circulation and destruction is explicitely represented throught the sequential macroeconomic accounting. The key features of the SFC approach can

be summarized as follows: (a) the consideration of both flow and stock variables and the related macro-accounting consistency constraints; (b) unlike real assets, financial assets held by an agent or sector have an accounting counterpart in the liability side of the balance sheets of other agents or sectors (Fontana et al., 2020); (c) the explicit formalization of a sequential process where all agents/sectors have to realize their transition in monetary terms; (d) the use of dynamic macroeconomic models, where endogenous variables move forward non-ergodically in historical time; (e) each financial stock is associated with its own flow, meaning that the former is continuously fueled by (and, in turn, fuels) the latter. In parallel, each flow comes from and goes somewhere, there are no black holes. This is coherent with the 'quadruple accounting' principle, according to which any economic transaction requires at least four recorded entries for the accounting matrices to balance out (Copeland, 1949; Godley and Lavoie, 2006).

The integration between the AB and SFC approaches allows for combining a high-level household heterogeneity with respect to balance sheet structures, income sources, portfolio decisions and wealth composition (and more actionable heterogeneous dimensions) with a macro framework that incorporates explicitly the dynamic impact of monetary policy on macroeconomic activity and the assets/liabilities of households. Furthermore, in AB-SFC models, the balance sheets expand though the endogenous creation of money by the banking sector. This permits an accurate analysis of the implications of monetary policy and the process of asset/liability accumulation.

In the model, households are characterized by different degrees of heterogeneity regarding income sources, bonds and stocks endowments, savings, wealth composition, and portfolio decisions. Agents interact in six markets: capital, consumption, labor, credit, equity and bond markets. Monetary policies can affect inequality through the income heterogeneity channel, the aggregate demand, the cost-push, saving remuneration and the asset price channels. We use the model to assess both the short- and lung-run impact of monetary policies on wealth and income inequality, and we study the different effects when the initial distribution of endowments and the heterogeneity in portfolio composition change.

We consider different measures of income inequality (Gini, Theil index, Atkinson index and the interdecile ratio) to show how monetary policy differently affects inequality depending on the representativeness of each share of the population characterized by each index. Such approach is required since the estimated effects of monetary policy could depend on the representativeness of the inequality measures. For instance, it has been shown that, in the USA, the dynamics of income inequality is mainly driven by the variation in this upper end of the distribution (Atkinson et al., 2011; Harris et al., 2011; Kenworthy and Smeeding, 2014). Then, we adopt the factor decomposition to study which income source mostly contributes to income/wealth inequality, and through which monetary policies affect inequality indicators. This approach is relevant to identify those assets whose distribution mostly explains the change in income inequality due to the implementation of monetary policy. The change in the contribution will depend on both the change in the weight of each income source in GDP and the intra- and inter-group inequality caused by the MP. Moreover, it is consistent and allows to explain some empirical findings showing that income components vary substantially with the level of household income. According to the study of for the Euro-area, households in the lowest income quintile earn only roughly 20 percent of their gross income as employee income, while those in the top quintile earn about 60 percent. Similarly, the share of financial and rental income increases from 2 percent to almost 10 percent. In contrast, the share of transfers and unemployment benefits declines across income quintiles from almost 20 percent to about 3 percent.

Through the model, we provide a theoretical explanation for a number of empirical findings, pointing out that the possibility of having both disequalizing and equalizing effects of monetary policy depends on the different distribution of households along relevant heterogeneous dimensions. In detail, the key dimensions result to be the heterogeneity in income sources and the composition of household wealth. The income source heterogeneity lastly depends on the initial distribution in firms and bank shares. In

line with the outcomes of empirical studies, the results of our model show that the impact of monetary policy is non-linear. In particular, the paper points out four main results: i) The sign and the magnitude depend on the initial inequality in the distribution of endowments across households, the labor share, and the level of unemployment benefits. In particular, the degree of asymmetry in the distribution of bank and firm shares plays a key role in determining the sign of the effect. ii) The magnitude of the impact is not independent of the inequality measure considered. The inter-decile ratio is much more sensitive to monetary policies and their impact is described by a U-shaped function of the initial inequality in the distribution of corporate shares, and a concave function of the initial inequality in the distribution of bank shares. Conversely, the impact on Gini and Generalized Entropy indexes is a convex function of the initial inequality in the distribution of corporate shares, while it is a concave function of the initial inequality in the distribution of bank shares. iii) The short-run effects on wealth inequality due to capital gains/losses (CGL) on long-term bonds are correlated with the degree of heterogeneity in the portfolio preferences of households. In the long-run, such effect vanish. The short-run effect is null in the case of zero heterogeneity; iv) If the monetary shocks have a non-asymmetric impact on portfolio decisions, the monetary policy can have a long-lasting impact on wealth inequality through the CGLs in the stock market. In the presence of symmetric shocks, CGLs in the stock market have no effect, neither in the short nor in the long term; v) The higher the labor share, the higher the impact of monetary policy on inequality.

Finally, our paper strictly relates to the AB literature studying the broad effect of monetary policies. In this regard, most of the papers focus on the transmission channels of monetary policies (Schasfoort et al., 2017; Gatti and Desiderio, 2015; Alexandre et al., 2023), however, few of them cope with the impact of monetary shocks on income inequality. To our knowledge, only Fierro et al. (2023) study how income inequality may constrain central bank operations Anyhow, while the authors study the linkage that goes from inequality to monetary policy, AB models studying the causality that goes from monetary policies to income inequality are still absent. To this extent, this paper represents one of the first attempts at studying the relationship between monetary policies and inequality within this literature.

The rest of the paper is organized as follows. Section 2 discuss the transmission channels and how they are treated by existing theoretical models. Section 3 presents the behavioural equations and the monetary structure of the AB-SFC model. Section 4 analyses the results of the mode within two extreme scenarios of highly unequal and equal societies, and considering different degrees of heterogeneity in portfolio composition. Section 5 analyzes the impact of monetary policies according to different starting conditions on the distribution of firm and bank shares, labor share and the level of unemployment benefits. Section 6 concludes.

2 Transmission channels and theoretical models

The most studied channels through which monetary policy can affect income distribution are: i) savings remuneration channel; ii) asset price channel; iii) cost-push channel; iv) aggregate demand channel.

The saving-remuneration channel stems from differences in the size and composition of household balance sheets. Because of those differences, a change in interest rates will have opposing effects on the economic conditions of net borrowers and net savers and asymmetric effects depending on the distribution of liquidity preferences across households.

The price-asset channel stems from the heterogeneity of household portfolios and the diverse capital gains (or losses) that are produced when the monetary policy stance changes. In this respect, asset price movements induced by expansionary policies are more likely to benefit the wealthy (and, in some cases, the middle class) to the extent that they hold longer-term assets and stocks. Through this channel, the

impact of monetary policies on wealth inequality depends on the composition of households portfolio.

The cost-push channel is related to the cost component of interest rates. It represents a founding cost for firms and directly affects prices and functional income distribution(Panico, 1988; Pivetti, 1991; Barth and Ramey, 2002; Chowdhury et al., 2006). The co-movement of prices and interest rates has also been referred to as the Gibson's paradox (Keynes, 1930), the Cavallo-Patman effect (Taylor, 1983) and the "price puzzle" (Bernanke, 1990; Eichenbaum, 1992; Hanson, 2004; Castelnuovo and Surico, 2010). If non-financial sectors strive to preserve their markup over production costs, any rise in the long-term interest rate translates into a general increase in the level of prices and a reduction in real wages. Namely, a tight monetary policy would lead to a redistribution from workers to bank shares owners (Christiano et al., 1994; Barth and Ramey, 2002; Adolfson et al., 2005; Dedola and Lippi, 2005; Deleidi and Levrero, 2020). Only in the case where all productive sectors of the economy hold prices almost constant by reducing their profit rate in response to rising interest rates, a restrictive monetary policy does not affect real wages, leading to a redistribution between the industrial and banking sectors. Of course, a combination of the mentioned effects can generally take place. Through this channel, the effectiveness of monetary policy depends on the degree of market competition.

Through the aggregate demand channel, MPs affect labor inequality and inter-group inequality having a non-symmetrical impact on labor and capital income. Since the elasticity of employment relative to the business cycle is heterogeneous across individuals and dependent on individual characteristics, Mps can affect income distribution by modifying the level and composition of output. Generally, individuals belonging to the lowest percentiles have the highest elasticity of employment. For instance, empirical researches find that the impact of expansionary MPs in the EU-area on the unemployment rate is negative. As a result of changes in the unemployment rate, the income of lowest quintile rises by more than 3, while those of other quintiles increase by around 0.5[1]. Furthermore, a contraction in aggregate demand reduces the dividends perceived by each households and the income of households losing their jobs, while leaving unaffected the wages perceived by households that keep being employed. As a result, households whose income mostly depends on capital could experience a higher percentage reduction of income compared to households whose income mostly depends on wages and keep being employed. The same cannot be said when comparing the variation in income between profit-earners and workers losing their jobs. The overall effect will also depend on the inequality measure considered. While a reduction in aggregate demand could be beneficial for inequality measures that give higher weight to median, average and top income, the effect on measures that take into account the distribution tails cannot be defined a priori.

In general, monetary policies can affect aggregate demand in the following ways. i) investment channel: higher bank lending rates discourage business investment. This mechanism is operative if, at the macro-level, firms are not able to discard the increase in the interest rate into an increase in prices. In this case, the discounted value of future cash flows is a decreasing function of the interest rate. ii) Consumption channel: changes in interest rates might affect household consumption decisions through a wealth effect, as interest rate hikes affect asset values (Lettau et al., 2002) or depressing credit to consumption and residential investments (Góes and Deleidi, 2022). iii) Value of the multipliers: first, a rise in the interest rate could lead to a persistent change in income distribution, favouring profit earners. If this is the case, the average propensity to consume is reduced, leading to a lower value of the multiplier and long-run output and employment levels. Second, countries with government budget constraints would have to pay higher interest on their outstanding debt, leading to lower capital or

[1]Trivially, individuals are impacted by the overall decrease in the unemployment rate in many varied ways; households in the lowest quintile generally benefit most from it. All other income quintiles' unemployment rates decreased by less than 0.5 percentage points, whereas theirs decreased by more than 2 percentage points.

recurrent expenditures with higher multiplier values. For instance, under the scheme of rules developed initially in the 1992 Maastricht Treaty and reinforced later in the 2012 Fiscal Compact, monetary tightening has severely contracted European countries' fiscal space by increasing public debt interest payments. iv) Banking channel: the increase in the interest rate causes a reduction in firms' net worth, reducing the bankability of firms or by increasing the premium risk required by banks (this reduces both the amount of loan demand that is satisfied and the loan demand). Furthermore, the increase in the interest rate causes a reduction in banks' net worth (typically, the value of deposits does not change while the value of equities or public bonds decreases), leading to potential credit crunches. In this sense, since income sources are heterogeneous across households, contractionary monetary policy can directly affect inequality by reducing the income of workers who have lost their jobs and, indirectly, affecting the bargaining power of unions, Vice versa, an expansionary monetary policy can reduce the unemployment rate, increasing the growth rate of monetary wages. Monetary policy can indirectly affect income distribution only when firms are not able to fully discharge the increase in nominal wages on prices, in this case, markups decline and a redistribution of income between capitalists and workers takes place.

While such channels are addressed in the empirical literature, on the theoretical side, little attention has been reserved to the analysis of transmission channels through which monetary policies can affect income inequality. Besides, the representative agent hypothesis characterizing traditional general equilibrium models does not allow to capture distributional dynamics. In a one-agent economy, personal income distribution does not exist by construction. In these models, the impact of monetary policy is composed of a direct effect which spreads from the change in consumption due to general equilibrium forces and a direct effect which comes from the intertemporal substitution of consumption. Moreover, as argued by Kaplan et al. (2018), in the Representative Agent New Keynesian (RANK) model, monetary policy works almost exclusively through a substitution effect, while income and wealth effects are small. However, the strong response of aggregate consumption to movements in real rates is at odds with the data. Macro-econometric analysis of aggregate time-series data finds a small sensitivity of consumption to changes in the interest rate after controlling for income (Campbell and Mankiw, 1989; Yogo, 2004; Canzoneri et al., 2007). Recently, General equilibrium models and RANK models have been expanded including incomplete markets and agents that are heterogenous both in therms of wealth and income. These models stems from general equilibrium Bewley model with borrowing constraints (Nardi and Fella, 2017; Bewley, 1977) where, at any point in time, there are agents with low endowments while others have high endowments. Agents sign state-contingent contracts that insure endowment risks and allow for consumption smoothing. With these contracts, agents receive payments when their endowments are low and make payments when their endowments are high. If markets were complete, the framework would reduce to one with a representative agent. With incomplete markets, the model leads to heterogeneity. In these models, the results are mainly driven by household precautionary savings in response to self-insure against idiosyncratic earning shocks. As a result, the saving rate decreases when net worth increase and it is negative for the very wealthy people. However, this is in contrast with most of the data showing that the saving rate of rich people is higher than poorer people,

A very recent literature is represented by Heterogeneous Agents New Keynesian (HANK) models (Kaplan et al., 2018) with a simpler alternative known as Two Agents New Keynesian Models (TANK) (Debortoli and Galí, 2017; Bilbiie, 2008; Colgiago, 2011). HANK models incorporate diverse consumer behaviors and a continuum of agents characterized by a distribution of wealth and marginal propensities to consume. TANK models present types of consumers: "Ricardian" and "Keynesian." Ricardian consumers are traditional utility maximizers who use financial markets to smooth consumption, whereas Keynesian consumers spend all of their disposable income each period. In TANK models, a portion of agents have zero net wealth, while the rest evenly share aggregate wealth. So far, much of the HANK lit-

erature has focused on how inequality alters monetary policy transmission. For example, it stresses that aggregate demand responds differently to shocks and policies when households are borrowing-constrained (Kaplan et al., 2018; Auclert, 2019) or engage in precautionary savings in response to idiosyncratic income risk (e.g. Challe et al., 2017; Acharya and Dogra, 2020). The main difference between RANK and HANK lies in the fact that, whereas in the former, the monetary policy works almost eclusively through intertemporal subistitution, in the second the direct effect can be small, while the indirect effect, driven by general equilibrium forces, can be substancial. On the other hand, HANK models feature two assets, a liquid and illiquid asset characterized by differentiated rates of return leading to different wealth and income distribution (Kaplan et al., 2018). Moreover, since Ricardian equivalence doesn't hold in HANK models, the transmission of monetary policy can vary significantly depending on fiscal policy, as it influences income and wealth distribution among different types of consumers. However, while these models have been used to study how wealth inequality can impact the transmission of monetary policies (Acharya and Dogra, 2020), the effect of these on income inequality has still not been studied using HANK models. To our knowledge, an attempt has been provided by Komatsu (2023) who studies the impact of monetary policy on consumption inequality. Following the model proposed by (Debortoli and Galí, 2017), the author develops a TANK model in which a fraction of the households are credit-constrained and consume hand-to-mouth, and search-and-matching frictions are included. He finds that expansionary monetary policy shock decreases consumption inequality between those two households through three channels: (i) the income composition channel, through fluctuations in labor and profit income; (ii) the savings redistribution channel, through fluctuations in real interest rate; and (iii) the earnings heterogeneity channel, through fluctuations in unemployment.

Within the AB and SFC literature, most of the papers study the main transmission channels of monetary policies and their impact of main macroeconomic variables. For instance, Schasfoort et al. (2017) develop an AB macroeconomic model to study the transmission channels of monetary policies. Their model is able to reproduce the interaction of four main transmission channels: bank lending, investment, consumption and cost. Their results show that bank lending is the strongest channel, although the overall effect of monetary policy is weak. Gatti and Desiderio (2015) develop an AB model to study the impact of monetary policy on the business cycle and GDP. They find that monetary policy are non-neutral, while the main transmission mechanism is the credit channel. Alexandre et al. (2023) study how the shock to the policy interest rate affects some key topological measures of a bank–firm credit network, such as density, assortativity, and degree distribution. However, none of them address the relationship between monetary policy and the inequality dimension. To our knowledge, only Fierro et al. (2023) study how income inequality affects monetary policy through the inequality-household debt channel. Their results show that inequality may constrain the central bank, even when it is not explicitly targeted.

3 The model

The macroeconomy is populated by firms operating in the capital sector (K), firms producing consumption goods (C), households (H), Government (G), Central Bank (CB) and a commercial bank (B) interacting in six markets: Consumption market, Capital market, Labor market, and Credit, Equity and Bond markets.

The household sector consists of a multitude of heterogeneous agents. The initial income heterogeneity depends on the initial distribution of different types of endowments, namely bank and firms shares. Given such endowments, the income of agents is made up of wages, dividends from corporate and bank shares, interests on deposits and public bonds, and capital gains from the equity market. Households hold their wealth in the form of deposits, public equities, and public bonds. The initial distribution of

private equity and bank shares defines the starting level of inequality in the society. Financial inequality is endogenous.

C-firms produce the consumption good by means of labor and capital, while capital sector is a vertically integrated sector in which firms produce using labor as only external input. C-firms define the level of production based on the expectations of future demand and the desired level of inventories. They adjust productive capacity to satisfy the expected demand at a target degree of capacity utilization. Investments are realized if the net present value is positive. Once K-firms receive the order, they fix current production depending on the number of periods needed to produce a single capital good. The price of the goods is set according to the normal historical cost of production, and the markup is applied over normal - unitary costs. Markups evolve according to the attractiveness of goods and target market shares.

The number of firms is fixed, while their size varies endogenously depending on the evolution of aggregate demand and its distribution across firms. In each sector, firms start with the same technical conditions (capital-to-output ratio, labor productivity and target degree of capacity utilization). Depending on the leverage target, firms finance production decisions through a mix of self-financing, loans and issuing equities. Firms with negative net wealth that are unable to repay debts go bankrupt. In order to maintain the number of firms fixed, the bankrupt firm is replaced by a new firm with a lower expected quantity to be produced. The interest rate on loan includes a premium risk which depends on the financial exposure of each single firm. There is one commercial bank that provides credit to firms and collects household deposits. The interest rate on deposits and loans depends on the rate set by the monetary authority. Government issues public bonds to finance the deficit. The share of public bonds not acquired by households is held by CB which acts as a lender of last resort. The Government's direct public spending is distributed among C firms proportionally to their productive capacity. Public spending and investments financed by debt creation represents the injection of purchasing power into the system. The first one is partially exogenous[2], the second one is fully endogenous. Below are the behavioral and accounting equations of the agents in the various sectors.

3.1 Consumer Sector

C-firms employ labor and capital as inputs and fix current production ($y^d_{t,i}$) based on expected demand ($q^e_{t,i}$). In addition, firms consider a store of inventories to address the discrepancies between expected demand and realized one. The expected demand ($q^e_{t,i}$) and the desired production ($y^d_{t,i}$) are defined as follows:

$$q^e_{t,i} = q^e_{t-1,i} + \beta_i(q^r_{t-1,i} - q^e_{t-1,i}) \tag{1}$$

$$y^d_{t,i} = \max\left\{0,\ q^e_{t,i}\left(1+\sigma^T\right) - inv_{t-1,i}\right\} \tag{2}$$

Where β is the expectation parameter, $q^r_{t-1,i}$ is the amount of realized sales in the previous period, σ^T is the desired ratio of inventory on sales and $inv_{t-1,i}$ is the amount of inventories from the previous period. The degree of capacity utilization in correspondence of the planned production is:

$$\omega^e_{t,i} = \min\left\{1, \frac{y^d_{t,i} v^*_{t,i}}{k_{t,i}}\right\}, \tag{3}$$

[2]Primary public spending is exogenous, while debt service and unemployment benefits are endogenous.

where $v^*_{t,i}$ is the capital-to-output ratio at the full utilization of the productive capacity. Given the amount of capital needed to produce $y^d_{t,i}$ and the capital-to-labor ratio ($\alpha_{c_{t,i}}$), firms determine the labor demand:

$$L^d_{t,i} = \frac{y^d_{t,i} l_{t,i}}{h^m}, \tag{4}$$

where h^m is the maximum amount of working hours that each worker can afford in a period and $l_{t,i} = \frac{v^*_{t,i}}{\alpha_{t,i}}$ and correspond to the number of required working hours per unit of output.

The production function is characterized by fixed coefficients of production (Leontief technology). The feasible production is:

$$y_{t,i} = \min\left(\frac{L_{t,i} h^m}{l_{t,i}}; \frac{k_{t,i}}{v^*_{t,i}}\right) \tag{5}$$

C-firms adjust productive capacity in order to satisfy expected demand at the normal (desired) degree of capacity utilization (in the period in which the capital will be available, that is in $t + dk$):

$$I_{t,i} = \max\left\{0; q^e_{t+dk,i}(1+\sigma^T) v^n_{t,i} - k_{t+dk,i}\right\} \tag{6}$$

where $v^n_{t,i}$ is the normal capital-to-output ratio, $k_{t+dk,i}$ is the residual stock of capital in the period in which the ordered capital good would be installed if the investments were not made and dk is the number of periods needed to produce one unit of the capital good. Firms carry out the investments if the net present value (NPV) is higher than zero.

$$NPV\left(I_{t,i}\right)_e = \sum_{j=1}^{t+dk+z} \frac{\mathbb{E}_t\left[P_{f,j}\right] \Delta q_{f,j} - WB_j - OF_j}{(1+r)^j} - p_k I_{t,i} \tag{7}$$

where:

$$\Delta q_{f,j} = \frac{I_{t,i}}{v^n_{t,i}} a \tag{8}$$

where $\mathbb{E}_t\left[P_{f,j}\right]$ is the expected price, $\Delta q_{f,j}$ is the additional amount of production in each period given by the capital investment, r is the interest rate and OF_j are the financial charges.

3.2 Capital sector

Given the orders received and the number of periods required to produce the capital good (dk), the quantity that K-firm wishes to produce and labor demand are:

$$y^d_{t,i} = \sum_{j=t-dk}^{t} \frac{orders_{j,i}}{dk} \tag{9}$$

$$L^d_{t,i} = \frac{y^d_{t,i} l_k}{h^m} \tag{10}$$

where the sum corresponds to the number of capital goods ordered to firms i, from previous dk periods to period t.

3.3 Price Setting

Firms apply a markup over the unit cost of production. This is computed according to the historical normal-cost pricing (Andrews, 1949; Andrews and Brunner, 1975). The unit cost is defined in corre-

spondence with the normal degree of capacity utilization, amortization is computed by adopting the effective cost methodology[3] and takes into account that the capital stock is made up of different vintage capital goods. The unit cost of the capital good is:

$$c_{t,i} = w_{t,i} l_{t,i} \tag{11}$$

The unit cost of the consumer good is:

$$c_{t,i} = w_{t,i} l_{t,i} + \frac{\frac{1}{a\ z} \sum_{j=t-z+1}^{t} p_{k_j} K_j^{ins} \left(1 + r_j bl_j\right) (j + z - t)}{\frac{1}{v_{t,i}^n} \sum_{j=t-z+1}^{t} K_j^{ins} \left(\frac{j+z-t}{z}\right)} \tag{12}$$

Where $w_{t,i}$ is the nominal wage, $l_{t,i}$ is the direct amount of labor, p_{k_j} is the price of the capital acquired in period j, a is the multiplicative factor to compute total debt service and amortization, z is the useful life of the capital good and the payback time of loans, r_j is the interest rate on the loans granted in period j, l_j is the leverage of the loan granted in period j.

Firms apply a markup over unit-cost of production. C-firms increase their markup ($\varphi_{t,i}^{uc}$) if two conditions are fulfilled: (1) the market share has been higher for $\rho^{\lim,inc}$ consecutive periods than the target level (s^T); (2) the weighted average of the degree of capacity utilization has been above the normal one during these periods (see Caiani et al., 2016). Firms reduce markup in case the market share has been lower than the target for $\rho^{\lim,dec}$ consecutive periods and the weighted average of the degree of capacity utilization has been lower than the normal one. In all other cases, C-firms keep markups constant. These conditions are formalized as follows:

$$\phi_{t,i}^{uc} = \begin{cases} \phi_{t-1,i}^{uc}(1 - FN) & \text{if } (\bar{u}_{t-1,\ldots,t-s}^{r} < u_n \wedge \rho_{t-1,i}^{r,dec} > \rho^{lim,dec}) \\ \phi_{t-1,i}^{uc}(1 + FN) & \text{if } (\bar{u}_{t-1,\ldots,t-s}^{r} > u_n \wedge \rho_{t-1,i}^{r,inc} > \rho^{lim,inc}) \\ \phi_{t-1,i}^{uc} & \text{otherwise} \end{cases} \tag{13}$$

where FN is drawn from a Folded Normal Distribution with parameters (μ_{FN}, σ_{FN}^2); $\rho_{t-1,i}^{r,dec}$ is the number of consecutive periods during which the market share has been lower than target; $\rho_{t-1,i}^{r,inc}$ is the number of consecutive periods during which the market share has been higher than target; $\bar{u}_{t-1,\ldots,t-s}^{r}$ is an exponentially decaying weighted average of the realized degree of capacity utilization.

3.4 Equity, loan demand and debt service

Firms have a leverage target to attain over time. They can finance investments using retained profits, loans or issuing equities. A proportion (σ) of firms investments is financed issuing equities. The supply of equity is:

$$e_{t,i}^{S} = e_{t-1,i} + \frac{I_{t,i}\sigma}{pe_{t,i}} \tag{14}$$

In case C-firms have enough liquidity (deposits, equity and retained profits), they finance investments with the desired leverage, otherwise, they increase this proportion. If liquidity is scarce, priority is given to the payment of wages. Loan demand is defined as follows:

$$L_{t,i}^{d,long} = I_{t,i} l_k^T \tag{15}$$

$$L_{t,i}^{d,short} = WB_{t,i} l_w^T \tag{16}$$

[3]The amortization includes the borrowing costs.

where $L_{t,i}^{d,long}$ is the long-term loan to finance the purchase of the capital good, l_k^T is the leverage target to finance investments, l_w^T is the leverage target to finance the wage bill. In case the amount of collected equities and planned retained profits are not enough, loans act as buffer to finance investments (the realized leverage can be higher than the target). In each period, firms have to payback a share of the debt stock. Total debt service includes debt instalments of short- and long-term loans, rollover loans and financial charges:

$$\begin{aligned} \mathrm{SD_{tot}}t,i = \frac{1}{az}\sum_{j=t-z}^{t-1} l_{i,j}K_{i,j}^{d}(1+b^{long}r_j)(j+z-t) \\ +\frac{1}{z^{short}}\sum_{j=t-z^{short}}^{t-1} l_j WB_{(j,i)}(1+a^{short}r_j)(j+z^{short}-t) \\ +\frac{1}{z^{ponzi}}\sum_{j=t-z^{ponzi}-1}^{t-2} L_{(j,i)}^{ponzi}(1+a^{ponzi}r_j)(j+z^{ponzi}-t) \end{aligned} \tag{17}$$

Financial charges are computed on the outstanding stock of debt and debt installments are decreasing over time. This is consistent with the evolution of amortization.

At the end of the period, firm cash is:

$$\begin{aligned} \mathrm{Cash}_{t,i} = \mathrm{Cash}_{t-1,i} + \mathrm{revenues}_{t,i} + e_{t-1,i}p_{(e_{t-1})} \\ +L_{t,i}^{d,short} + L_{t,i}^{d,long} + L_{t-1,i}^{ponzi} - \mathrm{WB}_{(t,i)} \\ -\sum p_{indexk,t}k_{i,t}^{D} - \mathrm{SD_{tot}}t,i \end{aligned} \tag{18}$$

where $CashF_{t,i}$ is the cash available to the firm, , $L_{j,i}^{ponzi}$ is the loan granted to payback the outstanding debt, $\sum p_{indexk,t}k_{i,t}^{D}$ is the expenditure to acquire the capital good and $SD_{\mathrm{tot}}t,i$ is the total debt service including financial charges.

If cash is negative, firms can ask for an additional loan to pay the outstanding debt. This possibility is granted by the bank for a maximum number of periods lim^{ponzi} within the same window of the debt repayment. If the net wealth is positive or the number of periods of (over) indebtedness is less than lim^{ponzi} the firm is granted a further loan; otherwise, it goes bankrupt. The net wealth of firms is:

$$NW_{t,i} = am_{t,i}^{residual} + cashF_{t,i} - L_{t,i} + inv_{t,i}uc_{t,i}^{h} \tag{19}$$

where $am_{t,i}^{residual}$ is the residual value of the capital stock and $inv_{t,i}uc_{t,i}^{h}$ is the value of inventories.

3.5 Households

The household sector is composed of a multitude of agents which receive income from labor, dividends and interests on public bonds and deposits. The initial distribution of wealth is defined by the distribution of firms and bank shares. The power law describing the distribution of firms' and bank shares across the population is the following:

$$y = ax^{k} \tag{20}$$

where k describes the degree of inequality and $a = \frac{1}{\sum_1^n x^k}$.[4] Financial wealth is held in form of public bonds, stocks and deposits. Initial financial wealth is equal to zero.

The disposable income in each is period is:

[4] $\sum_1^n y = 1$, that is the sum of the shares held by each household has to be equal to one.

$$YD_{t,i} = \left(w_{t,i} + M_{t-1,i} r_t^m + \sum_{j=t-T^b}^{t-1} B_{j,i}^h r_{b_j} + s_i^h \sum_{j=1}^{NF} \mathrm{div}_j^h + s_i^b \sum_{j=1}^{NB} \mathrm{div}_j + s_i^e \sum_{j=1}^{NF} \mathrm{div}_j^e \right) (1 - \tau_i) \quad (21)$$

where $w_{t,i}$ is the nominal wage, $M_{t-1.i}$ is the stock of deposits, $\sum_{j=t-T^b}^{t-1} B_{j,i}^h r_{b_j}$ is the amount of interests accrued on the stock of public bonds held by the household, s_i^h is the share of private equity held by household i and $\sum_{j=1}^{NF} \mathrm{div}_j^h$ is the total amount of dividends generated by private equities, s_i^b is the percentage of bank shares held by household i and $\sum_{j=1}^{NB} \mathrm{div}_j^b$ is the total amount of dividends distributed by banks, s_i^e is the share of public equity held by household i and $\sum_{j=1}^{NF} \mathrm{div}_j^e$ is the total amount of dividends generated by public equities.

Consumption demand is a function of disposable income and wealth:

$$C_{t,i} = YD_{t-1,i} c_{1,i} + V_{t-1,i} c_{2,i} \quad (22)$$

where $c_{i,1}$ is the propensity to consume out-of-income and $c_{i,2}$[5] is the propensity to consume out-of-wealth.

Unemployed workers get an unemployment benefit:

$$w_{t,i} = \begin{cases} w_{t,i} h_{t,i}^{\mathrm{work}} & \text{if employed} \\ w_{\mathrm{gov}} & \text{otherwise} \end{cases} \quad (23)$$

where, w_{gov} is the unemployment benefit and τ^{work} is the tax rate on workers income. The stock of wealth is made up of deposits, public bonds and firms equity:

$$V_{t,i} = M_{t,i} + B_{t,i}^h + E_{t,i}^h = V_{t-1,i} + YD_{t-1,i} - C_{t,i} \quad (24)$$

3.6 Portfolio decisions

Portfolio equations are based on Tobinesque principles. The portion of wealth held in the form of each financial asset is defined by an autonomous component, the rate of return on that asset (positive effect), the rates of return on other assets (negative effect), and the disposable income to net wealth ratio (negative effect, except for cash). The latter is a proxy of the liquidity preference of investors.

The demand for public bonds, equities and deposits is:

$$B_{t,i}^h = \lambda_{10_i} V_{t,i} + \lambda_{11_i} V_{t,i} r_t^b + \lambda_{12_i} YD_{t,i} + \lambda_{13_i} V_{t,i} re_t \quad (25)$$

$$E_{t,i}^d = \lambda_{20_i} V_{t,i} + \lambda_{21_i} V_{t,i} r_t^b + \lambda_{22_i} YD_{t,i} + \lambda_{23_i} V_{t,i} re_t \quad (26)$$

$$M_{t,i}^d = \lambda_{30_i} V_{t,i} + \lambda_{31_i} V_{t,i} r_t^b + \lambda_{32_i} YD_{t,i} + \lambda_{33_i} V_{t,i} re_t \quad (27)$$

where λ_{j0_i} is the autonomous share of asset j to total wealth held by household i, whereas λ_{j1_i}, $\lambda_{j2_i}, \lambda_{j3_i}$ link the share of asset j to total wealth with the rate of return on public bonds, deposits, and equities, respectively. [6] The value of each λ_{k,f_i} is a negative function of the initial household endowments in

[5] We perform simulations with both heterogeneous and homogeneous propensities to consume across the population.

[6] Notice that λs are defined in such a way that:

terms of corporate (s_i^h) and bank shares(s_i^b). Depending on the degree of heterogeneity in the portfolio decisions, expressed by μ, it is defined in proportion to the of the wealthier household:

$$\lambda_{k,f_i} = \lambda_{k,f}\left(1 + \mu\frac{s_i^h + s_i^b}{\max(s_i^h + s_i^b)}\right) \tag{28}$$

The λ_{k,f_i} parameters obey the standard constraints for asset demand functions. Formally:

$$\lambda_{00_i} + \lambda_{10_i} + \lambda_{20_i} = 1 \tag{29}$$

$$\lambda_{01_i} + \lambda_{11_i} + \lambda_{21_i} = 0 \tag{30}$$

$$\lambda_{02_i} + \lambda_{12_i} + \lambda_{22_i} = 0 \tag{31}$$

$$\lambda_{03_i} + \lambda_{13_i} + \lambda_{23_i} = 0 \tag{32}$$

$$\lambda_{04_i} + \lambda_{14_i} + \lambda_{24_i} = 0 \tag{33}$$

And the symmetry constraint is:

$$\lambda_{01_i} = \lambda_{23_i};\ \lambda_{02_i} = \lambda_{13_i};\ \lambda_{11_i} = \lambda_{22_i} \tag{34}$$

3.7 Equity market

The equity market is centralized. Price clears demand and supply. The demand of equity results from the aggregation of each household demand. The supply of equity results from the aggregation of the shares of investments that firms plan to finance issuing equities. Therefore, there is one homogeneous price for all the equities of firms belonging to the same sector. The clearing price is:

$$p_{e_t} = \frac{\sum_{i=1}^{N} E_{t,i}^d - \sum_{i=1}^{n_f} I_{t,i}\sigma}{\sum_{i=1}^{n_f} e_{t-1,i}} \tag{35}$$

The amount of equities is:

$$\sum_{i=1}^{n_f} e_{t,i} = \sum_{i=1}^{n_f} e_{t-1,i} + \frac{\sum_{i=1}^{n_f} E_{t.i}^s}{pe_t} \tag{36}$$

The total amount of money collected by firms by issuing equities is:

$$E_t = pe_t\left(\sum_{i=1}^{n_f} e_{t,i} - \sum_{i=1}^{n_f} e_{t-1,i}\right) \tag{37}$$

This is distributed to each firm according to its share in the equity supply.

3.8 Supplier selection

Households and firms choose the supplier with the lowest price. In model initialization, C-firms and households are matched randomly with suppliers. In each period, buyers visit a subsample of potential

a) $\lambda_{j1} = -(\lambda_{j2} + \cdots + \lambda_{j3})$ for $j = 1, 2$ (horizontal constraints on coefficients of rates of return for the j-th financial asset);

b) $\lambda_{1k} + \lambda_{2k} = 0$ for $k = 1, 2, 3$ (vertical constraints for cross-asset coefficients of rates of return); and

c) $\lambda_{10} + \lambda_{20} < 1$ (vertical constraints for autonomous shares of assets to total wealth). The latter is lower than unity because households can also opt for deposits.

suppliers and select the cheapest one. The probability that the firm would change its supplier depends on the price differential between the previous supplier and the cheapest supplier in period t:

$$Pr_{t,i} = \begin{cases} 1 - e^{\frac{\epsilon\left(p_{t,\text{indexC}} - p_{t,\text{indexC}_{t-1}}\right)}{p_{t,\text{indexC}}}} & \text{if } p_{t,\text{indexC}} < p_{t,\text{indexC}_{t-1}} \\ 0 & \text{otherwise} \end{cases} \tag{38}$$

where ϵ express the degree of customer loyalty, $p_{t,indexC}$ is the price of the firm selected at time t and $p_{t,indexC_{t-1}}$ is the price offered by the supplier of the previous period. The larger value of parameter ϵ increases the probability that a firm would change its supplier. The same matching mechanism applies to all markets.

3.9 Labour market

We model a simple labor market with aggregate bargaining and homogeneous wages. Labor skills are homogeneous across firms and workers and constant over time.

The growth rate of nominal wage depends on the level of the unemployment rate and the difference between the real wage target (w^T) and the actual real wage (w^r):

$$g_t^w = \begin{cases} \frac{(w^T - w_{t-1}^r)}{w_{t-1}^r} + \mu E_t & \text{if } w_t^T > w_{t-1}^r \\ \mu E_t & \text{altrimenti} \end{cases} \tag{39}$$

In each period, depending on labor demand, firms can fire or hire workers. In the labor market matching, firms randomly pick up an unemployed worker and hire him. Firms reiterate this operation until they have satisfied their labor demand.

There are no frictions in the labor market, that is each firm can fire or hire workers whenever it needs.

3.10 Government

The public sector has a direct and exogenous component of expenditure consisting of consumer goods demand and an endogenous component linked to unemployment benefits and debt service. Direct public expenditure is constant, while unemployment benefits and debt service result to be countercyclical:

$$\bar{G}_t = \bar{G}_{t-1}(1+\pi)(1+g_G) \tag{40}$$

$$G_t = \bar{G} + U_t w_{G_t} \tag{41}$$

where $\bar{G}_t$ is direct public expenditure (demand for consumption goods), g_G is the real growth rate of direct public expenditure, π is the inflation rate and U_t is the number of unemployed. The unemployment benefit (w_{G_t}) is a percentage of the expected average wage paid by the private sector. Government accounting is:

$$S_t = G_t - \sum_{i=1}^{N} y_i \tau_i + \sum_{i=t-T^b}^{t-1} B_i^s r_{b_i} - F_t^{cb} \tag{42}$$

where F_t^{cb} are distributed profits by CB, τ_i is the tax rate, B_i^s is the nominal value of bonds issued in period i, T^b is the maturity of bonds. The supply of public bonds is:

$$B_t^s = b_{t-T^b} + S_g \tag{43}$$

The price of public bonds depends on the expected returns:

$$p_t^b = \sum_{i=1}^{T} \frac{1}{(1+r)^i} \tag{44}$$

The stock of public debt is:

$$SB_t = \sum_{i=t-T^b+1}^{t} B_i^s \tag{45}$$

3.11 Commercial bank

The banking sector consists of one single commercial bank. It supplies credit to firms, collects household deposits and buys public bonds. The asset of the bank consists of loans, public bonds and reserves. Banks are obliged to hold minimum reserves against deposits:

$$H_t = \gamma M_t \tag{46}$$

where H_t is the reserve stock and γ is the capital requirement. The bank liabilities consist of deposits and CB advances. If deposits are higher than loans and reserves, the CB use the difference to buy public bonds. Otherwise, the commercial bank asks for advances to the CB.

$$\begin{cases} B_t^b = M_t - L_t - H_t & \text{if: } H_t + L_t < M_t \\ A_t^b = L_t + H_t - M_t & \text{otherwise} \end{cases} \tag{47}$$

In case the demand of public bonds is higher than the supply, the bank held the remaining share as extra-reserves[7]. If the Net Worth of the bank is negative it cannot supply loans to firms and a credit crunch takes please. The bank applies a markup on the rate set by the central bank to fix the normal interest rate on loans and deposits.

$$r_t^l = r_t^{CB} + \chi_l + r_{t,i}^P \tag{48}$$

$$r_t^m = r_t^{CB} + \chi_m \tag{49}$$

Where r_t^{CB} is the policy rate, $\chi_l > \chi_m$ and $r_{t,i}^P$ is the premium risk that the bank applies over the normal rate depending on each specific financial position of firms:

$$r_{t,i}^P = r_t^{CB} \left(\frac{NW_{t,i}}{L_{t,i}^d} \right)^v \tag{50}$$

Finally, the bank grant a loan to the firm only if the net worth is higher then zero. The profits of commercial bank are as follows:

$$F_t^b = \sum_{i=1}^{n} \sum_{j=-z}^{t} \left(L_{j,i} r_j + H_t r_h + \sum_{i=t-T^b}^{t-1} B_i^b r_{b_i} - D_t r_t^m - A_t r_t^a \right) \tag{51}$$

[7]In the selling of public bond market, the priority is given in the following order: households, commercial bank and CB.

3.12 Central Bank

The Central Bank acts as the lender of last resort in the public bonds market:

$$B_t^{CB} = B_t^s - \sum_{j=1}^{n} B_{t,j}^h - B_t^b \tag{52}$$

where $\sum_i^n B_{t,i}^h$ is the mominal amount of bonds purchased by households and B_t^b is the nominal amount of bond purchased by the commercial bank. Indirectly, the amount of public bonds held by CB is a function of the reserve ratio. Central bank profits depend on the interests earned on public bonds, advances and interests paid on reserves:

$$F_t^{cb} = \sum_{i=t-T^b}^{t-1} B_i^{CB} r_{b_i} r_{t-1}^b - H_{t-1}^{cb} r_{t-1}^h + A_{t-1} r_{t-1}^a. \tag{53}$$

See Appendix A for all the equations regarding the stock-flow consistency, bankruptcy, accounting and sequence of events.

4 The contribution to inequality: the decomposition by income factor

We now explore the determinants of income inequality using the income factor decomposition (cit.). This approach is relevant to study the channels through which monetary policy affects income inequality. The initial distribution of wealth is defined by the distribution of firms and bank shares across households. These are described by power-law functions and the value of the power (k) defines the initial level of inequality[8]. The initial distribution of firms and bank shares, together with the markup, the interest rate, endogenously determine the distribution of income, which, in in turn affect the distribution of financial wealth. The latter is endogenously determined by the saving rate and portfolio preferences of households. In the first period, all financial stocks are zero. While the markup, the interest rate, and the distribution of saving rates determine the values of income shares (labor share, non-financial profit share, bank profit share and financial share), the distribution of corporate and bank shares determines the income belonging to each income factor across the population.

Keeping the interest rate, the markup and saving rate constant[9], we perform model simulations to show how income distribution and the contribution of each income source change as the initial inequality in the distribution of firm and bank shares increases.

Figure 1 reports the different income distributions generated by the model in the stationary-state as the inequality in the initial distribution of firms and bank shares increases (the lowest value is at the top, the highest at the bottom of the plot). The two k-powers move together, hence, the two distributions are symmetric.

[8]When k is equal to zero, assets are equally distributed across households. The initial inequality rises as the k-power increases.

[9]We are assuming homogeneous saving rate across the population. Namely, the saving rate is not a function of the income level

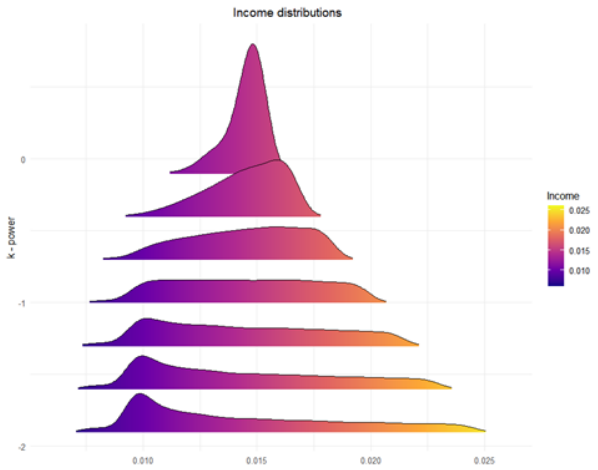


Figure 1: Income distributions for different values of k-power

Figure 2 (a) displays the log values of different inequality measures of the distributions displayed in Figure 1. We adopt four measures of inequality: Gini coefficient, inter-decile ratio, Theil-H and Athkinson indexes. Figure 2 (b) reports the decomposition of total inequality by income factors (wage[10], firm dividends, bank dividends and financial rents). We adopt the decomposition factor of the Generalized Entropy index, the formulation for each income factor is the following:

$$s_k(I) = \frac{cov\left(X^k, X\right)}{\sigma^2(X)} \tag{54}$$

where X^k is the distribution of income by factor k and X is the general distribution of income. As demonstrated in Shorrocks (1982), such ratio gives us a unique decomposition rule for any inequality measure. Moreover, it gives the relative importance of different income components, independent of the choice of inequality measure., Table 1 reports also the values of Theil-L ($c = 0$) and Theil-H ($c = 1$) index decompositions. The formulations of the contribution of each income factor are, respectively:

$$s_k\left(I_0\right) = \frac{\sum_{i=1}^{N} \frac{x_i^k}{x_i} log\left(\frac{\mu}{x_i}\right)}{\sum_{i=1}^{N} log\left(\frac{\mu}{x_i}\right)} \tag{55}$$

$$s_k\left(I_1\right) = \frac{\sum_{i=1}^{N} x_i^k log\left(\frac{x_i}{\mu}\right)}{\sum_{i=1}^{N} x_i log\left(\frac{x_i}{\mu}\right)} \tag{56}$$

Measures expressed in eq. (54) and (56) respect the additive decomposability principle, but are non-unique and peculiar of the inequality measure considered.

[10]Wages also include unemployment benefits.

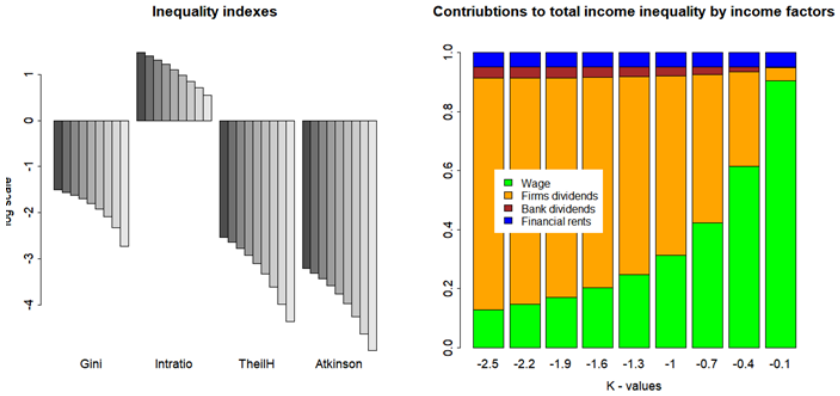


Figure 2: Log-values of the inequality indexes (a) and inequality decomposition by income source (b) *Note: The value of each index is reported as the k-power decreases moving from the right side to the left side.*

As initial inequality in the distribution of corporate and bank shares increases, personal income inequality rises. The factor decomposition shows that the distribution of firms shares is the main driver of income inequality. Indeed, the industrial profit share presents the highest value in the ratio between the GDP share and intra-group inequality[11]. Although wage income represents a relevant share of the cake, it shows a lower level of intra-group inequality. Therefore, its contribution to total inequality is far lower. Conversely, concerning the contribution of the banking sector to total income inequality, although it presents the highest intragroup inequality, its contribution to total inequality is lower because the profit share of the banking sector is relatively low compared to the industrial profits share. Finally, the distribution of financial rent is endogenously determined by income inequality, which originates from other sources of income. As a result, the inequality in the distribution of financial wealth and income is mostly explained by the distribution of firms shares and markup (which determine the labor share).

These properties are easily detectable by looking at the factor decomposition: the contribution of the wage income increases as the inequality in the distribution of firms and bank shares decreases (see Table 3 in the Appendix). For values of k-power close to zero, wage inequality, although low, begins to represent the ultimate source of inequality in the economy. It is worth noticing that any factor decomposition requires that we examine each income component separately and neglect the feedback effects on other income sources (Shorrocks, 1982). In this sense, the real contribution of firms shares to total inequality is higher since it indirectly determines also inequality in financial rents.

For high levels of initial inequality in the distribution of corporate and bank shares, personal income distribution is strongly correlated to the functional distribution, and the share of income from corporate dividends accounts for the largest contribution to total inequality. In such a case, the interest rate and markup, modifying the functional distribution of income, are the main determinants of inequality. As equality in the initial asset allocation increases (shifting left to right in the plot), the relationship between functional and personal income distribution is broken, and wages become the factor with the greatest contribution to inequality.

5 Short- and long-term effects of the monetary policy

In this section, we investigate the short- and long-run impacts of monetary policies and the transmission channels through which they impact income and wealth inequality considering two opposite and extreme

[11]The intra-group inequality is the inequality within each source of income.

scenarios: "business as usual" (BAU) and "Thatcher dream" (TD)[12]. In the first scenario, firms and bank shares are concentrated within a small subgroup of households ($k_f = k_b = 2$), in the second, they are equally distributed across the population ($k_f = k_b = 0.5$). The distribution of bank and firm shares is symmetric. The cases on non-symmetric distributions of firms and bank shares will be analyzed in Section 5 where all possible combinations of starting distributions are studied. [13]In the first part, we analyze the transmission mechanisms and the overall effect on income inequality. In the second part, we discuss the effects on wealth inequality generated by the capital gains/loses (CGL) channel. The analysis of such scenarios is useful to understand the role of heterogeneity in income sources in influencing the impact of monetary policies. The heterogeneity in income sources is at its highest level in the BAU scenario and, in particular, when the distributions of corporate and bank shares are asymmetric. In the TD scenario, on the other hand, heterogeneity is minimal and, in the first instance, is related exclusively to inequality in labor income. Then, such initial source of heterogeneity also led to a second source of income heterogeneity, through the saving remuneration channel.

In the model, monetary policies can affect income inequality through the cost-push channel, the saving remuneration channel, the price asset channel and the aggregate demand channel. While the cost-push and aggregate demand channels are related to the heterogeneity in income sources across the population, the price-asset channel depends on the heterogeneity in the composition of household portfolios (or portfolio preferences). The saving remuneration channel depends on both.

Figure 3 and 5 report the effect of monetary policy tightening on Gini coefficients and macroeconomic variables (income and wealth inequality) for different degrees of heterogeneity in the composition of household portfolios in the BAU and TD scenarios, respectively. Figure 4 reports the changes in income factor contribution. The heterogeneity in portfolio preferences is related to the share of public bonds and stocks in total wealth. This share is positively correlated with the income (and wealth) level; as income increases, the proportion of wealth held in the form of bonds and stocks increases and the share of deposits decreases. The impact on interdecile ratios are reported in Appendix C.

In the BAU scenario, the monetary policy thickening worsen income and wealth inequality (see Figure 3). The short- and -long run impact on income inequality is independent of the degree of heterogeneity in portfolio preferences. Conversely, portfolio heterogeneity plays a role in the short-run impact of MP on wealth inequality. The resultant effect is due to both a change in the weight of each income source in GDP and in the intra-group inequality. The first effect passes through the cost-push channel and aggregate demand channel, the second passes through the aggregate demand and financial remuneration channels [14]. The impact on wealth inequality is directly linked to the channels determining income inequality plus the price assets channel.

Since the interest rate represents a financing cost for firms, the monetary policy directly affects distribution by modifying income shares. If markups are constant, the industrial profit rate is not affected and the increase in the interest rate is fully discharged into an increase in prices. As a result, the real wage and wage share drop while the banking and financial share grows[15]. In the BAU scenario,

[12]In what follows, we will refer to short-run as a transition phase, and with long-run as the permanent policy effect.

[13]We are not considering the case in which the relative inequality in the initial distribution of firms and bank shares is positive or negative. To this extent, in this section, the case in which the contractionary monetary policy can have an equalizing effect is not included

[14]Note that, since markup are constant, we are not considering the effect of the unemployment rate on the functional income distribution.

[15]The positive effect of the interest rate on prices can be considered as generally valid only in a closed economy. When considering an open economy, the increase in the interest rate, by positively affecting the exchange rate, can decrease the domestic price level by lowering the price of imported goods. The resulting effect depend on the input-output structure of the economy.

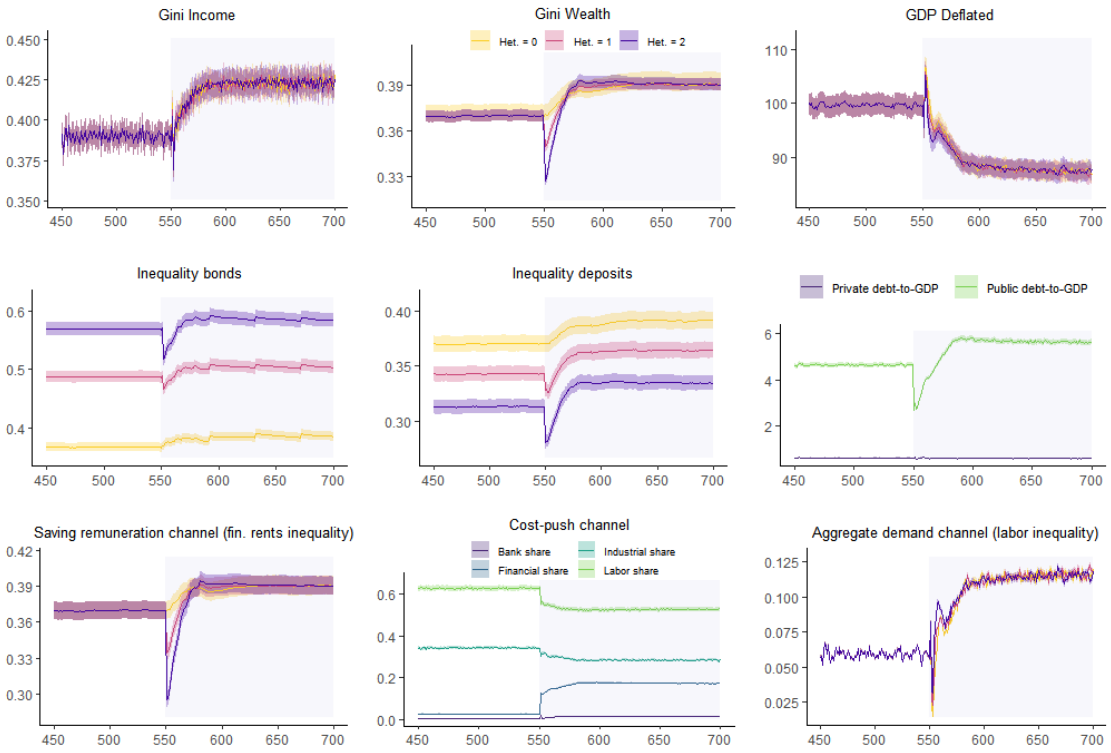


Figure 3: The impact of restrictive monetary policy (BAU scenario)

because firms and bank dividends are concentrated across a small subgroups of households, the dynamic of personal income inequality is strictly linked to the labor share, and they are negatively correlated. Parallelly, the monetary policy affects income inequality by modifying unemployment, total profits and the financial rents. The saving remuneration channel affects intragroup inequality by increasing inequality in financial yields and favouring wealthier households.

The aggregate demand channel modifies both intra- and inter-group inequality. Through this channel, restrictive MPs negatively affect intra-group inequality by increasing the unemployment rate, and the labor income inequality. On the other hand, it modifies inter-group inequality by lowering the income differential between households whose income mostly depends on corporate profits and labor, in favour of the latter[16] . The aggregate demand effect is due to a decrease in public spending multipliers and a negative wealth effect. In economies with constrained public spending, the rise in debt service, causes a decrease in primary spending in favour of the latter, leading to a reduction in public spending multipliers. The negative wealth effect is due to both the increase in the price level and in the capital losses registered by bonds and equity owners[17]. The wealth effect has a short-run impact on consumption and GDP[18]. Through the aggregate demand channel, labor income inequality rises and the differential between households whose income mostly depends on firms' profits and households whose

[16]For example, if we assume an unemployment benefit equal to the market wage, an increase in the interest rate, via the aggregate demand channel, would have an equalising effect. Indeed, it would reduce the income of profit-earners, leaving the income of labour-earners unchanged.

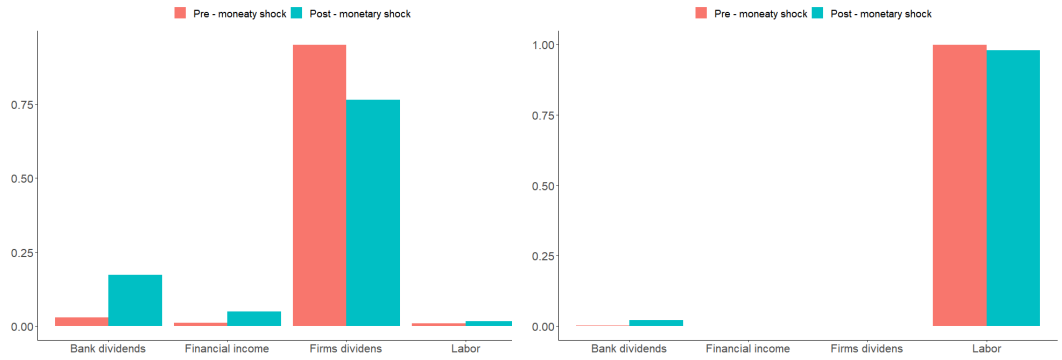
[17]The negative wealth effect caused by a reduction in bond values depends on the presence of market price illusion. If households compute their stock of wealth considering the value at maturity of securities, such effect is absent. Conversely, if they consider the market price, a negative wealth effect on consumption emerge. However, once the rollover is exhausted, such effect disappear.

[18]Once, through the endogenous money process, the wealth stock adjusts to the new price level, the negative effect vanishes.

income mostly depends on labor decreases. Indeed, a drop in aggregate demand generates a reduction in shareholders' dividends, leaving the income of workers who do not lose their jobs unchanged. The overall effect depends on the initial distribution of firms and bank shares. In more equal societies, the impact of the aggregate demand channel overlaps with the effect on the employment rate and contractionary monetary policies, through such a channel, have an unequalizing effect. In an unequal society, the effect is ambiguous: on the one hand, the reduction of households' income that are mostly dependent on corporate profits could be higher than that experienced by households located in the middle of the distribution whose incomes depend mostly on wages. On the other hand, the percentage income reduction of workers who lose their jobs can be higher than that of profit earners, exacerbating the differentials between the tails of the distribution. For these reasons, through the aggregate demand channel, the restrictive MP can have an equalizing effect when considering the Gini coefficient and an unequalizing effect when considering the interdecile ratio.

If the structure of bank and firms ownership is not affected, the inequality related to firms and banks dividends do not change, while, through the saving remuneration channel, financial inequality grows.

Notably, the heterogeneity in portfolio composition only has a "beneficial" short-run effect on financial rent inequality, in the long-run the impact of the saving remuneration channel is independent of household portfolio preferences. The short-run effect of heterogeneity in the composition of household portfolios is due to the fact that richer households hold a higher portion of wealth in the form of bonds with long maturities. Therefore, they can only benefit from the interest rate increase on a smaller percentage of wealth, i.e. that related to new purchases. In the short term, most of the wealth has a return linked to past interest rates. In contrast, the returns of 'more liquid' households or those with a higher percentage of wealth in the form of deposits are more responsive to interest rate changes. Once the roll-over on bonds is exhausted, the effect through the heterogeneity channel of portfolio composition vanishes.



BAU Scenario TD Scenario

Figure 4: Contribution to income inquality by income factor

These results are in line with Auclert (2019), showing that unhedged interest rates exposures (UREs), that is, the difference between all maturing assets and liabilities at a point in time, are the correct measure of households' balance sheet exposures to real interest rate changes. In this sense, agents whose financial wealth is primarily invested in short-term certificates of deposit tend to have positive UREs, while those with large long-term bond investments or adjustable-rate mortgage liabilities tend to have negative UREs. A drop in the real interest rate causes a redistribution from the first group toward the second. Since in the BAU scenario the ownership structure of bank and firms is not affected by monetary policy, the intragroup inequality of firms and bank dividends remains constant, while labor and financial inequality change. The changes in the contribution of each income factor to inequality are

displayed in Figure 4. Such changes are the results of both a change in the weight of the income factor and the intragroup inequality.

The contribution of the banking sector to income inequality increases because of a rise of the banking share on GDP. The contribution of labor income, although weak, changes because of both the increase in intragroup inequality (aggregate demand channel) and the decrease in labor share (cost-push channel). The first effect dominates the second, and the contribution of labor income rises. The contribution of financial income rises because of both an increase in the financial share and intra-group inequality (savings remuneration channel). In sum, the worsening in income distribution is due to both an increase in intragroup inequality and an increase in the weight of those income sources characterized by the highest intragroup inequality.

In the TD scenario, the restrictive monetary policy keep having a long-run unequalizing effect. However, in this scenario, the cost-push channel is absent, while the aggregate demand channel plays the key role. In this case, workers are able to recover the fall in real wage through the dividends of the banking sector. The linkage between the labor share and personal income inequality is lost and the final effect is only due to the change in the labor and financial rents inequality. In particular, the aggregate demand channel determines also the effect that pass through the saving remuneration channel which acts as a sounding board for the former. On the other hand, since corporate profits are equally distributed, the aggregate demand channel does not affect the inter-group inequality between wage and profit earners. As shown in Figure 4, total inequality is fully explained by labor inequality and the impact of monetary policy on total income inequality is almost explained by the change in the employment level. The residual inequality due to the saving remuneration channel is endogenously generated by inequality in labour income. Indeed, monetary policy, by increasing the unemployment rate, creates a greater gap in the accumulation of household savings and, consequently, in the financial returns generated by them.

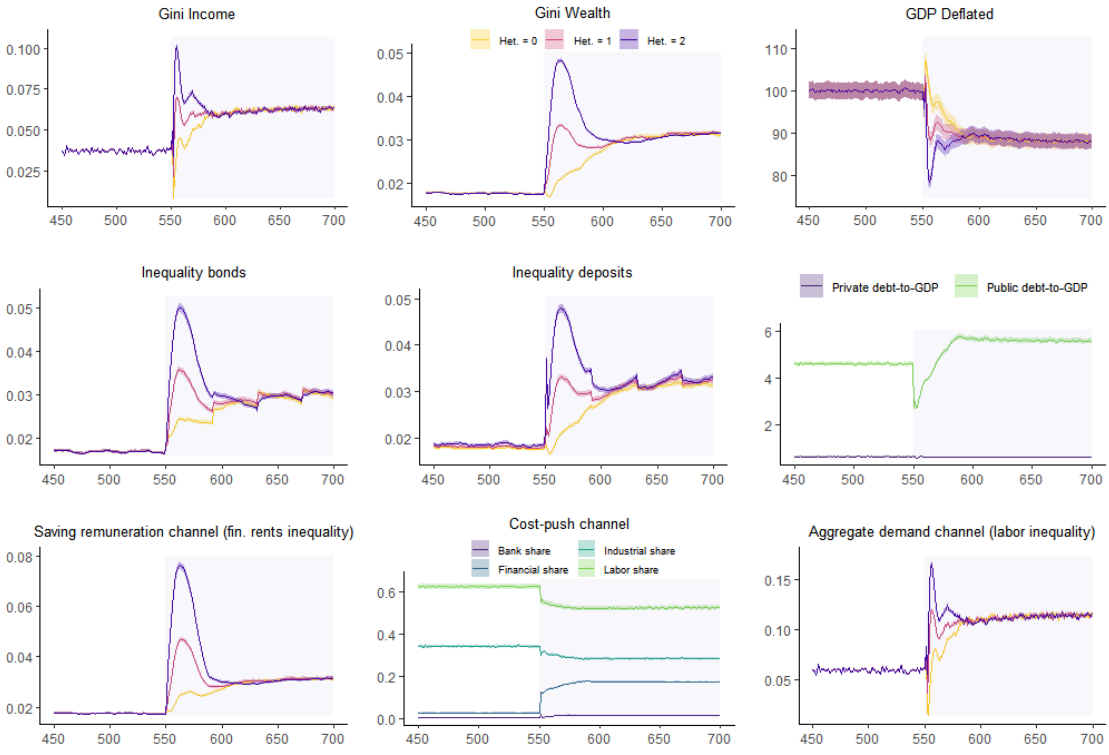


Figure 5: The impact of restrictive monetary policy (TD scenario)

It is important to note that, in contrast to the BAU scenario, heterogeneity in portfolio composition plays an important role in influencing income inequality in the short run, while it keep being irrelevant in the long run (all measures of inequality - bonds, deposits, labour income and financial rents - converge to the same value regardless of the degree of heterogeneity in the long-term). In equal societies, the higher the heterogeneity in portfolio preferences, the higher the short-run unequalizing effect of restrictive MPs. Such effect passes through the interaction between the asset-price and aggregate demand channel. As the heterogeneity rises, the negative wealth-effect on consumption rises. As a results, output and employment reduces and labor inequality grows. In addition, while in the BAU scenario heterogeneity has a 'beneficial' effect on short-run wealth inequality, in the TD scenario, short-run inequality rises as portfolio heterogeneity increases. This is due to the fact that aggregate effects are dominated by labour inequality while the effect of roll-over on long-run securities is very weak precisely because inequality in financial wealth is very low. Therefore, the trend in inequality follows the trend in unemployment, which in the short run suffers a more pronounced shock (GDP shows a pronounced drop the short run and, then, stabilises at a higher level, but still lower than the pre-shock level).

In sum, as inequality in the initial distribution of equities decreases, the channels through which monetary policy impacts inequality are reduced and its effect tends to coincide with that on labor inequality. Furthermore, while the long-run effect presents the same sign in the TD and BAU scenarios, the short-run effects have opposite signs and strongly depend on the heterogeneity in households portfolios. Instead, the symmetry in the distribution of firms and bank shares matters also for the long-run effect. Table 4 in the appendix summarizes the short- and long-run results according to different degrees of portfolio heterogeneity and different degrees of symmetry in the distribution of firms and bank shares.

This aspect will be analyzed more in depth in Section 5 where we discuss the heterogeneous impacts that MPs have when the relative inequality in the distribution of firms and bank shares change.

The interdecile is particularly sensitive to the aggregate demand channel. On the one hand, such channel mostly affects the labor income of the bottom 10 percent by changing the employment status of agents belonging to such group. On the other hand, the aggregate demand channel strongly affects the status of household whose income mostly depends on firms profits (the top 10%). Conversely, the income of households which are concentrated in center of the distribution of the distribution have a lower percentage of their income depending on profits and a lower probability to lose their job. Then, the impact of changes in aggregate demand on such groups is less relevant. For the same reason, Generalized Entropy measures (such as the Gini index) are less sensitive to aggregate demand compared to the D90/D10 ratio.

Besides the degree of symmetry in the initial distribution of firms and bank shares, the possibility of having an equalizing or unequalizing effect depends on the starting level of unemployment. For instance, in unequal societies with high level of unemployment, contractionary monetary policies can reduce the inter-decile ratio. In this case, the decrease in the labor income of the bottom inter-decile is weaker that the decrease in dividends distributed to the top ten-percent due to lower aggregate demand[19]. Conversely, when the unemployment rate is low, the increase in labor income inequality can offset the impact due to the reduction in total profits and the inter-decile ratio rises.

The direct impact of monetary policy on wealth inequality depends on the heterogeneity in households portfolio preferences[20]. Conversely, if portfolio preferences are homogeneous across the population, the movements in wealth inequality are fully explained by movements in income inequality[21]. Figure 6

[19]If the majority of households belonging to the bottom 10 % are already unemployed, the aggregate demand channel will be almost ineffective on the income of such group

[20]In the terms of the model, the λ of portfolio choices are equal cross the population.

[21]Obviously, asymmetrical income variation among the population depends, in turn, on the distribution of wealth before monetary shock. This is particularly true for the saving remuneration channel.

reports the effect of a restrictive monetary policy on wealth inequality for different degrees of heterogeneity in portfolio preferences. In case of homogeneous portfolio preferences, all households experience, in the same proportion, a decrease in the value of assets as the interest rate increases and no effect comes through the capital gains/losses (CGL) channel. Indeed, although a wealthy agent may have a larger amount of bonds/equities than a poor household, if the percentage of bonds/equities on total wealth is equal, the distributional effect of CGL is zero[22]. The story slightly changes when households have heterogeneous portfolio preferences.

The red line displays the case of homogeneous preferences: the CGL channel is inoperative, and the sign of the monetary policy is homogeneous in the short and long run. Wealth inequality co-moves with income inequality. Conversely, in the BAU scenario, when households have heterogeneous preferences (light blue and blue lines) and the percentage of wealth held in the form of deposits is a negative function of the wealth stock, the monetary policy has a short-run equalizing effect, while it keeps being disequalizing in the long-run. The short-run effect is due to the distribution of CGLs, while the long-run effect is still dominated by the changes in income shares and labor inequality. Since an increase in the interest rate causes a reduction in the value of bonds and equities, wealthier agents (i.e. agents with a higher percentage of wealth in the form of bonds and equity) experience a higher percentage decline in the value of their wealth than agents holding all their wealth in the form of deposits. However, because bonds at maturity are repaid at their nominal value, the distributional effect of CGL is transitory. Once the rollover is exhausted, the pre-shock nominal value of wealth is restored (the corresponding amount is held in terms of more bonds at a lower price). Conversely, in the TD scenario, the changes in wealth inequality are fully driven by the changes in the unemployment. In the short-run the rise in the wealth inequality follows the drop in GDP. In particular, the short-run drop in GDP is positively correlated with the degree of heterogeneity in portfolio decisions. Indeed, the negative wealth effect rises with the increase in the percentage of wealth held in the form of bonds.

These results are consitent with the findings of the empirical literature. For instance, Lenza and Slacalek (2018) show that non-standard monetary policy has only negligible effects on wealth inequality. In contrast, expansive monetary policy compresses the income distribution since many households with lower incomes become employed. In particular, they find that the policy temporarily increases the value of stocks of wealthier households. The effects of quantitative easing on net wealth tend to be stronger for leveraged households, relatively to their wealth level although, poorer households have a lower level of net wealth and the effects of QE relative to the wealth level do not immediately translate into the effects on inequality.

Finally, when considering the effect that passes through the stock market channel, monetary policy does not influence wealth inequality, even in the short term. Indeed, the decrease in the equity value is simply the result of a different allocation of household wealth. After the shock, the yield differential between bonds and equity increases, leading households to allocate a higher percentage of wealth to bonds. As a result, net of short-term effects given by CGL on stocks, the value of wealth held in bonds increases, while the value held in equity decreases, yet the total wealth remains unchanged (net of capital gains generated by the change in the market value of bonds). In this sense, the change in prices stocks is not a "manna from heaven", it is merely an "accounting" indicator of changes in portfolio decisions that modifies the value of the equity stock accordingly. When the monetary flow into this market decreases, prices drop accordingly. The decrease in the value of equity in perfectly compensated by an increase in the value of wealth held in terms of bonds. The value of equity is subordinated to the amount of monetary wealth allocated by households to this type of asset. The missing or additional flow has gone somewhere else or has been diverted to some other stock.

[22]Levels are irrelevant in the measurement of inequality variations, only ratios are.

It is important to specify that this holds true when households response to the monetary shock is symmetric. In this context, we refer to the hypothesis of homogeneous elasticities in the portfolio preferences with respect to the interest rate ($\lambda_{i,1}$ are homogeneous across the population)[23]. That is, considering initial heterogeneous portfolio compositions ($\lambda_{i,0}$ are heterogeneous across the population), these must remain constant over time or must not vary asymmetrically among agents in response to shocks. In general, such assumption is supported by the empirical evidence on considerable inertia in household portfolios (see Ameriks and Zeldes, 2011; Fagereng et al., 2020, among others). According to this hypothesis, household portfolios are not rebalanced in response to the announcement of monetary policies. Conversely, if we consider a trading market with asymmetric reactions, some agents might see a decrease in their wealth without changing their wealth allocation[24] (then realizing a net loss), while agents who have shifted an higher percentage of their wealth towards bonds (thus causing the drop in equity prices) would see an increase in their total wealth proportional to the loss of the former. Precisely, it is the decision of the latter that changes the assets values of the former. This is because stock prices decline less than they should compared to the case of an homogeneous reallocation of assets. Of course, the same applies if some agents increase their liquidity preference in response to a monetary shock. In these cases, through the CGLs channel, the monetary policy would have a long-lasting effect on wealth inequality. To be said, nothing could be argued on the sign of the case. Only if we assume that wealthier agents are endowed with better information about the future market effects of their operations or they have an higher elasticity to the interest rate, restrictive monetary policy have a long-lasting unequalizing effect through the CGLs channel.

6 Endowments distributions and the impact of monetary policies on income inequality

This section analyzes the impact of monetary policy on income inequality, considering different combinations in the initial distribution of firms and bank shares across the population. We pursue the analysis contextually with the study of the role of labor share and unemployment subsidies. Such combinations produce a plethora of starting distributions characterized by different degrees of heterogeneity in the income sources of households. The heterogeneity increases as the initial inequality in the distribution of firm and bank shares rises and the degree of asymmetry between these two distributions expands. Figure 7 reports the impact of monetary policy on the Gini coefficient for any given combination of the initial inequality in the distribution of firm and bank shares. Figure 8 displays the impact on the inter-decile ratio. Appendix B reports the results of the simulation for the Theil and Atkinson indexes. However, these results are almost similar to those characterizing the Gini coefficient[25]. The k-powers (k_f and k_b) defining initial inequality in the distribution of each asset ranges between -2.5 and 0. The z-axis reports the percentage change in the Gini coefficient due to the implementation of the monetary policy. Each point on the z-axis express the difference between the pre- and post-shock stationary states. The green plane corresponds to zero values, namely no effect of the monetary policy.

The results show that monetary policy has a non-linear impact on income and wealth inequality. The magnitude of the impact is an inverse convex function of the initial inequality in the distribution of firm shares, while it is a concave function of the initial inequality in the distribution of bank shares.

[23] If $\lambda_{i,1}$are heterogeneous across the population, after the monetary shocks, the share of wealth held by households in terms of each assets change in a non-symmetric direction

[24] In the model, such eventually realizes when some agents have zero elasticity to the change in the interest rate in the portfolio preferences

[25] Besides, the Gini coefficient is a measure of Generalized entropy as well as Theil and Atkinson indexes (Biró and Néda, 2020)

However, the effect depends on the inequality measure taken into consideration. We first analyze how the non-linearity emerges. Then, we study the relationship between the percentage change in the Gini coefficient and the starting topology of inequality.

The values below the green plane reveal that, in correspondence with those combinations of k_f and k_b, the monetary policy has an equalizing effect (bottom right corner). Conversely, in correspondence of the combinations of k_f and k_b where the value of Gini is above the green plane, the monetary policy has an unequalizing impact.

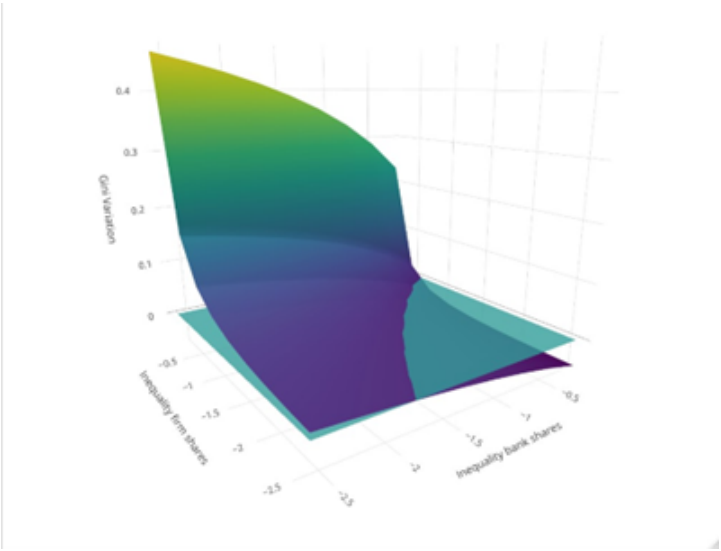


Figure 6: The impact of monetary policy on Gini for different combinations of the initial inequality in the distribution of firms and bank shares. *Note: The z-axis reports the percentage variation in the Gini coefficient; the y-axis reports the k-power describing the initial inequality in the distribution of firms shares; the x-axis reports the k-power describing the initial inequality in the distribution of bank shares.*

Monetary policy affects long-run income inequality by modifying the weight of each income source on GDP, intragroup and intergroup inequality. The sign and the magnitude depend on the initial inequality in the distribution of endowments across households, along as the labor share, the unemployment benefit and the elasticity of aggregate demand to the interest rate.

Two potentially contrasting forces operate in determining the long-run sign of the impact of MPs. On the one hand, as shown in Section 5, restrictive monetary policy expands intragroup inequality and affects intergroup inequality. On the other hand, through the cost-push channel, it modifies the share of the cake belonging to each income source: bank and financial shares rise, while labor and industrial shares lower. In this context, a restrictive MP may reduce inequality by lowering the weight of those income factors characterized by higher intragroup inequality. Since restrictive MPs increase the share of the banking sector, MPs worsen income inequality if the banking sector presents higher intragroup inequality compared to other income sources. In this case, both the change in intragroup inequality and income shares concur in increasing income inequality. Conversely, if the banking sector presents lower intragroup inequality, under specific conditions, MPs can have an equalizing effect. Such a possibility depends on the values of unemployment subsidies, labor share, and the elasticity of aggregate demand to the interest rate.

The value of unemployment benefits influences the impact of the aggregate demand channel on labor inequality and the gap between non-financial profit and wage earners[26]. We define the latter ad

[26]By profit and wage earners, we mean the agents whose income mostly depends on dividends or

the "capital-labor effect" of the aggregate demand channel. The higher the unemployment benefits, the lower the increase in intergroup inequality following the restrictive MP.

The value of the markup, which determines the labor share, influences the impact of the aggregate demand channel on the change in the Gini coefficient through the "population effect" and the "capital-labor effect". The higher the markup, the lower the increase in the Gini coefficient following monetary policy thickening. These two aspects will be analyzed with the proceeding of the section.

Given the value of the markup and the value of unemployment benefits, the resultant effect depends on the ratio between the initial degree of inequality in the distribution of corporate shares and that characterizing bank shares. The sign is negative for values of such ratio that are much larger than one, while it is positive when it is close to or lower than one. We derived the approximated function describing in closed form the macro results of the AB model. (See Appendix, for the methodology of approximation). The approximated function, describing the variation in Gini as a function of the inequality in the distribution of bank and firm shares is the following:

$$z = a + b(e^{k_f})^c - [d + f(e^{k_f})^g] \cdot (e^{k_b})^{h+i(e^{k_f})^l} \tag{57}$$

where a, b, c, d, f, g, h, i, l have been estimated accordingly (see Appendix C). We find that, for the given set of parameters, the threshold over which the MP has an equalizing effect is $k_f/k_b = 1.4$

When $|k_f| > |k_b|$, income inequality is mostly explained by the inequality in the distribution of corporate shares. This is due to both the greater weight of the industrial profit share and the greater intragroup inequality of income generated by corporate dividends. In this case, an increase in the interest rate can have an equalizing effect if the impact on labor and wage-profit intergroup inequality is weak enough. This is because restrictive policy increases the weight of the distributional share characterized by lower intragroup inequality, namely bank dividends, at the expense of the distributional share characterized by higher intragroup inequality, namely corporate dividends. The cost-push channel generates an equalizing effect and dominates the unequalizing effect produced by the aggregate demand channel. On the other hand, when $|k_f| \leq |k_b|$, the restrictive monetary policy gives greater weight to the banking profit share which is characterized by greater intragroup inequality, while simultaneously decreasing the weight of the distributional share characterized by lower intragroup inequality. The same effect emerges when k_f and k_b are similar. In both cases, workers are not able to recover the fall in real wages through the collection of bank dividends. In this case, all transmission channels (cost-push, aggregate demand and saving remuneration channel) concur in worsening income distribution.

Figures 8 and 9 explain these results in detail. In figure 9, $k_f = -2.5$ and k_b ranges between -2.5 and 0[27]. In Figure 10, $k_f = -0.5$, and k_b ranges between -2.5 and 0. When $k_f = -2.5$ (Figure 9), as k_b approaches to zero, the relative inter-group inequality increases and the magnitude of the impact of restrictive monetary policy lowers. In particular, above a certain threshold, it starts having an equalizing effect. Conversely, when $k_f = -0.5$ (Figure 10), the magnitude is negatively correlated with the initial degree of inequality in the distribution of bank shares and the non-linearity does not emerge. Here, intragroup inequality characterizing the shares of the banking sector is always higher than that characterizing corporate shares. As a result, restrictive monetary policy, by increasing the distributive share of the banking sector, causes an increase in income inequality.

The role of relative intragroup inequality can be understood by looking at the variations in the contribution of each income factor to total inequality after the implementation of the monetary policy. When $k_f = -2.5$ (the corporate shares inequality is at its maximum), as the inequality in the distribution of bank shares increases, the variation in the contribution of the bank dividends to total inequality

wages, respectively

[27]The results generated by each possible combination of k_b and k_f are provided in Appendix B.

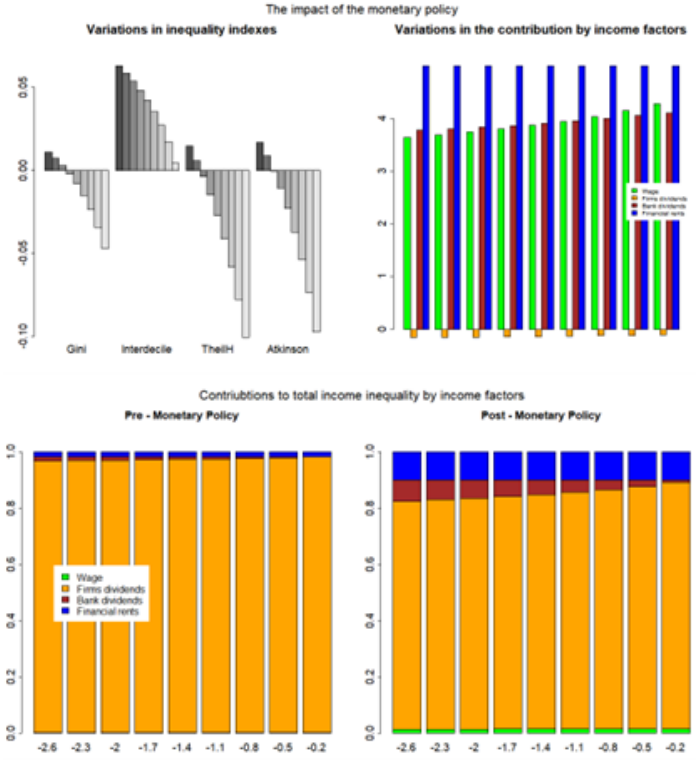


Figure 7: Variation of inequality measures and variation in the contribution of income factors after the implementation of restrictive monetary policy. $k_f = -2.5; k_b \in [-2.5,\ 0]$

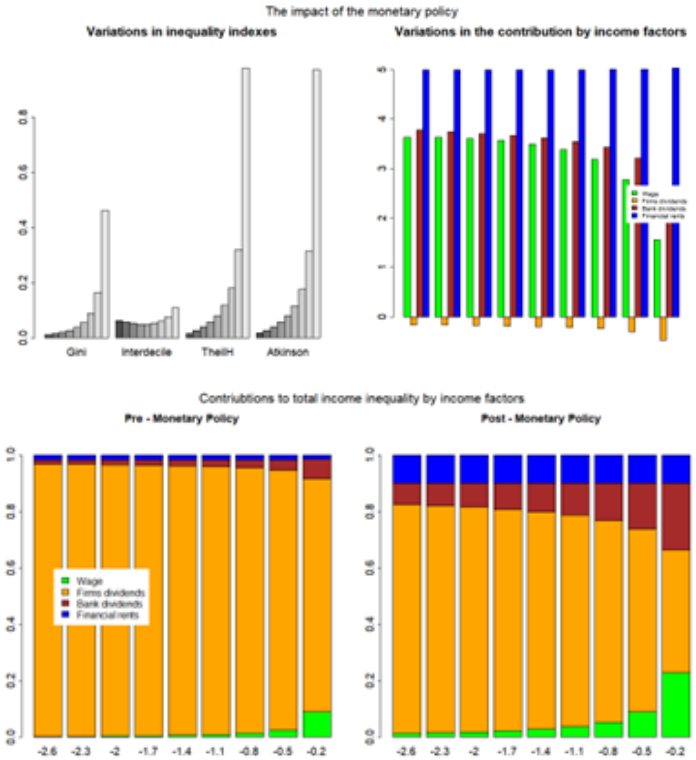


Figure 8: Variation of inequality measures and variation in the contribution of income factors after the implementation of restrictive monetary policy. $k_f = -0.5; k_b \in [-2.5,\ 0]$

decreases. Parallelly, the absolute value of the variation in the contribution of corporate dividends increases. Conversely, when $k_f = 0$, the higher the inequality in the distribution of bank shares, the lower the variation in the contribution to total inequality by bank dividends, while the absolute value of the variation in the contribution of corporate dividends lowers.

In sum, if monetary policy increases the weight of the income factor characterized by lower intragroup inequality and such effects is able to offset the general increase in the intragroup and integroup inequality, the sign of the effect will be negative. It will be positive in all other cases.

The necessary, but not sufficient, condition for the realization of an equalising effect is the negative asymmetry in the distribution of bank shares with respect to corporate shares. Namely, the inequality in the distribution of bank shares must be much lower than the inequality in the distribution of corporate shares. Once this condition is satisfied, the possibility of having an equalising effect of restrictive MPs depends on the value of the markup and unemployment benefits. These two factors determine the possibility that the "cake share" effect dominates the increase in labor, inter-group and financial inequality. The higher the unemployment benefit, the lower the increase in labor inequality. Parallelly, as the unemployment benefit increases, the possibility that the percentage decrease in the incomes of households whose inflows depend mostly on non-financial profits is greater than the decrease in the incomes of households whose incomes depend mostly on labour rises. Similarly, a higher level of markup, by increasing the weight of the industrial sector and the income differentials between profits and wage earners, lowers the expansion in inter-group inequality (between wage and non-financial profit earners). In this sense, via the aggregate demand channel, both unemployment benefits and markup concur in lowering the impact on intergroup inequality.

Figure 10 displays the countor plot of the impact of the restrictive MP on the Gini coefficient for different combinations in the initial distribution of firm and bank shares. Figure 10.a displays the results for different levels of the unemployment subsidy. Figure 10.b displays the results for different values of the markup. Appendix C reports the associated 3D plots. In these simulations, the initial inequality in the distribution of bank shares is lower than the inequality in the distribution of firm shares. It can be seen that the threshold over which monetary policy has an equalizing effect moves to the right when the unemployment benefit and markup decrease.

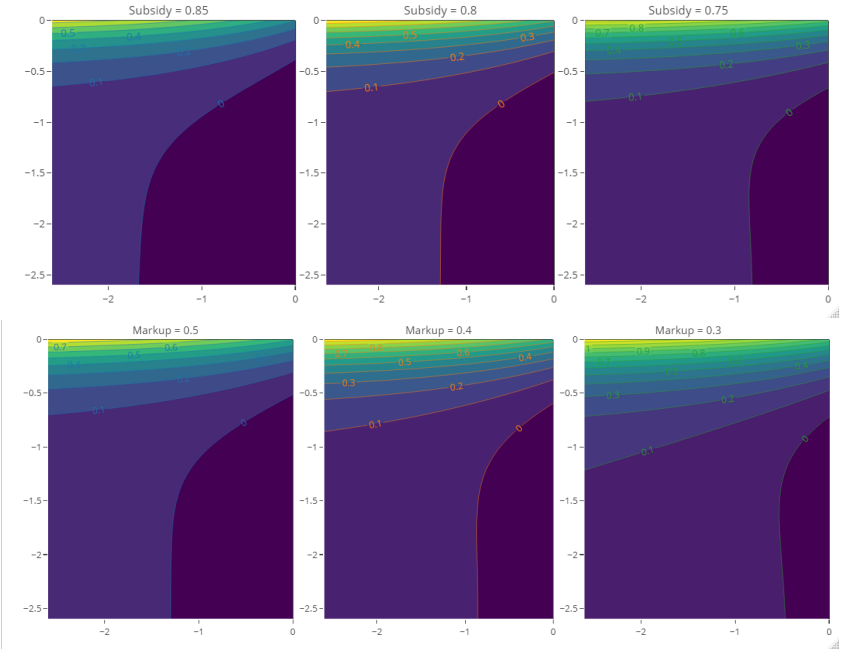


Figure 9: Non-linearity thresholds for different values of markup and unemployment subsidies.

Figure 11.a reports the impact of restrictive MP for different values of the markup when the distribution of firms and bank shares is symmetric and the k-power is equal to 0.5. Figure 11.b displays the change in the contribution of each income factor to overall inequality. Appendix D reports the same results for different initial distributions of endowments and different values of unemployment benefits.

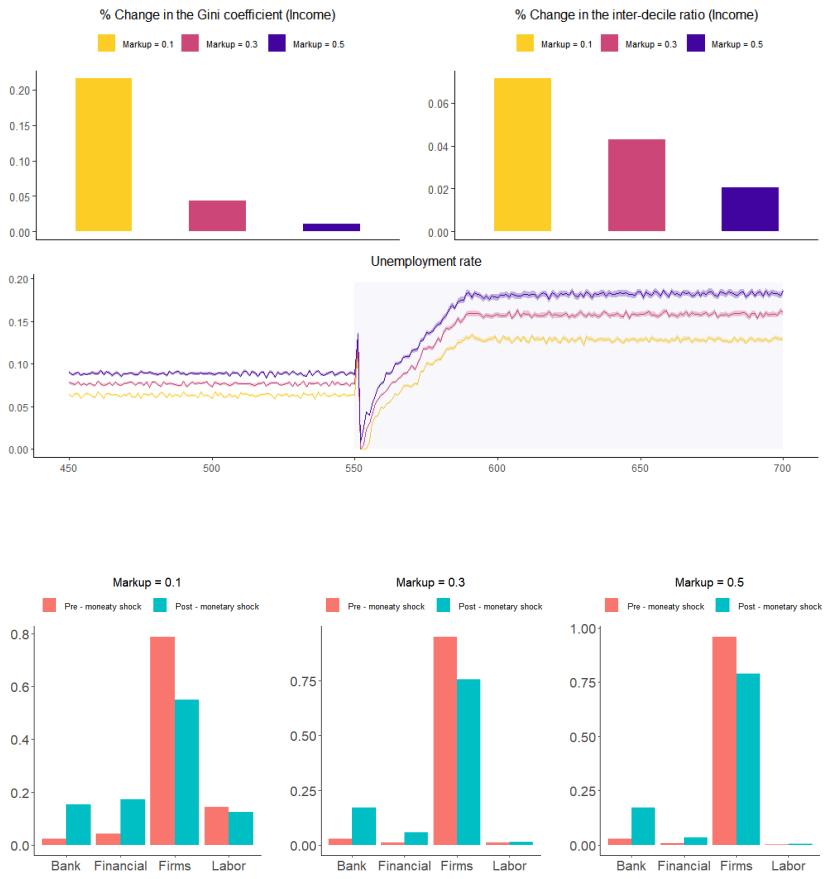


Figure 10: The impact on inequality measures for different values of the markup ($k_b = k_f = 0.5$)

It is worth noticing that, to have an equalizing effect of monetary policy, it is not required that the intergroup inequality lowers dominating the increase in intragroup inequality. It is required that the markup and the unemployment benefits be sufficiently high to generate a sufficiently weak negative impact of aggregate demand on overall income inequality. Of course, the lower the increase in intergroup and labor inequality, the wider the margins for generating an equalizing effect of restrictive MPs.

In addition, higher levels of the markup reduce the negative impact that the aggregate demand channel has on the Gini index through the "population effect". Indeed, the Gini coefficient is more sensitive to changes (albeit small) in the income of the agents located in the center of the distribution. That is, Gini is more sensitive to those incomes that have higher frequencies. These incomes are characterized by similar shares of income sources. When markup lowers, a higher share of total income is concentrated across a group of higher dimension, and the percentage change in Gini is higher. Conversely, the Gini becomes less responsive when the bulk of income is concentrated across a small group of the population. For these reasons, the impact of MP on Gini increases when the markup decreases. Then, the negative correlation is the result of both the "capital-labor effect" and the "population effect". Of course, the relevance of the markup for studying the impact of MP depends on the initial distribution of corporate shares. In equal societies (as in the TD scenario), it is irrelevant.

Contrary to the Gini coefficient, the interdecile ratio does not suffer from the population effect.

Lastly, the magnitude of the impact is an inverse convex function of the initial inequality in the distribution of firm shares, while it is a concave function of the initial inequality in the distribution of bank shares. Keeping constant the inequality in the distribution of bank shares, the magnitude of the impact of monetary policy is negatively correlated with the inequality in the distribution of corporate

shares (the slope of the curve in Figure 7 is increasing as k_f decreases). Keeping the distribution of bank shares constant, the difference in intragroup inequality between the two income sources rises as the inequality in the distribution of corporate shares decreases. When such a difference grows, the impact of contractionary MP, boosting the banking share, expands, and an increasing weight is given to the income source characterized by the highest intragroup inequality. As a result, the percentage variation in Gini is maximum when the inequality in the distribution of corporate shares is at its lowest level, and it is minimum when it is at its highest value. Conversely, keeping the distribution of corporate shares constant, the impact of monetary policy is positively correlated with the degree of inequality in the distribution of bank shares. In this case, the net effect almost depends on the winner (and the extent of the win) in the trade-off between the cost-push channel and the aggregate demand channel. When k_b is low, the contractionary MP, on the one hand, reduces income inequality by raising the income share characterized the lowest intragroup inequality (i.e. the banking sector), on the other hand, it raises income inequality by negatively affecting the employment rate. In this scenario, the first effect can be relevant and can even dominate the second one. In any case, when k_b is low, the struggle between the two opposite forces is significant, and as a result, the impact of monetary policy on income inequality is "weak". When k_b rises, the first effect fades, and the sign of the impact begins to change, leading to an increase in inequality. In detail, as the k_b increases, the trade off between the two channels also disappears.

Results slightly change when considering the inter-decile ratio. In this case, the impact of monetary policy has a U-shaped function of the initial inequality in the distribution of corporate shares, while it is a concave function of the initial inequality in the distribution of bank shares. The sign inversion emerges at different degrees of inequality at inception depending on the indicator used (see Figure 11 in the Appendix). In particular, the inter-decile exhibits the non-linearity threshold for a significantly lower value of k compared to the Gini, Atkinson and Theil indexes. Indeed, the inter-decile is more sensitive to income differential between the tails of the distribution, is strongly affected by the variation in unemployment and the income of bank stock holders.

7 Conclusions

The literature on the relationship between monetary policies and inequality presents controversial and often contrasting findings (Aye et al., 2019; Galbraith et al., 2007; Mumtaz and Theophilopoulou, 2017; Saiki and Frost, 2014, 2018; Villarreal, 2014; Hafemann et al., 2018; Herradi and Leroy, 2021; Inui et al., 2017; Samarina and Nguyen, 2024; Taghizadeh-Hesary et al., 2020). Empirical studies reveal both equalizing and disequalizing effects, while results diverge depending on the inequality measure taken into consideration (Davtyan, 2016). By developing an AB model, this paper addresses the role of different starting conditions in the distribution of endowments across households and heterogeneity in portfolio choices. We analyze four main transmission channels of monetary policy: cost-push, aggregate demand, saving remuneration, and asset price channels. Through the cost-push channel, MP modifies the income shares. Through the aggregate demand channel, MP affects labor income inequality and the inter-group inequality characterizing non-financial profit and wage earners. Through the saving remuneration channel, MP affects financial inequality. Through the price assets channel, MP directly affects wealth inequality and consumption decisions, triggering a feedback loop with the aggregate demand channel. Of course, wealth inequality responds to the same channels influencing income inequality. The two dimensions interact.

Our results points out that the possibility of having both disequalizing and equalizing effects and the differences between the short- and long-run impacts, lastly, depends on the different distributions of households along relevant heterogeneous dimensions. In the model, the starting degree of heterogeneity

depends on both the initial level and the topology of distribution characterizing firm and bank share, as well as the heterogeneity in portfolio decisions. The first one, together with the markup, determines the initial distribution of income and the endogenous accumulation of individual wealth. To this extent, also financial inequality is endogenously determined. As the degree of heterogeneity rises, the transmission channels of MP and associated competing forces become more complex, and the overall impact unpredictable. Conversely, as the general degree of heterogeneity lowers, and society tends towards more equal configurations, the effect of MPs tends to be more deterministic, relying mostly on labor income inequality and the aggregate demand channel. In this sense, it is not possible to define "a priori" the magnitude and sign of the impact of monetary policies on income and wealth inequality. Each dimension activates different transmission channels with potential opposite signs.

Monetary policy affects long-run income inequality by modifying the weight of each income source on GDP and intragroup inequality. The short-run effects depends on the heterogeneity in portfolio preferences. The sign and the magnitude depend on the initial inequality in the distribution of firm and bank shares across households as well as the labor share, the unemployment benefit, and the elasticity of aggregate demand to the interest rate. In this context, two forces are at work.

On the one hand, contractionary MPs always have a negative effect on intragroup inequality. Generally, through the aggregate demand channel, MP negatively affect labor income inequality. Depending on the value of unemployment benefits and markups, the aggregate demand channel has a different impact on the inter-group inequality. In particular, while in unequal societies the inter-group inequality between wage and profit earners is affected by the aggregate demand channel, in more equal societies, it has a weak effect.

If the structure of bank and firm ownership is not affected, the inequality related to firm and bank dividends does not change, while, through the saving remuneration channel, financial inequality grows.

On the other hand, MPs may reduce income inequality by increasing the weight of those income factors characterized by lower intragroup inequality (cost-push channel). Since restrictive MPs rise the share of the banking sector, reducing the industrial and labor share, inequality worsens if the intragroup inequality of the banking sector is higher compared to other income sources. Conversely, if the banking sector presents lower intragroup inequality, MPs can have an equalizing effect.

Besides the degree of asymmetry in the distribution of firms and bank shares, the resultant effect depends on the elasticity of aggregate demand to the interest rate, the level of unemployment subsidies, and the markup. The latter two influence the percentage increase in the Gini caused by the change in intra- and inter-group inequality. The unemployment benefit influences the impact of the aggregate demand channel on labor inequality and inter-group inequality. The higher the unemployment benefit, the lower the unequalizing effect of the aggregate demand channel. In extreme cases, for very high levels of unemployment benefits, MP can have an equalizing effect through this channel. The markup level affects the percentage change through both the "population effect" and the change in intergroup inequality. On the one hand, higher is the markup, and lower is the responsiveness of Gini to an increase in the income share of wealthier agents. On the other hand, the higher the markup, the higher the percentage reduction in the income of profit earners compared to wage earners through the aggregate demand channel.

When unemployment benefits are high and/or the labor share is low, and the inequality in the income belonging to the banking sector is lower than the composite inequality characterizing firm shares and labor income groups, the equalizing effect produced by the increase in the banking share can dominate the negative effect produced by the increase in labor, financial inequality, and "potentially" inter-group inequality. In this case, restrictive MPs have a long-run equalizing effect. In all other cases, inequality grows.

Notably, the equalizing effect of a monetary policy can be realizable only in societies where the

inequality in the distribution of bank shares is much lower than the inequality in the distribution of firm shares. Such a difference has to be high enough to offset the negative impact that the monetary shock has on labor, financial, and inter-group inequality. High levels of unemployment benefits and markups support this process.

In any case, given the variation range of personal inequality in response to the monetary policy shock, the magnitude of the effect is a convex non-linear function of the initial degree of wealth inequality, and it is not independent of the inequality measure considered. For instance, keeping the distribution of bank shares constant across the population, the percentage variation in the Gini coefficient increases as the concentration in the distribution of firm shares rises. Conversely, keeping the distribution of firm shares constant, the percentage variation decreases as the inequality in the distribution of bank shares rises.

These results are in line with the empirical findings resumed in Dolado et al. (2021) showing that the ambiguous results in the empirical literature are due to the different distribution of households across relevant heterogeneity dimensions. In this regard, it has been shown that the effect of monetary policies on inequality depends on the initial wealth distribution, the composition of household financial assets (O'Farrell and Rawdanowicz, 2017; Guerello, 2018) and the initial wage share (Furceri et al., 2018).

The impact of the asset price channel on wealth inequality depends on the degree of heterogeneity in portfolio preferences. The latter plays a crucial role in the short term, while, in the case of symmetric response of agents to monetary shocks, is irrelevant in the long run. Conversely, if portfolio preferences are homogeneous across the population, the movements in wealth inequality are fully explained by movements in income inequality, and the asset price channel has no role also in the short-run.

In general, following the decrease in bond and stock prices, wealthier agents, characterized by a lower liquidity preference, can experience higher capital losses than "poor" households holding a higher percentage of their wealth in the form of deposits. In unequal societies, this produces a short-run decrease in wealth inequality. When the rollover of bonds is completed, such an effect vanishes.

Conversely, in more equal societies, the heterogeneity in portfolio composition is limited, and the asset price channel can be dominated by the change in the post-shock accumulation of savings across the population. The latter is the result of other transmission channels, such as the aggregate demand channel. For instance, in the TD scenario, wealth inequality is mostly explained by labor income inequality, and the CGLs channel is offset by the aggregate demand channel. As a result, wealth inequality grows in the case of heterogeneous portfolio composition, and decreases in the case of homogeneous preferences. Conversely, the BAU scenario is characterized by high levels of wealth inequality and preference heterogeneity, while income inequality depends on a multitude of income sources. In this case, the CGLs channel dominates the change in savings accumulation associated with the aggregate demand channel, and short-run inequality decreases in the case of heterogeneous preferences while expands in the case of homogeneous preferences.

Finally, monetary policies have a long-lasting effect on wealth inequality through the CGLs channels only if household reactions to the monetary shock are asymmetric. In particular, if wealthier agents have a higher sensibility to interest rate variations, restrictive MP exacerbates wealth inequality.

The future developments of the work involve two lines of development: i) the study of the relationship between the time duration of restrictive monetary policies and long-lasting effects on inequality.; ii) the inclusion of inflation expectations in nominal wage setting to include the inflation channel in the study of the impact of monetary policies.

References

Acemoglu D, Johnson S. 2012. Who captured the fed? *The New York Times Economix* Online article.

Acemoglu D, Robinson JA. 2008. Persistence of power, elites, and institutions. *American Economic Review* **98**: 267–93.
URL https://www.aeaweb.org/articles?id=10.1257/aer.98.1.267

Acharya S, Dogra K. 2020. Understanding hank: Insights from a prank. *Econometrica* **88**: 1113–1158.
URL https://onlinelibrary.wiley.com/doi/abs/10.3982/ECTA16409

Adolfson M, Laséen S, Lindé J, Villani M. 2005. The role of sticky prices in an open economy dsge model: a bayesian investigation. *Journal of the European Economic Association* **3**: 444–457.

Alexandre M, Lima GT, Riccetti L, Russo A. 2023. The financial network channel of monetary policy transmission: an agent-based model. *Journal of Economic Interaction and Coordination* **18**: 533–571.

Ameriks J, Zeldes SP. 2011. *How do household portfolio shares vary with age?* SSRN.

Ampudia M, Cooper R, Le Blanc J, Zhu G. 2024. Mpc heterogeneity and the dynamic response of consumption to monetary policy. *American Economic Journal: Macroeconomics* **16**: 343–388.

Atkinson AB, Piketty T, Saez E. 2011. Top incomes in the long run of history. *Journal of Economic Literature* **49**: 3–71.
URL https://www.aeaweb.org/articles?id=10.1257/jel.49.1.3

Auclert A. 2019. Monetary policy and the redistribution channel. *American Economic Review* **109**: 2333–67.
URL https://www.aeaweb.org/articles?id=10.1257/aer.20160137

Aye GC, Clance MW, Gupta R. 2019. The effectiveness of monetary and fiscal policy shocks on U.S. inequality: the role of uncertainty. *Quality & Quantity: International Journal of Methodology* **53**: 283–295.
URL https://ideas.repec.org/a/spr/qualqt/v53y2019i1d10.1007_s11135-018-0752-3.html

Barth MJ, Ramey VA. 2002. The Cost Channel of Monetary Transmission. In *NBER Macroeconomics Annual 2001, Volume 16*, NBER Chapters. National Bureau of Economic Research, Inc, 199–256.
URL https://ideas.repec.org/h/nbr/nberch/11066.html

Bergbauer S, Giovannini A, Hernborg N. 2022. Economic inequality and public trust in the european central bank. *Economic Bulletin Articles* **3**.

Bernanke BS. 1990. The federal funds rate and the channels of monetary transnission.

Bewley T. 1977. The permanent income hypothesis: A theoretical formulation. *Journal of Economic Theory* **16**: 252–292. ISSN 0022-0531.
URL https://www.sciencedirect.com/science/article/pii/0022053177900096

Bilbiie FO. 2008. Limited asset markets participation, monetary policy and (inverted) aggregate demand logic. *Journal of economic theory* **140**: 162–196.

Biró TS, Néda Z. 2020. Gintropy: Gini index based generalization of entropy. *Entropy* **22**. ISSN 1099-4300.
URL https://www.mdpi.com/1099-4300/22/8/879

Bulir A. 2001. Income inequality: Does inflation matter? *IMF Staff Papers* **48**: 1.
URL https://EconPapers.repec.org/RePEc:pal:imfstp:v:48:y:2001:i:1:p:5

Bunn P, Pugh A, Yeates C. 2018. The distributional impact of monetary policy easing in the UK between 2008 and 2014. Bank of England working papers 720, Bank of England.
URL https://ideas.repec.org/p/boe/boeewp/0720.html

Caiani A, Godin A, Caverzasi E, Gallegati M, Kinsella S, Stiglitz JE. 2016. Agent based-stock flow consistent macroeconomics: Towards a benchmark model. *Journal of Economic Dynamics and Control* **69**: 375–408. ISSN 0165-1889.
URL https://www.sciencedirect.com/science/article/pii/S0165188915301020

Campbell JY, Mankiw NG. 1989. Consumption, Income, and Interest Rates: Reinterpreting the Time Series Evidence. In *NBER Macroeconomics Annual 1989, Volume 4*, NBER Chapters. National Bureau of Economic Research, Inc, 185–246.
URL https://ideas.repec.org/h/nbr/nberch/10965.html

Canzoneri MB, Cumby RE, Diba BT. 2007. Euler equations and money market interest rates: A challenge for monetary policy models. *Journal of Monetary Economics* **54**: 1863–1881. ISSN 0304-3932.
URL https://www.sciencedirect.com/science/article/pii/S0304393206002297

Carney M. 2016. The spectre of monetarism. *Speech given as Roscoe Lecture, Liverpool John Moore University* **5**.

Casiraghi M, Gaiotti E, Rodano L, Secchi A. 2018. A "reverse robin hood"? the distributional implications of non-standard monetary policy for italian households. *Journal of International Money and Finance* **85**: 215–235.

Castelnuovo E, Surico P. 2010. Monetary policy, inflation expectations and the price puzzle. *The Economic Journal* **120**: 1262–1283.

Challe E, et al. 2017. Uninsured unemployment risk and optimal monetary policy. *American Economic Journal: Macroeconomics* .

Chowdhury I, Hoffmann M, Schabert A. 2006. Inflation dynamics and the cost channel of monetary transmission. *European Economic Review* **50**: 995–1016.
URL https://ideas.repec.org/a/eee/eecrev/v50y2006i4p995-1016.html

Christiano L, Eichenbaum MS, Evans C. 1994. The effects of monetary policy shocks: some evidence from the flow of funds.

Coibion O, Gorodnichenko Y, Kueng L, Silvia J. 2017. Innocent bystanders? monetary policy and inequality. *Journal of Monetary Economics* **88**: 70–89.
URL https://EconPapers.repec.org/RePEc:eee:moneco:v:88:y:2017:i:c:p:70-89

Colgiago A. 2011. Rule-of-thumb consumers meet sticky wages. *Journal of Money, Credit and Banking* **43**: 325–353.
URL https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1538-4616.2011.00376.x

Copeland MA. 1949. Social accounting for moneyflows. *The Accounting Review* **24**: 254–264.

Davtyan K. 2016. Income inequality and monetary policy: An analysis on the long run relation. AQR Working Papers 201604, University of Barcelona, Regional Quantitative Analysis Group.
URL https://EconPapers.repec.org/RePEc:aqr:wpaper:201604

Debortoli D, Galí J. 2017. Monetary policy with heterogeneous agents: Insights from TANK models. Economics Working Papers 1686, Department of Economics and Business, Universitat Pompeu Fabra.
URL https://ideas.repec.org/p/upf/upfgen/1686.html

Dedola L, Lippi F. 2005. The monetary transmission mechanism: evidence from the industries of five oecd countries. *European Economic Review* **49**: 1543–1569.

Deleidi M, Levrero ES. 2020. The price puzzle and the hysteresis hypothesis: Svec analysis for the us economy. *Review of Political Economy* **32**: 22–29.

Di Bucchianico S, Lofaro A. 2023. The impact of monetary policy on functional income distribution: a panel svar analysis (1970-2019). Department of economics university of siena, Department of Economics, University of Siena.
URL https://EconPapers.repec.org/RePEc:usi:wpaper:900

Di Domenico L. 2023. Multiplicity and not necessarily heterogeneity: implications for the long-run degree of capacity utilization. *Journal of Economic Interaction and Coordination* **18**: 835–877.

Dolado JJ, Motyovszki G, Pappa E. 2021. Monetary policy and inequality under labor market frictions and capital-skill complementarity. *American Economic Journal: Macroeconomics* **13**: 292–332.
URL https://www.aeaweb.org/articles?id=10.1257/mac.20180242

Dosi G, Roventini A. 2019. More is different... and complex! the case for agent-based macroeconomics. *Journal of Evolutionary Economics* **29**: 1–37.
URL https://EconPapers.repec.org/RePEc:spr:joevec:v:29:y:2019:i:1:d:10.1007_s00191-019-00609-y

Dossche M, Slacalek J, Wolswijk G. 2021. Monetary policy and inequality. *Economic Bulletin Articles* **2**.

Draghi M. 2016. Stability, equity and monetary policy. 2nd DIW Europe Lecture, German Institute for Economic Research (DIW). President of the ECB.

Eichenbaum M. 1992. 'comments on 'interpreting the time series facts: The effects of monetary policy'by christopher sims,". *European Economic Review* **36**: 1001–1011.

Fagereng A, Guiso L, Malacrino D, Pistaferri L. 2020. Heterogeneity and persistence in returns to wealth. *Econometrica* **88**: 115–170.
URL https://onlinelibrary.wiley.com/doi/abs/10.3982/ECTA14835

Fagiolo G, Roventini A. 2016. Macroeconomic policy in dsge and agent-based models redux: New developments and challenges ahead. *Available at SSRN 2763735* .

Fierro LE, Giri F, Russo A. 2023. Inequality-constrained monetary policy in a financialized economy. *Journal of Economic Behavior & Organization* **216**: 366–385.

Fontana G, Realfonzo R, Passarella MV. 2020. Monetary economics after the global financial crisis: what has happened to the endogenous money theory? *European Journal of Economics and Economic Policies* **17**: 339–355.

Furceri D, Loungani P, Zdzienicka A. 2018. The effects of monetary policy shocks on inequality. *Journal of International Money and Finance* **85**: 168–186. ISSN 0261-5606.
URL https://www.sciencedirect.com/science/article/pii/S0261560617302279

Galbraith JK, Giovannoni O, Russo AJ. 2007. The fed's real reaction function: Monetary policy, inflation, unemployment, inequality-and presidential politics. Economics working paper archive, Levy Economics Institute.
URL https://EconPapers.repec.org/RePEc:lev:wrkpap:wp_511

Gatti DD, Desiderio S. 2015. Monetary policy experiments in an agent-based model with financial frictions. *Journal of Economic Interaction and Coordination* **10**: 265–286.

Godley W, Lavoie M. 2006. *Monetary economics: an integrated approach to credit, money, income, production and wealth*. Springer.

Góes MCB, Deleidi M. 2022. Output determination and autonomous demand multipliers: An empirical investigation for the us economy. *Economic Modelling* **116**: 106004.

Guerello C. 2018. Conventional and unconventional monetary policy vs. households income distribution: An empirical analysis for the Euro Area. *Journal of International Money and Finance* **85**: 187–214.
URL https://ideas.repec.org/a/eee/jimfin/v85y2018icp187-214.html

Hafemann L, Rudel P, Schmidt J. 2018. Moving Closer or Drifting Apart: Distributional Effects of Monetary Policy. *Manchester School* **86**: 110–136.
URL https://ideas.repec.org/a/bla/manchs/v86y2018is1p110-136.html

Hanson MS. 2004. The "price puzzle" reconsidered. *Journal of Monetary Economics* **51**: 1385–1413.

Harris E, Sammartino F, Office USCB. 2011. Trends in the distribution of household income between 1979 and 2007. Technical report, Congress of the United States, Congressional Budget Office, Washington, D.C. [Pdf] Retrieved from the Library of Congress: https://www.loc.gov/item/2023692972/.

Herradi ME, Leroy A. 2021. Monetary Policy and the Top 1%: Evidence from a Century of Modern Economic History. *International Journal of Central Banking* **17**: 1–41.
URL https://ideas.repec.org/a/ijc/ijcjou/y2021q5a6.html

Inui M, Sudo N, Yamada T. 2017. The effects of monetary policy shocks on inequality in Japan. BIS Working Papers 642, Bank for International Settlements.
URL https://ideas.repec.org/p/bis/biswps/642.html

Kaplan G, Moll B, Violante GL. 2018. Monetary policy according to hank. *American Economic Review* **108**: 697–743.

Kenworthy L, Smeeding T. 2014. 695The United States: High and Rapidly-Rising Inequality. In *Changing Inequalities and Societal Impacts in Rich Countries: Thirty Countries' Experiences*. Oxford University Press. ISBN 9780199687428.
URL https://doi.org/10.1093/acprof:oso/9780199687428.003.0029

Keynes JM. 1930. *A Treatise on Money*. New York: Harcourt, Brace and Company.

Komatsu M. 2023. The Effect of Monetary Policy on Consumption Inequality: An Analysis of Transmission Channels through TANK Models. *Journal of Money, Credit and Banking* **55**: 1245–1270.
URL https://ideas.repec.org/a/wly/jmoncb/v55y2023i5p1245-1270.html

Lenza M, Slacalek J. 2018. How does monetary policy affect income and wealth inequality? evidence from quantitative easing in the euro area. *Journal of Applied Econometrics* .

Lettau M, Ludvigson SC, Steindel C. 2002. Monetary policy transmission through the consumption-wealth channel. *Economic Policy Review* **8**: 117–133.
URL https://ideas.repec.org/a/fip/fednep/y2002imayp117-133nv.8no.1.html

Montecino J, Epstein G. 2015. Did quantitative easing increase income inequality? Working Paper Series 28, Institute for New Economic Thinking. Available at SSRN: https://ssrn.com/abstract=2692637 or http://dx.doi.org/10.2139/ssrn.2692637.

Muinelo-Gallo L, Roca-Sagalés O. 2011. Economic Growth And Inequality: The Role Of Fiscal Policies. *Australian Economic Papers* **50**: 74–97.
URL https://ideas.repec.org/a/bla/ausecp/v50y2011i2-3p74-97.html

Mumtaz H, Theophilopoulou A. 2017. The impact of monetary policy on inequality in the UK. An empirical analysis. *European Economic Review* **98**: 410–423.
URL https://ideas.repec.org/a/eee/eecrev/v98y2017icp410-423.html

Nardi MD, Fella G. 2017. Saving and Wealth Inequality. *Review of Economic Dynamics* **26**: 280–300.
URL https://ideas.repec.org/a/red/issued/16-340.html

Neves PC, Silva SMT. 2014. Inequality and growth: Uncovering the main conclusions from the empirics. *Journal of Development Studies* **50**: 1–21.

Nikiforos M, Zezza G. 2017. Stock-flow consistent macroeconomic models: A survey. *Journal of Economic Surveys* **31**: 1204–1239.
URL https://onlinelibrary.wiley.com/doi/abs/10.1111/joes.12221

O'Farrell R, Rawdanowicz L. 2017. Monetary policy and inequality: Financial channels. *International Finance* **20**: 174–188.
URL https://onlinelibrary.wiley.com/doi/abs/10.1111/infi.12108

Panico C. 1988. *A Monetary Theory of the Rate of Profits*. London: Palgrave Macmillan UK. ISBN 978-1-349-09199-7, 181–191.
URL https://doi.org/10.1007/978-1-349-09199-7_7

Pivetti M. 1991. *An Essay on Money and Distribution*. St. Martin's Press. ISBN 9780312053598.
URL https://books.google.it/books?id=9aZfQgAACAAJ

Riccetti L, Russo A, Gallegati M. 2015. An agent based decentralized matching macroeconomic model. *Journal of Economic Interaction and Coordination* **10**: 305–332.

Saiki A, Frost J. 2014. Does unconventional monetary policy affect inequality? evidence from japan. *Applied Economics* **46**: 4445–4454.
URL https://doi.org/10.1080/00036846.2014.962229

Saiki A, Frost J. 2018. Japan's Unconventional Monetary Policy and Income Distribution: Revisited. Working Papers e126, Tokyo Center for Economic Research.
URL https://ideas.repec.org/p/tcr/wpaper/e126.html

Samarina A, Nguyen AD. 2024. Does monetary policy affect income inequality in the euro area? *Journal of Money, Credit and Banking* **56**: 35–80.
URL https://onlinelibrary.wiley.com/doi/abs/10.1111/jmcb.13017

Schasfoort J, Godin A, Bezemer D, Caiani A, Kinsella S. 2017. Monetary policy transmission in a macroeconomic agent-based model. Research Report 17010-GEM, University of Groningen, Research Institute SOM (Systems, Organisations and Management).
URL https://EconPapers.repec.org/RePEc:gro:rugsom:17010-gem

Shorrocks AF. 1982. Inequality decomposition by factor components. *Econometrica* **50**: 193–211. ISSN 00129682, 14680262.
URL http://www.jstor.org/stable/1912537

Taghizadeh-Hesary F, Yoshino N, Shimizu S. 2020. The impact of monetary and tax policy on income inequality in japan. *The World Economy* **43**: 2600–2621.
URL https://onlinelibrary.wiley.com/doi/abs/10.1111/twec.12782

Taylor L. 1983. *Structuralist macroeconomics*. Basic Books.

Villarreal F. 2014. Monetary policy and inequality in mexico. Mpra paper, University Library of Munich, Germany.
URL https://EconPapers.repec.org/RePEc:pra:mprapa:57074

Yellen J. 2016. Macroeconomic research after the crisis. Speech delivered at the Federal Reserve Bank of Boston.

Yogo M. 2004. Estimating the Elasticity of Intertemporal Substitution When Instruments Are Weak. *The Review of Economics and Statistics* **86**: 797–810.
URL https://ideas.repec.org/a/tpr/restat/v86y2004i3p797-810.html

Appendix A.1

Sequence of events

The sequence of events within each period is:

1. Updating of the capital stock;
2. Computing unit costs and fixing markups;
3. Firms C set desired production, labor and capital demand;
4. Matching in the capital market;
5. Firms-K, based on the percentage of completion of semi-finished products and new orders, set the desired production and labor demand;
6. Matching in the labor market;
7. Production start: If labor demand has been satisfied, the working hours are equally distributed among employees in such a way as to produce exactly the desired quantity. In case labor demand has remained unsatisfied, workers will work full time
8. Based on the quantity produced in sector K in current and last dk periods, the (previous) capital goods demand is satisfied;
9. Supply and demad in the credit market, payment of capital goods and wages (unemployed workers receive government subsidies);
10. Matching in the consumer market;
11. Cash flows computation. Some firms, if necessary, can apply for additional financing, those that do not meet the requirements go bankrupt;
12. Profits computation and dividends payment;
13. Matching in the bond and equity markets;
14. Accounting of CB, Public sector and Commercial bank

Appendix A.2

Capital stock, amortization and unit costs computations

The capital stock in period t is composed of the residuals of capital goods installed in the previous $z+1$ periods (vintage capital goods), with z representing the useful life of the capital good:

$$k_{t,i} = \sum_{j=t-z+1}^{t} k_{j,i}^{ins} \left(\frac{j+z-t}{z} \right),$$

where $k_{j,i}^{ins} = I_{t-dk,i}$ is the amount of capital installed in period j and corresponds to the gross investment carried out in dk previous periods. The absolute deterioration is constant, the total deterioration ($\zeta_{t,i}$) in each period is composed of the sum of the deterioration of capital goods installed in the previous z periods (including the current one):

$$\zeta_{t,i} = \sum_{j=t-z+1}^{t} \frac{k_{j,i}^{ins}}{z}.$$

The amortization for computing unit cost includes both the cost of capital and the cost of debt service considering the full leverage. The amortization for computing profits considers the realized leverage and is defined as follows:

$$\Lambda_{t,i} = \frac{1}{a\ z} \sum_{j=t-z+1}^{t} p_{i,indexK} k_j^{ins} \left(1 + r_j bl_j\right) (j + z - t),$$

where r_j e l_j represent, respectively, the interest rate in the period in which the debt was contracted and the *leverage* realized in purchasing the capital good.

$K_{j,i}^{ins}$ is the installed capital in period j from firm i and $p_{i,indexK}$ is its price (because z is the useful life of the capital good, 3.10 and 3.11 go back up to a maximum of z periods in the computation of amortization and depreciation). $a = \sum_{i=1}^{z} \frac{i}{z}$ e $b = \frac{1}{a\ z} \sum_{i=1}^{z} \frac{i^2+i}{2}$ are the multiplying factors for the calculation, respectively, of the interest accrued on loan granted in a given period and the (potential) cumulated production (in correspondence with the normal degree of capacity utilization) over the useful life of capital good. See Di Domenico (2020) for an explanation of amortization and unit cost computation and why this should be preferred to others commonly used within AB literature.

Appendix B

Table 1: Balance sheet matrix

Assets	**Households**	**Firms K**	**Firms C**	**Banks**	**Government**	**CB**	$\sum$
Check deposits	M_h^c	M_k^c	M_c^c	$-M^c$			0
Time deposits	$+M_h$			$-M$		0	0
Reserves				$+H_b$		$-H$	0
Advances BC				$-A$		$+A$	0
Loans			$-L_c$	$+L$			0
NPL			$+NL_c$	$-NL$			0
Fixed capital			$+K$				$+K$
Inventories			$+INV$				$+INV$
Equities	$+p_eE$		$-p_eE$				0
Public bonds	$+B_h$			$+B_b$	$-B$	$+B_{CB}$	0
Net Wealth	$-V_h$	$-V_k$	$-V_c$	0	$+V_G$	$-V_{CB}$	$-K_f$
$\sum$	0	0	0	0	0	0	0

Table 2: Transactions Matrix

Flows	**Households**	**Firms K**	**Firms C**	**Gov.**	**Bank**		**CB**		$\sum$
					Current	Capital	Current	Capital	
Consumption	$-C$		$+C$						0
Investments		$+I$	$-I$						0
Public exp.			$+G$	$-G$					0
Unemp. Benefit	$+U$			$-U$					0
Wages	$+W$	$-W_k$	$-W_c$						0
Tax	$-T$			$+T$					0
Dividends Firms	$+Div_F$	$-Div_k$	$-Div_c$						0
Dividends Bank	$+Div_B$				$-Div_B$				0
Profits CB				$+F_{CB}$			$-F_{CB}$		0
Recapitalization	$-K_r$		$+K_r$						0
Int. Deposits	$+r_m M_{h,t-1}$				$-r_m M_{t-1}$				0
Int. Loans		$-r_l L_{k,t-1}$	$-r_l L_{c,t-1}$		$+r_l L_{t-1}$				0
Int. Bond	$+r_b B_{h,t-1}$		$-r_b B_{t-1}$		$+r_b B^b_{t-1}$		$+r_b B_{CB,t-1}$		0
Int. Reserves					$+r_r H_{t-1}$		$-r_r H_{t-1}$		0
Int. Advances					$-r_a A_{t-1}$		$+r_a A_{t-1}$		0
Δ Check deposits	$-\Delta M^c_h$	$-\Delta M^c_K$	$-\Delta M^c_C$			$+\Delta M^c$			0
Δ Time deposits	$-\Delta M_h$					$+\Delta M$			0
Δ Loans		$+\Delta L_k$	$+\Delta L_c$			$-\Delta L$			0
Δ Bond	$-\Delta B_h$			$+\Delta B$		$-\Delta B_b$		$-\Delta B_{CB}$	0
Δ NPL			$-\Delta NPL_c$			$+\Delta NPL$			0
Δ Equities firms	$-\Delta e_c p_e$		$+p_e(\Delta e_c - \Delta e^f_c)$						0
Δ Reserves						$-\Delta H$		$+\Delta H$	0
Δ Advances						$+\Delta A$		$-\Delta A$	0
$\sum$	0	0	0	0	0	0	0	0	0

Appendix C

Unique contribution to inequality				Generalized Entropy (c = 0)				Generalized Entropy (c = 1)			
Wage	Div. F.	Div. B.	Fin. r.	Wage	Div. F.	Div. B.	Fin. r.	Wage	Div. F.	Div. B.	Fin. r.
0.014	0.811	0.076	0.099	1.710	-0.740	-0.069	0.099	-0.523	1.301	0.122	0.099
0.016	0.809	0.076	0.099	1.726	-0.755	-0.071	0.099	-0.525	1.303	0.122	0.099
0.019	0.806	0.075	0.099	1.742	-0.769	-0.072	0.099	-0.525	1.304	0.122	0.099
0.023	0.802	0.075	0.099	1.755	-0.781	-0.073	0.099	-0.524	1.302	0.122	0.099
0.030	0.796	0.075	0.099	1.762	-0.788	-0.074	0.099	-0.518	1.297	0.121	0.099
0.040	0.787	0.074	0.099	1.759	-0.785	-0.074	0.099	-0.504	1.284	0.120	0.099
0.061	0.768	0.072	0.099	1.728	-0.757	-0.071	0.099	-0.468	1.252	0.117	0.099
0.113	0.720	0.067	0.099	1.613	-0.651	-0.061	0.099	-0.366	1.158	0.108	0.099
0.352	0.502	0.047	0.099	1.051	-0.138	-0.013	0.099	0.125	0.709	0.066	0.099

Table 3: Factor contribution for different measures of inequality as the initial distribution in corporate and bank shares increases

		Income inequality		Wealth inequality	
		Short-run	Long-run	Short-run	Long-run
Asymmetrical distribution B $k_f(0) < k_b(2)$	H_p^0	↑	↑	↑	↑
	$H_p^{1,2}$	↑	↑	↑	↑
BAU $k_b = k_f = 2$	H_p^0	↑	↑	↑	↑
	$H_p^{1,2}$	↑	↑	↓	↑
TD $k_b = k_f = 0$	H_p^0	↑↓	↑	↓	↑
	$H_p^{1,2}$	↑↓	↑	↑	↑
Asymmetrical distribution F $k_f(2) > k_b(0)$	H_p^0	↓	↓	↑	↓
	$H_p^{1,2}$	↓	↓	↓	↓

Table 4: The impact of MP for different endowments distributions and degrees of portfolio heterogeneity

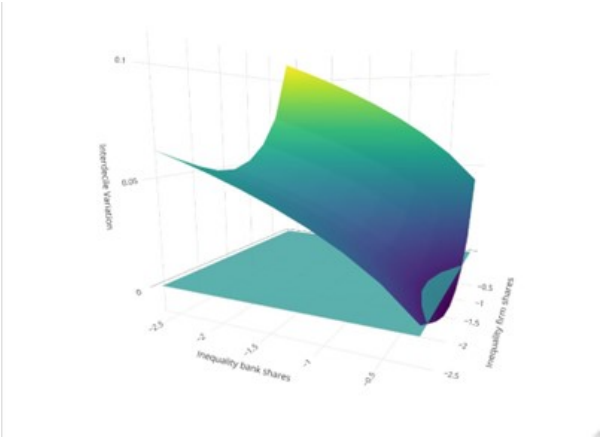


Figure 11: The impact of monetary policy on the inter-decile ratio for different combinations of the initial inequality in the distribution of firms and bank shares.

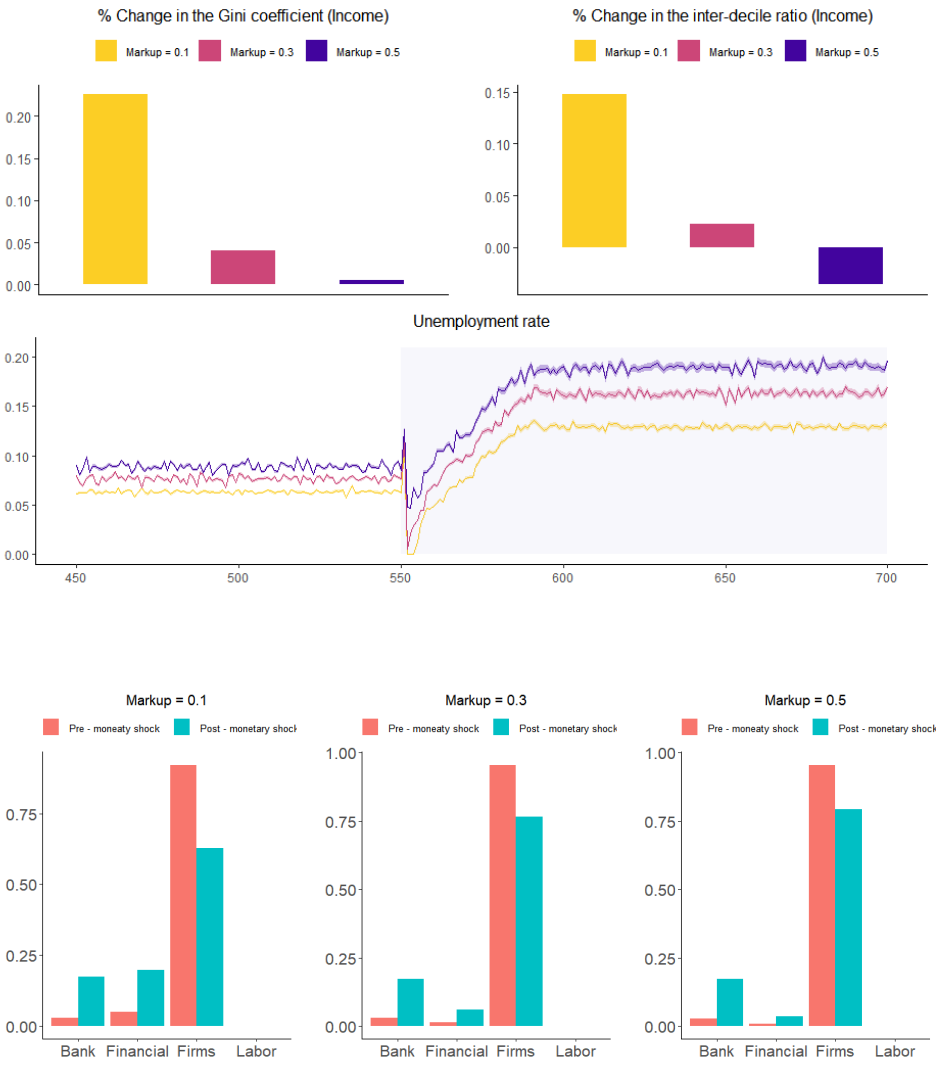


Figure 13: The impact on inequality measures for different values of the markup ($k_b = k_f = 2$)

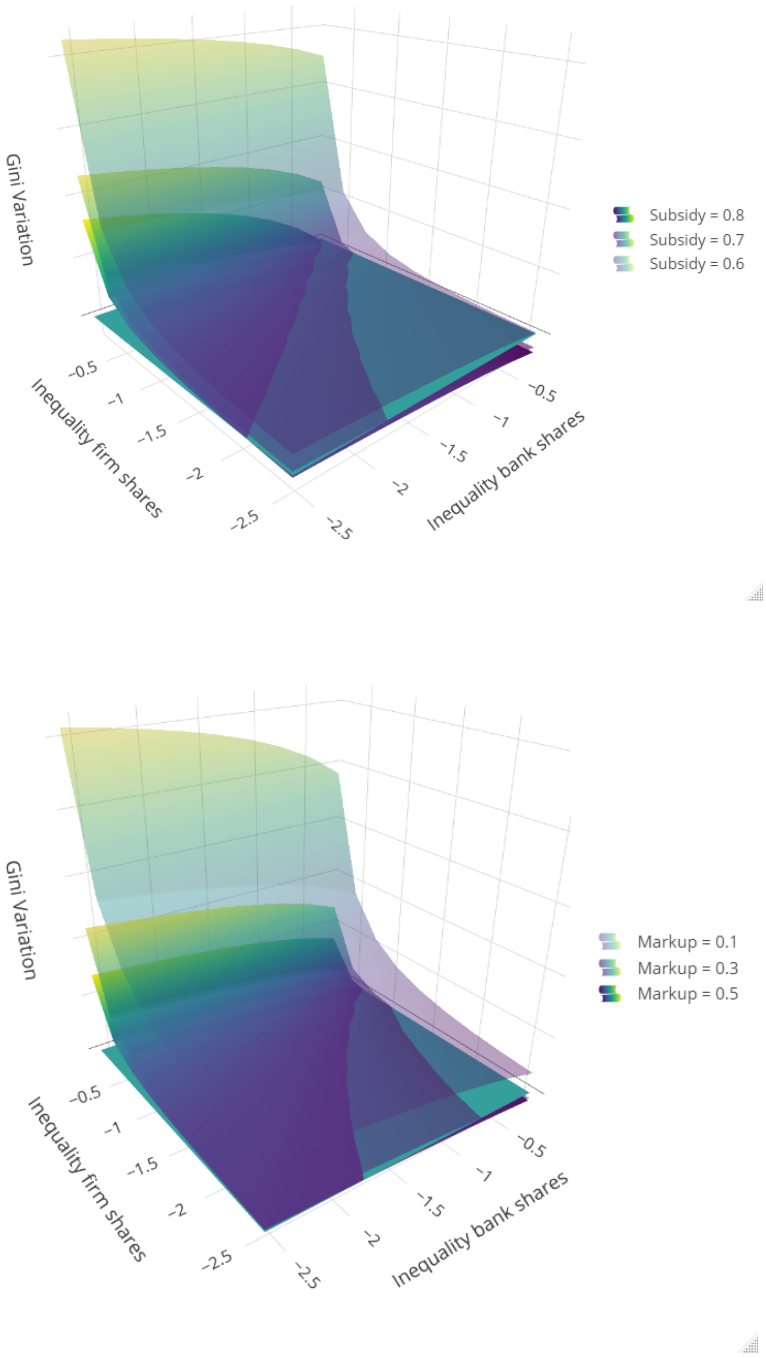


Figure 12: The impact of restrictive monetary policy on Gini for different values of markup and unemployment subsidies

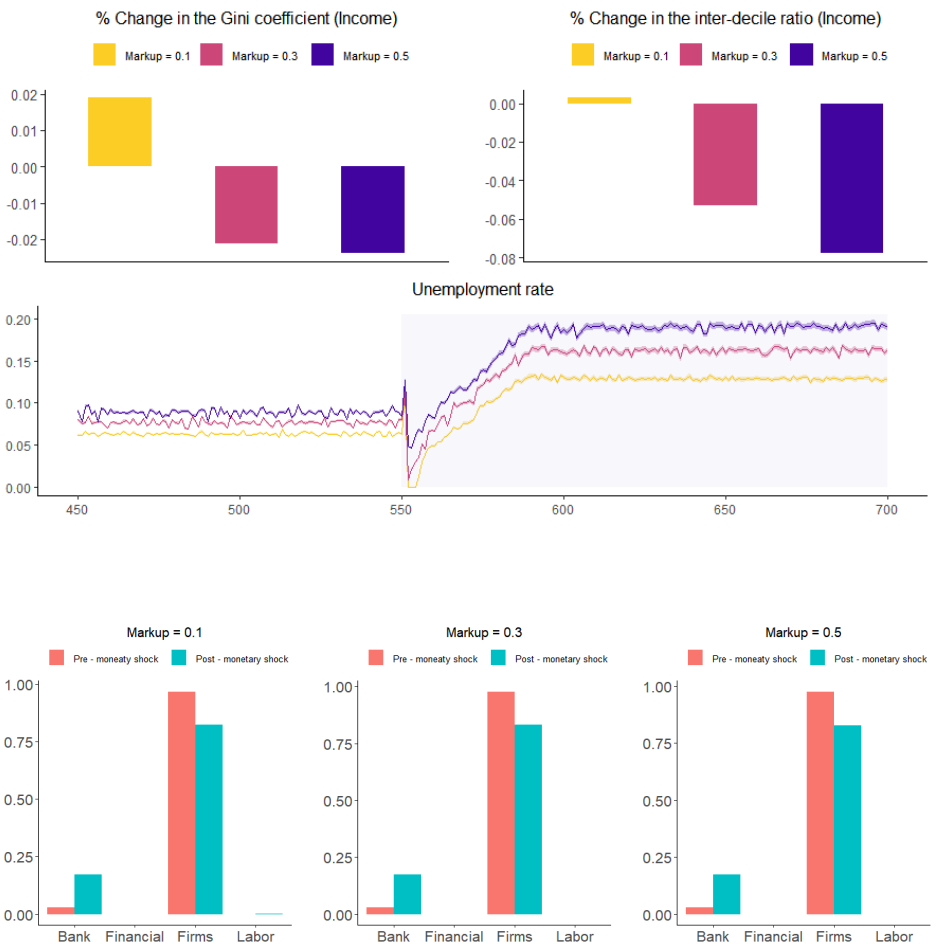


Figure 14: The impact on inequality measures for different values of the markup - $k_b = 0; k_f = 2$

Appendix D

The relationship between z (% Gini variation) and x (k_b) is well-approximated by the following function: $z = a + b(e^x)^c$. The relationship between z and k_b for different values of k_f is reported in the following Figure.

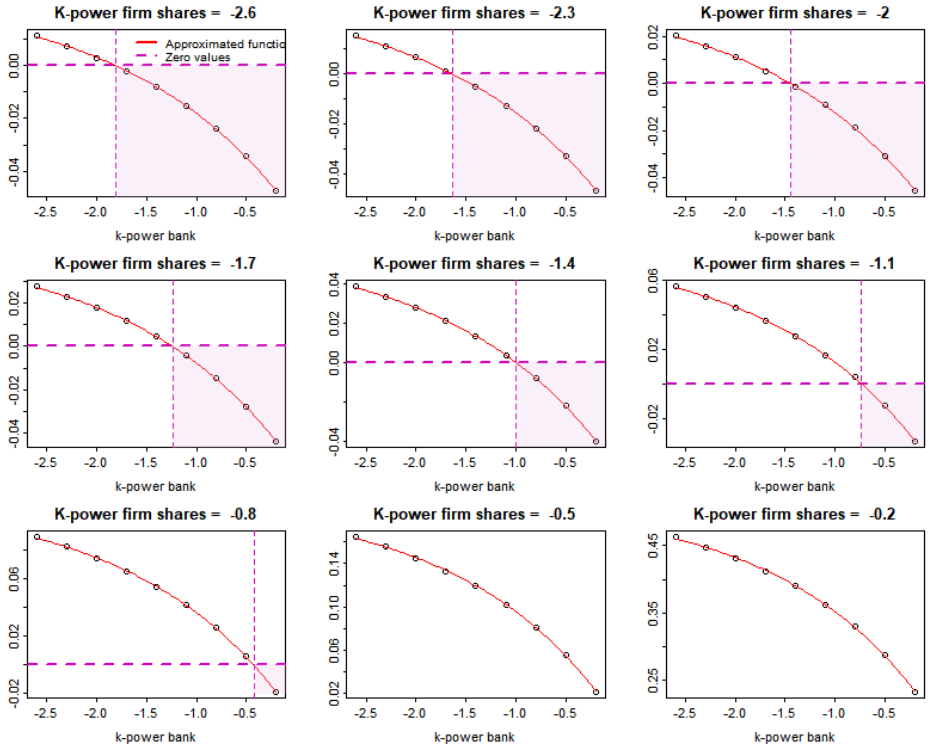


Figure 15: Approximating % Gini variation in function of k_b

Then, z can be rewritten as a function of k_b and k_f estimating a,b and c in function of k_f: $z = a(y) + b(y)(e^x)^(c(y))$. The graphical results of the estimation are reported in the following figure:

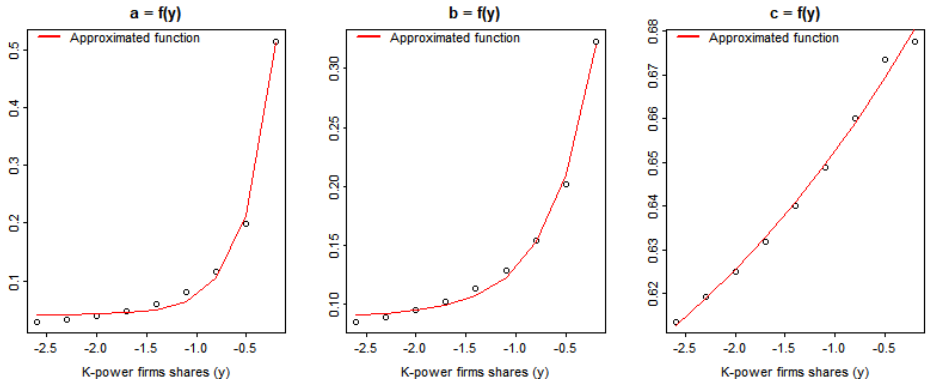


Figure 16: Approximating a,b and c in function of k_f

The general approximating function is:

$$z = a + b(e^{k_f})^c - [d + f(e^{k_f})^g] \cdot (e^{k_b})^{h+i(e^{k_f})^l} \tag{58}$$

The values of a,b,c,d,f,g,h,i,l have been estimated using the above-reported non-linear function, the following tables reports the estimated results.

	Estimate	Std. Error	t value	Pr(>|t|)
p	0.92	0.05	17.22	0.00
o	0.04	0.01	6.87	0.00
h	3.33	0.24	13.76	0.00

	Estimate	Std. Error	t value	Pr(>|t|)
pp	0.35	0.01	24.95	0.00
oo	0.09	0.00	25.56	0.00
hh	2.16	0.15	14.78	0.00

	Estimate	Std. Error	t value	Pr(>|t|)
ppp	0.15	0.03	4.31	0.01
ooo	0.54	0.04	15.15	0.00
hhh	0.28	0.10	2.79	0.03

The approximated and simulation resulting function almost overlaps (see next Figure).

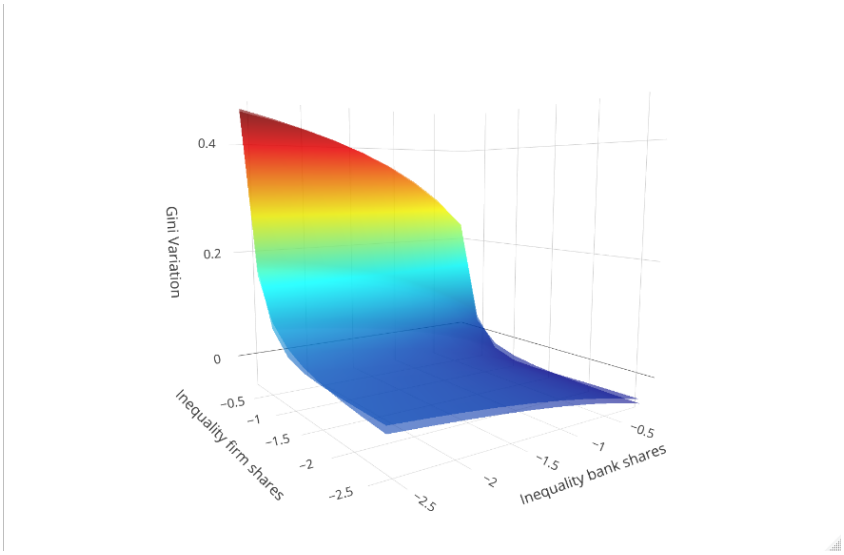


Figure 17: The impact on interdecile ratios - BAU and TD scenarios

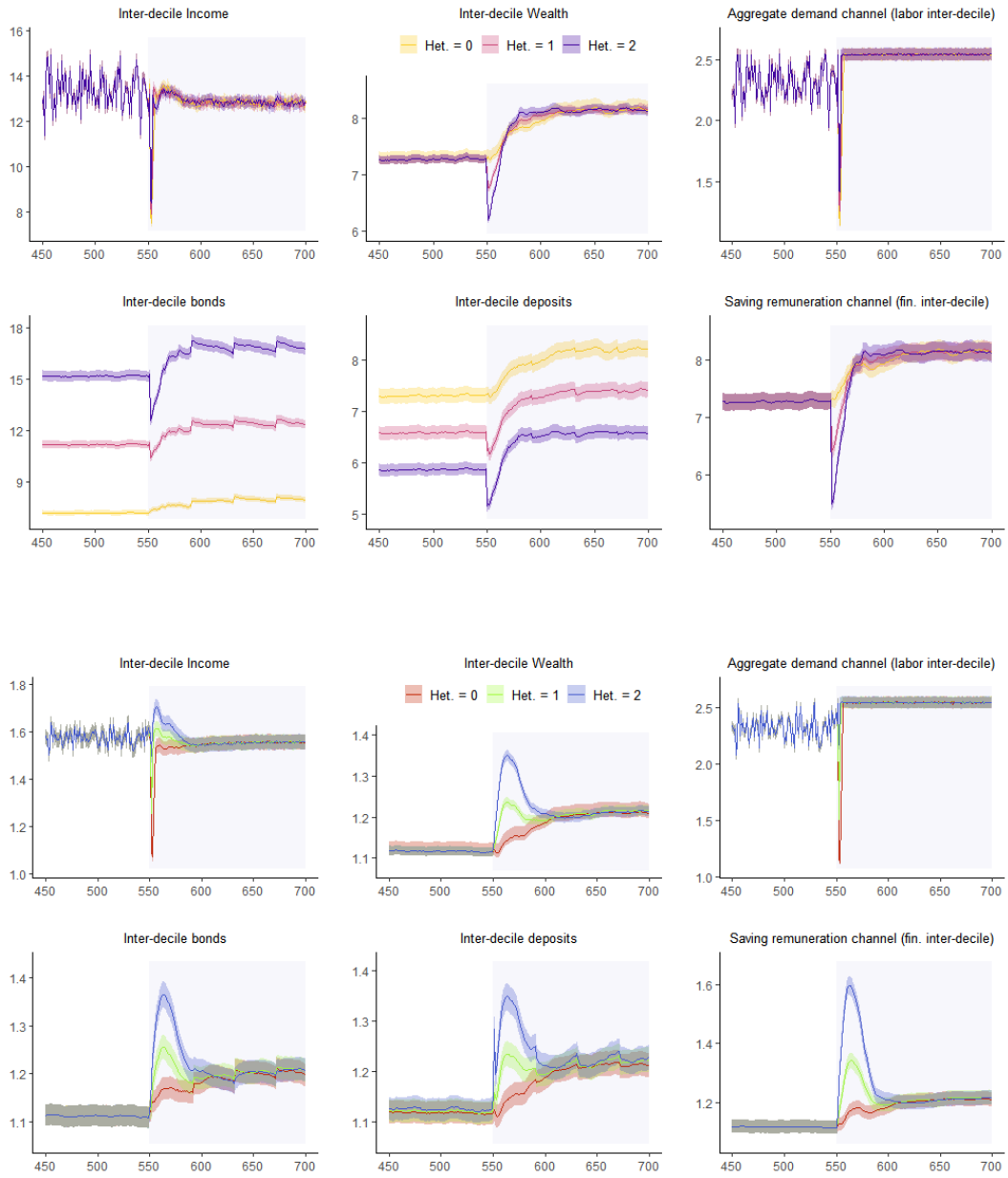


Figure 18: The impact on interdecile ratios - BAU and TD scenarios