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Monetary policy rules and the inequality-augmented Phillips curve

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Abstract

We explore the relationship between inequality, unemployment, and inflation by considering the evidence that low-wage workers are more exposed to business cycle fluctuations. The analysis is undertaken in an extended version of the stock-and-flow consistent agent-based model by Rolim et al. (2023), in which inflation and inequality result from the social conflict over income distribution. The inflation-unemployment-inequality nexus leads to the inequality-augmented Phillips curve relating higher levels of unemployment to lower inflation rates and more inequality. We then perform two sets of experiments to investigate the implications of this nexus further. The first experiment shows that the decrease in low-wage workers' bargaining power could explain the flattening of the Phillips curve and the increase in income and wage inequalities. The second experiment contrasts different monetary policy rules and compares the implications for inequality dynamics. In line with the inequality-augmented Phillips curve, the rules have important implications for wage and income inequalities: a monetary policy rule that prioritizes low inflation rates is associated with higher unemployment and higher inequality levels.

Keywords: Phillips curve, inflation, unemployment, inequality, monetary policy, bargaining power.

JEL codes: C63, D3, E2, E3, E4.

1 Introduction

The global acceleration of inflation in the aftermath of the Covid-19 crisis and amid the war in Ukraine has brought the potential trade-offs faced by Central Banks back to the center of the economic policy debate. In addition to well known questions over the need to generate a recession and a substantial rise in unemployment as a means to fight inflation, the sharp monetary policy tightening worldwide is raising concerns over its consequences for inequality within and between countries. In particular, while the cost of living crisis is disproportionately affecting those at the bottom of the world income distribution, interest rates hikes may also harm low-wage workers the most.

A prolific recent empirical literature has focused on estimating the effects of monetary policy on income distribution, with a majority of papers finding that monetary contractions lead to a persistent increase in inequality (see Kappes (2021) for an extensive survey). In what appears to be one of the main channels of transmission that could potentially explain these results, previous studies have also examined the cyclical relationship between employment and wage inequality. Mocan (1999) finds that, by worsening the position of low-wage groups, economic downturns can bring about an increase in inequality. A possible explanation for the disproportionate income loss faced by workers at the bottom of the distribution is the existence of heterogeneity in the sensitivity of their level of employment to the cycle. Indeed, a study by Solon et al. (1994) presents evidence that the cyclical volatility of unemployment is higher for low-wage groups, with their share in total employment (or worked hours) being pro-cyclical. More recently, Mueller (2017) shows that there is an increase in the pre-displacement wage and in the skill level of unemployed workers during recessions. This means that unemployed workers become more similar to the employed workers in recessions, despite the average unemployed worker having a lower skill level. As argued by the author, this finding is compatible with the observed increase in participation of high-wage workers during downturns.

These results reinforce the overall findings of a number of studies carried out in the 1970s and 1980s for the US economy, which suggest that young workers, unskilled workers, and less educated workers tend to face larger fluctuations in their employment rates (Clark and Summers, 1980, Kydland, 1984, Mitchell et al., 1985, Okun et al., 1973). For instance, when comparing the most educated with the least educated groups in his sample, Kydland (1984) finds that the number of hours worked by the latter presents a higher standard deviation and lower average than the former group.

In spite of mounting empirical evidence on the distributional impacts of monetary policy and the existence of a cyclical component of inequality, the standard macroeconomic literature still addresses any potential trade-offs faced by policymakers when deploying monetary policy tools based on the aggregate relationship between unemployment and inflation. This paper is an attempt to assess the distributive implications of monetary policy by adding a third dimension to the above-mentioned relationship, namely income inequality. Based on what we are calling an inequality-augmented Phillips curve, we are able to expand the analysis of the trade-offs faced by Central Banks to consider the role of heterogeneity in labor markets and the consequent response of wage disparities. In order to do so, we rely on an extended version of the stock-and-flow consistent agent-based (AB) model developed by Rolim et al. (2023), in which workers are affected differently by demand shocks. By exploring the inflation-unemployment-inequality nexus, we are able to investigate the role of changes in workers' bargaining power for the shape of the Phillips curve, as well as the distributive implications of different monetary policy rules.

Our paper relates both to the growing AB literature focused on the role of labor market institutions, policies, and technological progress as drivers of income inequality (Caiani et al., 2019, Carvalho and Di Guilmi, 2020, Dosi et al., 2017, Mellacher and Scheuer, 2021, Rolim et al., 2023), and to the few ABMs that examine the format of the Phillips Curve (Chen and Desiderio (2018), Guilmi and Fujiwara (2022)). Moreover, a number of recent papers in the AB literature focus on the effects of monetary policy on macroeconomic indicators (output growth, employment, and the inflation rate) and its key transmission mechanisms (Dosi et al., 2013, 2015, Gatti and Desiderio, 2015, Schasfoort et al., 2017). The model and experiments presented in this paper contribute to these three strands of the AB literature.

The remaining of this article is organized as follows. Section 2 presents the AB model structure. Section 3 presents the results for the baseline configuration and the construction of the inequality-augmented Phillips curve. Section 4 discusses the flattening of the Phillips curve and relates it to the reduction in the direct workers' bargaining power. Section 5 explores the effect of different monetary policy rules. Section 6 further analyses the model results through a sensitivity analysis. Finally, Section 7 presents concluding remarks.

2 The model

The model is a stock-and-flow consistent AB model in which inflation and income inequality result from the social conflict over income distribution between workers and firms (Rowthorn, 1977). This conflict is, nonetheless, mediated by monetary policy.

Our analysis is based on an extended version of the model put forward in Rolim et al. (2023), whose structure shares many similarities with other AB macroeconomic models (Dawid and Delli Gatti, 2018, Fagiolo and Roventini, 2017). Its main novelties are a novel wage bargaining process between workers and firms capturing the conflict over nominal wages, a new strategic component in mark-up rates, and a three-class structure based in Mohun (2006) that connects the functional and personal income distribution. In addition to reproducing numerous macro and micro empirical regularities, this model structure reproduces a wide variety of stylized facts related to income inequality. This latter property suggests that the model offers an adequate framework for the analysis undertaken in this paper.

More specifically, we extend the model in Rolim et al. (2023) by incorporating an explicit monetary policy rule and adding emulation consumption and household debt as additional channels through which monetary policy affects aggregate income (together with firms' debt, which was already included in the original model). Given our research question in this paper, a major simplification is that the innovation dynamics has been deactivated and thus labor productivity fluctuates around a constant level. This also means that the model captures cyclical output fluctuations without presenting long-term growth.

The model structure and the interactions between the agents are represented in Figure 1.[1] The economy is composed of a monopolist capital goods firm, heterogeneous consumption goods firms, a monopolist bank, heterogeneous households, which are divided into three heterogeneous classes (direct workers, indirect workers, and capitalists), and a public sector represented by a government and a central bank. The next subsections summarize the main equations for each type of agent.[2]

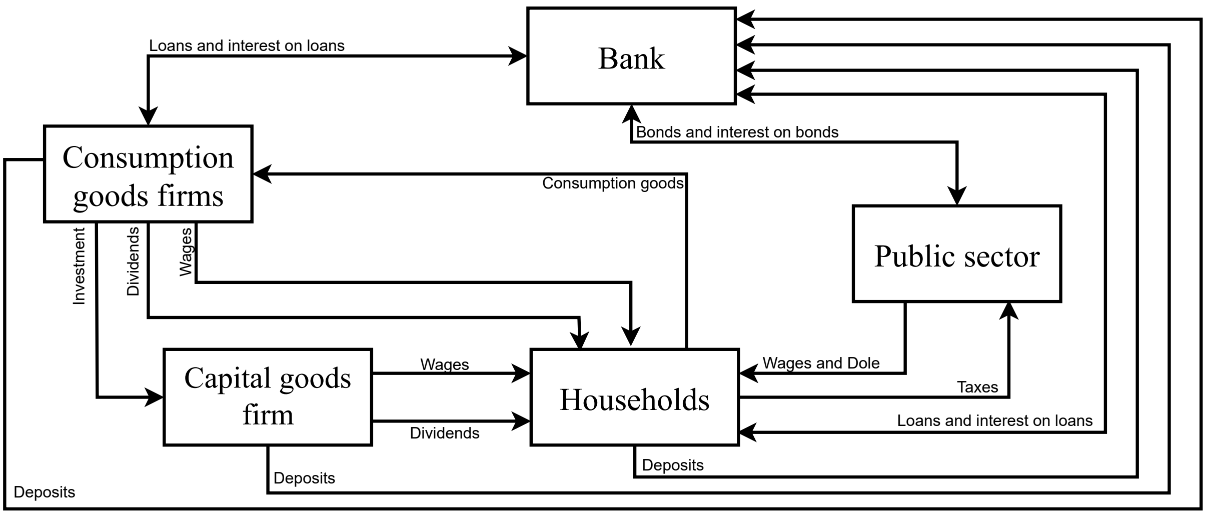


Figure 1: Model structure
Note: arrows point from paying sector to receiver sector.

2.1 The capital goods firm

The monopolist capital goods firm produces machines that are acquired by the consumption goods firms. These machines produce up to Q_m^{fc} units of consumption goods and are characterized by a direct labor productivity of y^c. Each machine can be used for a maximum of T^k periods, after which they are scrapped.

The desired production level for the capital goods firm is equal to the investment demand by the consumption goods firms ($\sum_{c=1}^{N^c} I_{c,t}^D$). After these firms place their orders, the capital goods firm sets its labor demand for direct and indirect workers, with the former being directly involved with production and the

[1] Appendix A presents the transaction-flow matrix for this economy. These relations are checked in the simulations to guarantee stock-and-flow consistency.

[2] The following subscripts are used throughout the text: h for households, c for consumption goods firms, m for machines, k for the capital goods firm, f for both firms, b for the bank, and g for the public sector. The superscripts res, man, ind, dir, and cap refer to researchers, managers, indirect workers, direct workers, and capitalists, respectively, while j refers to households from all classes. The superscripts \$, D, d , and e identify nominal, demand, desired, and expected variables, respectively. Variables that are not accompanied by \$ are real variables. Finally, the subscript t identifies the time period.

latter acting as managers and supervisors. The labor demand for each type of workers is given by Equations 1 and 2 respectively:[3]

$$L_{k,t}^{D,dir} = \left\lceil \frac{\sum_{c=1}^{N^c} I_{c,t}^{D}}{y^k} \right\rceil \tag{1}$$

$$L_{k,t}^{D,ind} = \left\lfloor \rho_1 L_{k,t}^{D,dir} \right\rceil \tag{2}$$

where y^k is the direct workers' productivity in the production of capital goods and ρ_1 is the fixed number of managers per direct worker.

The price of the new machines depends on a fixed mark-up rate applied to the unit labor costs, as follows:

$$p_{k,t}^{\$} = (1+\mu_k)\frac{(w_{k,t}^{dir,\$} + \rho_1 w_{k,t}^{ind,\$})}{y^k} \tag{3}$$

where μ_k is a fixed mark-up rate and $w_{k,t}^{j,\$}$ is the wage rate for each type $j = dir, ind$ of worker.

2.2 The consumption goods firms

The consumption goods sector is composed of N^c firms that produce a homogeneous nonperishable good using labor and capital goods. Production is sold to the households in the consumption goods market, which is characterized by imperfect competition. Accordingly, firms' sales depend on their market shares.

Firms form their sales expectations based on their past experience in the consumption goods market, in line with empirical evidence on adaptive expectation formation (Gennaioli et al., 2016, Boneva et al., 2020). This is formally represented as follows:

$$Q_{c,t}^{D,e,t} = \sum_{i=1}^{4} \omega_i Q_{c,t-i}^{D} \tag{4}$$

where $Q_{c,t-i}^{D}$ is the demand for the firms' products in $t-i$ and $\omega_1 > \omega_2 > \omega_3 > \omega_4 > 0$ are fixed parameters ($\sum_i^4 \omega_i = 1$). The desired production level ($Q_{c,t}^{d}$) is set by also taking into consideration a fixed desired share of inventories (n^{IN}) relative to $Q_{c,t}^{D,e,t}$ and deducting the inventory level from the previous period.

The demand for direct and indirect workers is given by Equations 5 and 6 respectively. Also in this sector the direct workers are the ones directly producing the goods. The indirect workers are hired both to supervise the direct workers and to manage the firm, so they are demanded in proportion to the demand for direct workers and to the size of the firm (proxied by the number of direct workers at full capacity utilization).[4]

$$L_{c,t}^{D,dir} = \left\lceil \frac{Q_{c,t}^{d}}{y^c} \right\rceil \tag{5}$$

$$L_{c,t}^{D,ind} = \lfloor \rho_2 L_{c,t}^{D,dir} + \rho_3 L_{c,t}^{dir,fc} \rceil \tag{6}$$

where $\rho_{2,3} > 0$ are parameters and $L_{c,t}^{dir,fc}$ is the demand for direct labor at the full capacity production level.

Prices are set by adding a variable mark-up rate over unit labor costs computed at the desired capacity utilization level. There are two levels of mark-up determination, reflecting firms' position relative to their competitors and relative to workers. As reported in Equation 7, the first component ($\mu_{c,t}^{*}$) depends on the

[3]The labor demand for direct workers is rounded up to guarantee that the desired production level is reached (as long as the firm can effectively hire these workers in the labor market) and the labor demand for indirect workers is rounded to the closest integer so that a stable average relation between the demand for indirect and direct workers is obtained.

[4]As explained in Rolim et al. (2023), since the size of the consumption goods firms can be measured through their production capacity, we incorporate to this sector the idea that managers also perform office administration activities that are, to some extent, independent from the current production of firms. Thus, some indirect workers are overhead workers.

evolution of firms' market share, which contains information with respect to each firm's position relative to its competitors.[5] The second component ($m_{c,t}$) is the deviation from $\mu^*_{c,t}$. As reported in Equation 8, it depends on the evolution of nominal wages, thus capturing firms' situation *vis-à-vis* workers and connecting workers' bargaining power with firms' pricing decisions.[6]

$$\mu^*_{c,t} = \mu^*_{c,t-1}\left[1 + \nu_1\left(\frac{ms_{c,t-1}/\sum_{i=1}^{N^c} ms_{c,t-1}}{ms_{c,t-2}/\sum_{i=1}^{N^c} ms_{c,t-2}} - 1\right)\right] \tag{7}$$

$$m_{c,t} = \nu_2 m_{c,t-1} - \nu_3\left(\frac{\Delta\Gamma^{u,\$}_{c,t}(u^d)}{\Gamma^{u,\$}_{c,t-1}(u^d)}\right) \tag{8}$$

where $1 > \nu_1 > 0$ is the sensitivity of the mark-up to the domestic market share, $1 > \nu_2 > 0$ is the persistence in the mark-up deviation, $1 > \nu_3 > 0$ is the sensitivity of the mark-up deviation to changes in unit costs, and $\Gamma^{u,\$}_{c,t}(u^d)$ is firms' unit costs at the desired capacity utilization rate (u^d). Prices are given by $p = (1 + \mu^*_{c,t} + m_{c,t})\Gamma^{u,\$}_{c,t-1}(u^d)$.

Aggregate demand for consumption goods is split between firms according to their market shares, which evolve following a "quasi" replicator dynamics. Accordingly, market shares depend on firms' competitiveness ($E_{c,t}$), which is given by the average between the normalized price level ($p^n_{c,t}$) and normalized unfilled demand level ($l^n_{c,t}$) (Dosi et al., 2010, Dweck et al., 2020, Silverberg et al., 1988). Equations 9 and 10 represent the firms' competitiveness and their market shares respectively.

$$E_{c,t} = \frac{(1 - p^n_{c,t}) + (1 - l^n_{c,t})}{2} \tag{9}$$

$$ms_{c,t} = ms_{c,t-1}\left(1 + \nu_4\frac{E_{c,t} - \bar{E}_t}{\bar{E}_t}\right) \tag{10}$$

where $\nu_4 > 0$ is a parameter capturing the market share sensitivity to competitiveness and $\bar{E}_t$ is the average competitiveness of the consumption goods firms weighted by their market shares in $t - 1$.

Firms invest in new machines whenever the expected capacity utilization is above the desired level. They first calculate their desired capital stock in $t + 1$, which depends on the desired capacity utilization rate ($Q^{fc,d}_{c,t} = Q^{e,t+1}_{c,t}/u^d$). Then, the desired investment is composed by the replacement investment, which is the investment level required to maintain the current production capacity by replacing machines older than T^k periods (as long as firms do not wish to reduce their capital stock), and the expansion investment, which is given by the difference between the current full capacity and $Q^{fc,d}_{c,t}$ multiplied by an investment adjustment speed parameter ($1 > v > 0$). This means that firms react slowly to changes in expected sales given the high uncertainty levels inevitably associated with investment.

When needed, these firms can ask for a loan from the bank in order to cover their production and investment costs. The bank only grants credit to clients considered creditworthy. Firms are evaluated by the ratio of interest payments to their average revenue in the previous four periods (adjusted to the current price level). They are considered creditworthy as long as this ratio is below a maximum ratio R.

Finally, the established firms exit the market whenever their market share is below a threshold given by the $1 > ms^{min} > 0$ parameter, when they have no production capacity, or when they have no deposits available and cannot ask for loans to cover their production or investment projects (in other words, when they are completely liquidity constrained). Each exited firm is replaced by a new firm, which is owned by ρ_4 capitalists selected among the capitalists whose previous firm left the market in the period. Their initial

[5]This specification is widely adopted in AB models, such as the KS model (Dosi et al., 2010) and the Micro-Macro Multisectoral model (Dweck et al., 2020).

[6]This second component captures how firms strategically deal with cost changes, as reported in the empirical evidence provided by Bertola et al. (2012). It also allows nominal wage adjustments to lead to lower mark-up rates because firms avoid fully passing on to prices the increase in costs in an effort to protect their competitiveness.

investment is equal to a share $1 > \delta > 0$ of the average capital stock of the established firms. For T^c periods after their entry, they receive all requested loan and are not subject to the exit criteria.

2.3 The bank

The banking sector is represented by a monopolist bank, which provides credit to firms and households and buys bonds from the government. It also holds non-interest bearing deposits owned by all private agents in the model. The interest rate on loans is equal to the interest rate set by the central bank (i_t).

2.4 The households

Households are split into three heterogeneous classes that are involved in different ways with the production process (Mohun, 2016). Accordingly, there are N^{dir} direct workers, N^{ind} indirect workers, and N^{cap} capitalists.[7] Capitalists own the firms and receive profit dividends (each firm is owned by ρ_4 capitalists), while workers receive wages from firms when employed and unemployment benefits from the government when unemployed.

Workers' desired wage depends on their employment history and on the inflation rate. Workers who were employed in the previous period desire a wage equal to their previous wage adjusted by the inflation rate (if positive) plus a positive adjustment factor γ. Workers who were unemployed in the previous period adjust downwards their desired wage by a factor γ multiplied by the number of periods in which they were unemployed since their last employment. Formally, workers' desired wage is given by Equation 11:

$$w_{h,t}^{d,\$} = \begin{cases} w_{h,t}^{d,*,\$}(1+\gamma) & \text{if } T_{h,t}^{w} = 0 \\ w_{h,t}^{d,*,\$}(1-\gamma T_{h,t}^{w}) & \text{otherwise.} \end{cases} \tag{11}$$

where $w_{h,t}^{d,*,\$}$ is the previous strictly positive wage adjusted by the inflation rate (if positive), $\gamma > 0$ is a parameter capturing the sensitivity of the desired wage to the employment status, and $T_{h,t}^{w}$ is the number of periods since the workers' last employment (if a worker was employed in $t-1$, $T_{h,t}^{w} = 0$).

Whenever the wage offered by the current employer is below their individual desired wage and below the average wage in the market, workers consider looking for a new job. This decision is based on a random draw from a Bernoulli distribution with the probability of success given by a parameter $s > 0$ multiplied by the difference between the wage offered by the current employer and the average wage in the market divided by the latter. When employed workers search for new job positions, they accept a job offer if the wage offered is above the wage offered by their current employer. On the other hand, unemployed workers are always looking for new job positions and accept any offer made by firms.

Households' consumption depends on their income and on emulation consumption (Duesenberry, 1949). Households have different propensities to consume out of income, since low-income households tend to consume relatively more out of their income (Dynan et al., 2004, Taylor et al., 2017). In addition, households have a certain degree of emulation in an effort to achieve the consumption pattern of the class immediately above their own class. Formally, consumption is determined as follows:

$$C_{h,t}^{D,\$} = c_1 \bar{C}_{t-1} \bar{p}_{c,t}^{*} + (1-c_1) c_2^{j} ((w_{h,t}^{\$} + \Pi_{h,t-1}^{h,\$})(1-\tau) + d_{h,t}^{\$}) \tag{12}$$

where $1 > c_1 > 0$ is the degree of consumption emulation, $\bar{C}_{t-1}$ is the average real consumption of the class above (for workers) or the maximum value between the average real consumption of capitalists or their own past real consumption (for capitalists), $\bar{p}_{c,t}^{*}$ is the average price level, $1 > c_2^{dir} > c_2^{ind} > c_2^{cap} > 0$ is the class-specific propensities to consume out of income, $w_{h,t}^{\$}$ is wages, $\Pi_{h,t-1}^{h,\$}$ is profit dividends, τ is the tax rate on income, and $d_{h,t}^{\$}$ is the tax-exempt unemployment benefit.

[7] The initial conditions of the simulations are calibrated so that the percentage of each type of class in the total households is similar to their participation in the total of tax units in the USA economy in 2012 (Mohun, 2016, p. 358)

Households can also request a loan from the bank in order to finance consumption when their deposits are insufficient to cover their desired consumption. The bank provides credit to households as long as the relation between the interest payments and their expected income (previous income adjusted by the average inflation rate in the previous T^i periods) is below the R threshold.

2.5 The public sector

The public sector is composed of a government and a central bank. The government collects taxes on households' income at a tax rate τ and pays unemployment benefits to unemployed workers at a value equal to the minimum wage. It also hires a fixed number of public servants from each class (L_g^{dir} and L_g^{ind}), who are paid the average wage for their class in the consumption goods sector.

The central bank keeps the government's current account balance and holds government bonds. We assume that it has a dual mandate, thus aiming for low unemployment and inflation rate. Accordingly, it sets the nominal interest rate following a monetary policy reaction function that considers both an inflation gap and an unemployment gap, as described in Equation 13:

$$i_t = i_{t-1}\{1 + \lambda_1(\bar{\hat{p}}_{t-1} - \hat{p}^T) - \lambda_2[(1-\bar{\eta})_{t-1} - (1-\eta)^T]\} \tag{13}$$

where $\bar{\hat{p}}_{t-1}$ is the average inflation rate in the previous $T^i \geq 1$ periods, $\hat{p}^T$ is the inflation rate target, $(1-\bar{\eta})_{t-1}$ is the average unemployment rate in the previous T^i periods, $(1-\eta)^T$ is the unemployment rate target, and $\lambda_{1,2}$ are parameters capturing the sensitivity of the nominal interest rate to the inflation gap and to the unemployment gap respectively. There is a lower bound for the nominal interest rate, which is given by i^{min}.

2.6 The labor market

There are two segmented labor markets, one for each type of worker. Firms follow an internal pay structure, so workers from the same class at the same firm earn the same wage. While employment is full-time and long-term, workers can be fired whenever firms reduce their demand for labor or to meet their turnover target (a $1 > \vartheta > 0$ share of current employees).[8] Firms use labor surveys to set wages (Bewley, 2007), consulting a random set of workers to consult their desired wage.[9] Wages are set as the weighted average between the wage desired by firms (for simplicity, the previous wage level) and the wage desired by workers, with the weight given to the desired wage by workers depending on their bargaining power (a class-specific parameter multiplied by the class-specific employment rate), as follows:

$$w_{f,t}^{j,\$} = (1-\phi^j\eta_{j,t-1})w_{f,t}^{j,d,\$} + \phi^j\eta_{j,t-1}w_{f,t}^{j,s,\$} \tag{14}$$

where $1 > \phi^j > 0$ is a fixed parameter capturing the sensitivity of $j = dir, ind$ workers' bargaining power to the class-specific employment rate in the previous period ($\eta_{j,t-1}$).

The hiring process starts with a random list of firms, with the capital goods firm always in the first position. The first firm tries to match with an indirect and a direct worker by randomly selecting a worker of each type. Workers accept an offer if the offered wage is above their reservation wage. After this, the second firm starts its hiring round and so on until all firms in the list have executed one hiring round for each type of worker. The process iterates until all firms have filled all open positions or reached the maximum number of hiring rounds for each type of worker, given by a multiple $n^w \geq 1$ of the number of open positions.

Finally, the labor market institutional framework is characterized by a minimum wage ($w_t^{min,\$}$) and nominal downward wage rigidity (Bewley, 2007, Dickens et al., 2007). The minimum wage is adjusted according to the growth rate of the average nominal wage.

[8]For simplicity, there is no turnover in the public sector.

[9]The number of workers consulted is given by the parameter $1 > n^{j,s} > 0$ multiplied by the firms' labor demand for each type of worker $j = dir, ind$.

2.7 Sequence of events

In each simulation period, the sequence of events is the following:

1. The central bank sets the nominal interest rate;
2. Consumption goods firms set desired production levels;
3. Nominal wages and prices are set;
4. Credit market opens;
5. Consumption goods firms set investment demand and all firms set labor demand;
6. Labor market opens;
7. Production takes place;
8. Unemployment benefits and wages are paid;
9. Households set their nominal consumption demand;
10. Consumption goods market opens;
11. Taxes and profit dividends are paid;
12. New machines are delivered and old machines are scrapped;
13. National accounts and statistics are computed;
14. Exit and entry of consumption goods firms take place.

3 The inflation-unemployment-inequality nexus

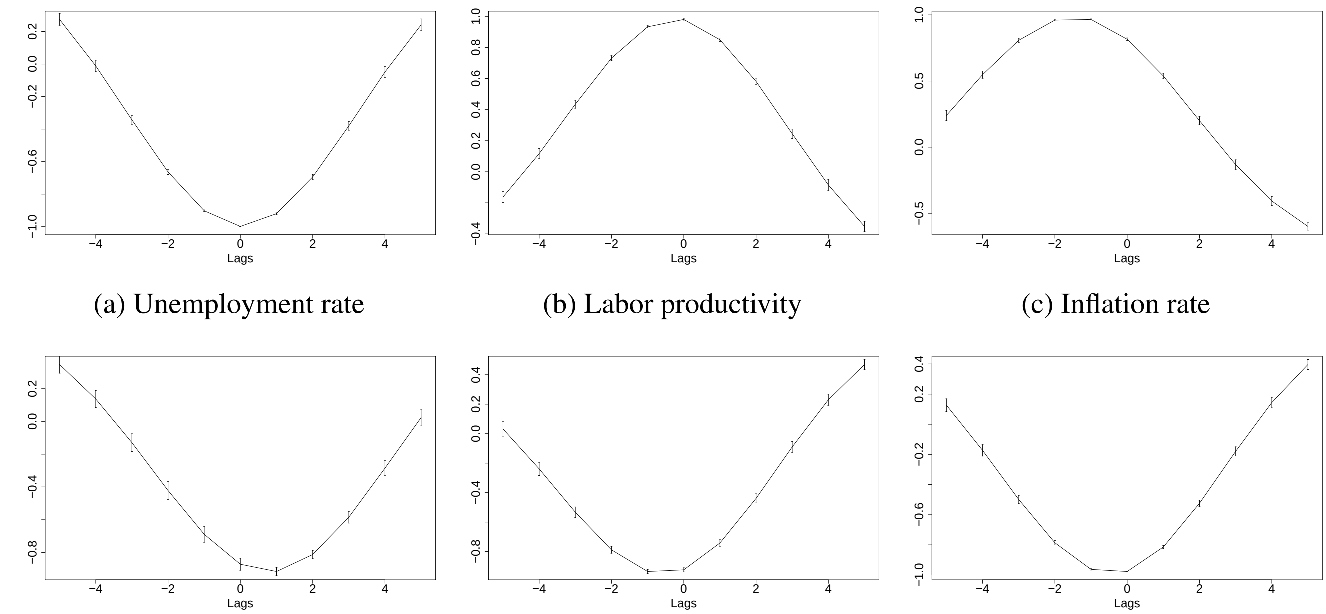
In this section we explore the basic properties of the 100 Monte Carlo runs for the baseline specification of the model described in Section 2, which was simulated for 500 periods (200 transient periods and 300 considered periods).[10] Our aim is to investigate how the cyclical properties of employment and income distribution lead to the inflation-unemployment-inequality nexus, which will be further explored in the following sections. The analysis of the baseline specification also provides a validation of the model, since we discuss empirically observed stylized facts concerning key variables that are reproduced by the model. Given the scope of this article, priority is given to stylized facts concerning inflation, inequality, and employment.[11] The robust empirical support for the cyclical patterns presented below suggests that there is also strong empirical basis for the inflation-unemployment-inequality nexus.

We start by analyzing the cyclical behavior of unemployment in the baseline specification. The unemployment rate is strongly countercyclical (Figure 2a), reflecting the fact that, when output increases, more workers are hired and, consequently, the unemployment rate decreases. Nevertheless, unemployment fluctuations show different behaviors depending on the class (Figure 3a). Indirect workers are hired to supervise the direct workers and to the manage firms. As such, they have an overhead characteristic, and firms will not necessarily fire managers in a direct proportion to the fluctuations in the production level. This leads to a larger exposure of direct workers to business cycle fluctuations compared to indirect workers, indicating that direct workers (which are also low-income workers) face more volatility in their unemployment rates, as largely found in the empirical literature (Solon et al., 1994, Clark and Summers, 1980, Kydland, 1984, Mitchell et al., 1985, Mueller, 2017, Okun et al., 1973). Since the elasticity of indirect workers' unemployment to output is

[10]The parameters for the baseline specification presented in this section are reported in Table B.1 in Appendix B.

[11]The model structure largely reproduces other empirically observed stylized facts, such as the cyclical fluctuations of output, consumption, investment, and inventories. Given the purpose of this article, we do not report these results and they are available upon reasonable request. See Rolim et al. (2023) for more details on the stylized facts reproduced by the model.

smaller, their aggregate income also tends to be relatively more stable than output. Consequently, the wage share of indirect workers in total output tends to be much more volatile than that of direct workers (Figure 3b). This property of overhead workers' income shares was observed by Kalecki (1971).[12]

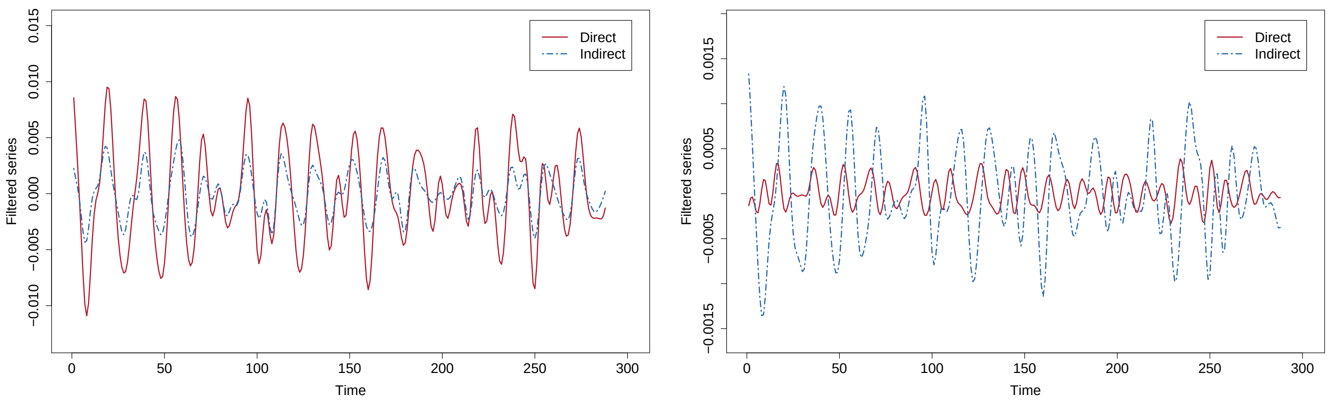


(a) Unemployment rate (b) Labor productivity (c) Inflation rate

(d) Wage share (e) Wage Gini coefficient (f) Income Gini coefficient

Figure 2: Correlation structure with output (baseline)

Note: Bandpass-filtered (6,32,12). Output series taken in logarithm. Bars are standard deviations of 100 Monte Carlo average cross-correlations.



(a) Unemployment rates (b) Wage shares

Figure 3: Cyclical behavior of unemployment rates and wage shares per class (baseline)

Note: Bandpass-filtered (6,32,12). Average of 100 Monte Carlo runs.

Given the relative degree of stability in the indirect workers' aggregate income levels, the wage share tends to be countercyclical (Figure 2d), as aggregate profits increase more than aggregate income in the expansion of the cycle (Giovannoni, 2010).[13] Moreover, when output increases, employment does not

[12] For a theoretical discussion on the implications of overhead labor, see Lavoie (2014, ch. 5). Further empirical evidence on the cyclical behavior of the wage share of indirect workers is provided by Rolim (2019).

[13] It should be mentioned that a countercyclical wage share is expected to be observed even if firms' mark-up rates are constant and as long as prices are based on unit costs computed at the desired capacity utilization level and overhead labor is present. Another reason for this behavior of the wage share could be labor hoarding.

increase proportionally because part of employment is overhead. Consequently, the overall labor productivity increases. Thus, even if the direct labor productivity in the consumption and capital goods sectors is fixed throughout the simulation periods, total labor productivity tends to be procyclical, as reported in Figure 2b .

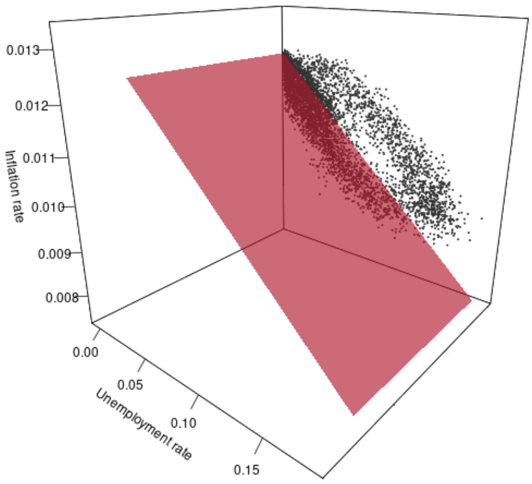
Also, by being more exposed to business cycle fluctuations, direct workers present a lower unemployment rate than indirect workers at the peak of the cycle, since their employment tends to follow more closely the output dynamics. This means that at the peak of the cycle nominal wage adjustments tend to be higher for direct workers (and lower in recessions), which reduces the wage differential and decreases the wage Gini coefficient. As a consequence, the wage Gini coefficient is countercyclical: wage inequality decreases at the peak of the cycle (Figure 2e). The behavior of the income Gini coefficient is also countercyclical (Figure 2f), as reported in the empirical literature (Hoover et al., 2009, Maestri and Roventini, 2012). This indicates that, despite of the lower wage share at the peak of the cycle, the lower wage Gini coefficient and the increase in employment levels (reducing the number of households that receive the unemployment benefit, which is normally smaller than wages) induce more equality in the personal income distribution at the peak of the cycle. These cyclical properties of inequality over the cycle means that unemployment is also closely related to inequality.

The cyclical dynamics of employment also relates to the inflation dynamics, which is procyclical (Figure 2c), in line with empirical findings (Stock and Watson, 1999).[14] At the peak of the cycle, the lower unemployment rates lead to an increase in workers' bargaining power, which translates into higher nominal wage adjustments. Since mark-ups do not fully absorb the higher costs, price levels grow at a higher rate.

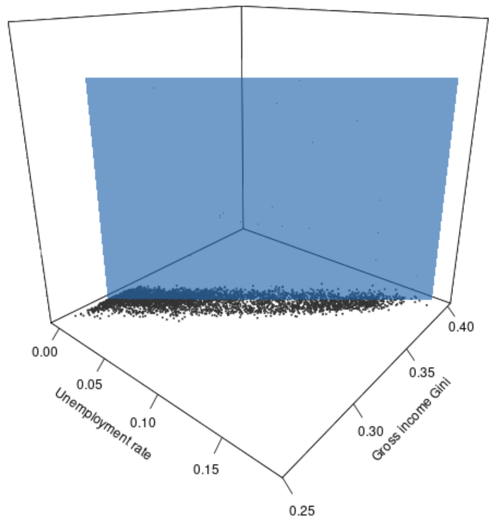
The cyclical properties discussed so far indicate a marked cyclical behavior of our three key variables, that is, the unemployment rate, inflation rate, and inequality. Consequently, we are able to explore how they relate to each other over the business cycle. Indeed, we find a negative relation between the unemployment rate and the inflation rate, reproducing the widely observed empirical regularity known as the Phillips curve.[15] This relationship is described by the distribution of the simulation points on the right part of Figure 4a and summarized by the line capturing the relationship between the variables, which is projected as a plane in a three-dimensional space. Moreover, our results suggest the existence of an unemployment-inequality curve, which is represented in Figure 4b and shows that the unemployment rate is positively associated with the gross income Gini coefficient. Also in this case, the line captures the relationship between the two variables plotted in the bottom of the figure and it is projected in a three-dimensional space. This relationship derives directly from the empirically-supported countercyclical unemployment rate and countercyclical Gini coefficient discussed above.

[14] Note that the above-mentioned procyclical labor productivity, which in our model is caused solely by changes in the composition of employment, does not have an effect on the price dynamics because prices are determined following the normal cost pricing procedure and, thus, are based on costs at the desired capacity utilization rate. Yet, even if the dynamics of labor productivity is also impacted by a procyclical innovation dynamics, as in Rolim et al. (2023), the inflation rate will be procyclical as long as nominal wage increases at the peak of the cycle more than compensate the negative effect of productivity on unit costs.

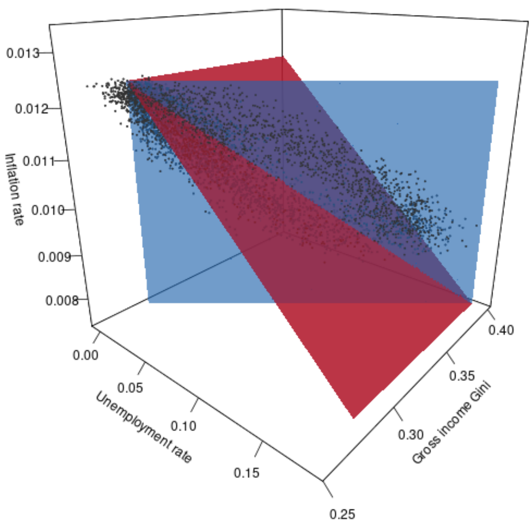
[15] There is a long debate about whether unemployment is related to the level of the inflation rate or to the change in the inflation rate. For a summary of the debate and an analysis of periods in which each type of relation was observed in the USA economy, see Setterfield and Blecker (2022). Also, for a theoretical discussion of the Phillips curve in a conflicting-claims inflation approach, see Serrano (2019) and Summa and Braga (2020).



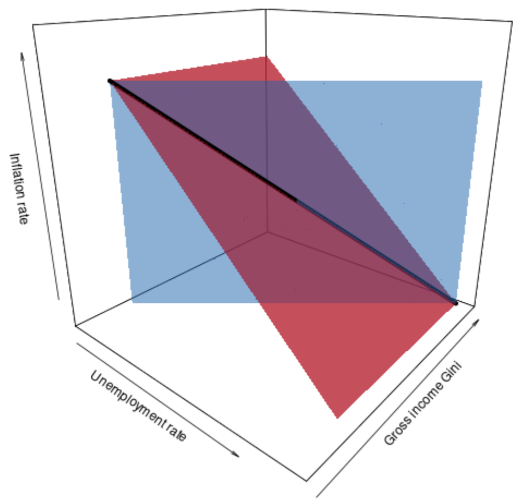
(a) Phillips curve (inflation x unemployment) and its projection to the 3D space



(b) Unemployment-inequality curve and its projection to the 3D space



(c) Inequality-augmented Phillips curve



(d) Generalized inequality-augmented Phillips curve

Figure 4: Construction of the inequality-augmented Phillips curve
Note: Average for the last 50 simulation periods for 100 Monte Carlo runs. The number of periods has been adjusted to allow a better visualization.

The combination of the Phillips and the unemployment-inequality curves indicates the strength of the inflation-unemployment-inequality nexus and leads to the emergence of the inequality-augmented Phillips curve in Figure 4c. This curve is constructed by plotting the data points in the three-dimensional space, so that they indicate the obtained values for the unemployment rate, inflation rate, and gross income Gini coefficient, and combining the planes describing the Phillips curve and the unemployment-inequality curve. The intersection between the both planes defines a line around which unemployment, inflation, and inequality fluctuate, as represented by the points in the three-dimensional space. The relation between these variables is clearer in Figure 4d, wherein the data points have been removed and a line defining the inequality-augmented Phillips curve at the intersection between both planes is drawn. This line indicates that higher unemployment rates tend to be associated with lower inflation rates and to higher inequality levels. Therefore, income inequality is an additional dimension of the traditional Phillips curve and the widely discussed trade-off between low inflation and low unemployment also involves a trade-off between low inflation and low inequality.[16]

A key implication of the inequality-augmented Phillips curve is that the trade-offs faced by policymakers are more perverse than what is captured by the original Phillips curve, since they indicate that a reduction in the inflation rate may bring about not only an increase in the unemployment rate, but also more income inequality. Moreover, the inequality-augmented Phillips curve suggests that inequality is largely associated with both other variables, indicating the need for a more comprehensive analysis. In the next sections we follow these insights and make use of the inequality-augmented Phillips curve to analyze the flattening of the Phillips curve and the trade-offs involved with monetary policy.

4 The bargaining power hypothesis and workers' heterogeneity

One of the puzzling phenomena in recent macroeconomics dynamics is the flattening of the Phillips curve. A hypothesis that has been put forward to explain it is related to institutional and structural changes that have reduced workers' bargaining power, thus lowering the sensitivity of nominal wage adjustments (and inflation) to changes in the unemployment rate. Stansbury and Summers (2020, p. 3), who consider the decline in workers' bargaining power "as one of the major structural trends in the U.S. economy", named this the "bargaining power hypothesis". The authors argue that the reduction in workers' bargaining power would be an explanation not only for the decline in the wage share, but also for the decline of the so-called NAIRU, making it the most consistent explanation for these economic phenomena in comparison to other hypotheses, such as the increase in firms' bargaining power, technological change, and globalization.[17] A similar argument has been presented by Ratner et al. (2022), who make use of a Two-Agent New Keynesian model with Kaleckian features to show that the decrease in workers' bargaining power can explain the flattening of the Phillips Curve and the "missing inflation puzzle" observed in the USA during the recovery from the Global Financial Crisis. In the conflicting-claims inflation tradition, the connection between lower bargaining power of workers and lower inflation rates is also emphasized . For instance, Setterfield (2005) argues that, in an era of "incomes policies based on fear" (Cornwall, 1990), the labor market framework provides workers with such a high income insecurity that their bargaining power decreases, making it possible to achieve lower inflation rates at high levels of employment, but at the price of higher inequality.[18]

In this section, we explore how workers' heterogeneity explains this phenomenon, while also providing an explanation for the increasing wage and income inequality that is observed in numerous economies. The explicit incorporation of workers' heterogeneity, which is allowed for by the AB framework, is an important contribution of our work relative to the literature discussed above. While in our baseline simulation we assumed that the sensitivity of the wage set by firms to the class-specific unemployment rates is equal for both types of workers,[19] this may be an unrealistic assumption given the institutional changes that may

[16]Setterfield and Blecker (2022) highlight that such trade-off also pertains to the functional income distribution. This relationship is also explored in Rolim et al. (2023), wherein there are also implications for the personal income distribution given the nexus between the personal and functional income distributions. The next sections add wage inequality as another dimension of this trade-off.

[17]It is worthwhile mentioning other relevant explanations for the flattening of the Phillips curve discussed by Hoang-Ngoc (2007). For instance, a horizontal section of the Phillips curve is recognized by some researchers who attribute it to the high level of credibility of central banks in the last decades. Additionally, in the post-Keynesian literature, the supply curve of firms is considered to be mostly horizontal as the majority of industries operate with constant returns. In this framework, prices would not be subject to upward pressures as long as firms operate below full capacity utilization. This could explain a flat section of the Phillips curve as long as nominal wages are not increasing. However, it does not explain the flattening of the Phillips curve over time.

[18]See also Setterfield and Blecker (2022), Setterfield and Lovejoy (2006), and Summa and Braga (2020)

[19]In other words, if their unemployment rates are equal, the wage set by firms will be the same proportion of the desired wage by workers for both classes. Formally, this means assuming that $\phi^{dir} = \phi^{ind}$ in Equation 14.

have had a stronger effect on low-wage workers. Indeed, one of the explanations for a decrease in workers' bargaining power is the reduction in unionism or in the "threat effect" of unions (Stansbury and Summers, 2020). Since union members are usually low-paid workers (Card et al., 2004), the observed decrease in unionism may have caused a stronger reduction in the bargaining power of low-wage workers than in that of high-wage workers. Similarly, other reasons for the decrease in workers' bargaining power, such as the increase in shareholder power or the competition with technology or with low-wage countries' workers (Stansbury and Summers, 2020), should also be expected to affect workers differently. Indeed, managers are close enough to the decision spheres in order to protect themselves from wage cuts,[20] while also being relatively more protected from competition with technology or with low-wage countries by the very nature of the activities they perform. Thus, not only heterogeneous workers are exposed differently to the business cycle (as discussed in Section 3), but also they present varying degrees of exposure to institutional changes.[21]

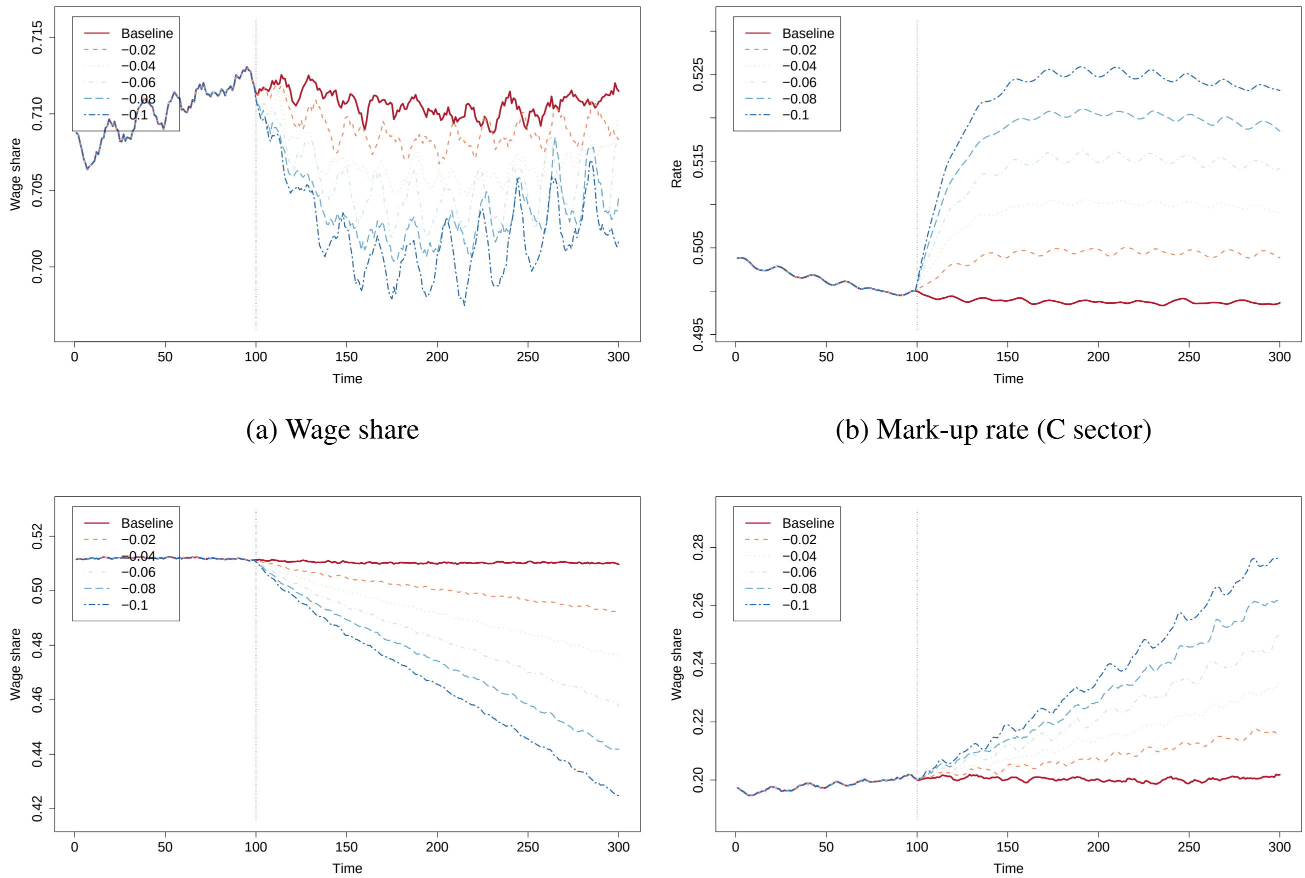
To explore the effect of the decrease in the bargaining power of low-wage workers and the implications for the inflation-unemployment-inequality nexus, we simulate different scenarios applying a one-time permanent negative shock at $t = 100$ of the considered simulation periods to the parameter capturing the sensitivity of the direct workers' bargaining power to their employment rate (ϕ^{dir}) in Equation 14, while the parameter relative to indirect workers (ϕ^{ind}) is kept constant at the baseline value.[22] In line with the "bargaining power hypothesis", we observe that the negative shocks on the direct workers' bargaining power are associated with a decrease in the wage share (Figure 5a), which is simultaneous to an increase in the average mark-up rate at the consumption goods sector (Figure 5b).[23] Nevertheless, the magnitude of the changes in these variables is relatively small in comparison to the most important effect of the negative shocks on ϕ^{dir}, which is on the wage income distribution. Indeed, the decrease in the wage share is entirely due to a decrease in the share of the direct workers' wages in total output (Figure 5c), since the share of indirect workers' increases with the negative shocks on ϕ^{dir} (Figure 5d). Thus, direct workers' income is squeezed by both a higher profit share and a higher wage share for indirect workers, as has been the case in the USA economy recently (Mohun, 2016). Consequently, both the wage and income Gini coefficients present an upward trend after the negative shocks on ϕ^{dir} (Figures 6a and 6b respectively).

[20] Managers can be considered to be allied to capitalists (Duménil and Lévy, 2015), acting to surpress wages in order to increase shareholder value (Guttmann, 2016). Consequently, managers have succeeded in increasing their own share of income in the form of salaries and executive stock options (Lazonick and O'Sullivan, 2000).

[21] For instance, Stansbury and Summers (2020) provide some evidence supporting this hypothesis by comparing the decrease in labor rents for non-college-educated workers relative to college-educated workers.

[22] The experiments values are reported in Table B.2 in Appendix B. Figure C.1 in Appendix C reports the box-plots for the variable discussed in this section.

[23] Interestingly, while the higher mark-up rates driven by the weaker cost pressures seems to be permanent, the wage share seems to come closer to the baseline value after some periods. This is probably due to other factors affecting the dynamics of the wage share, such as the capacity utilization rate.

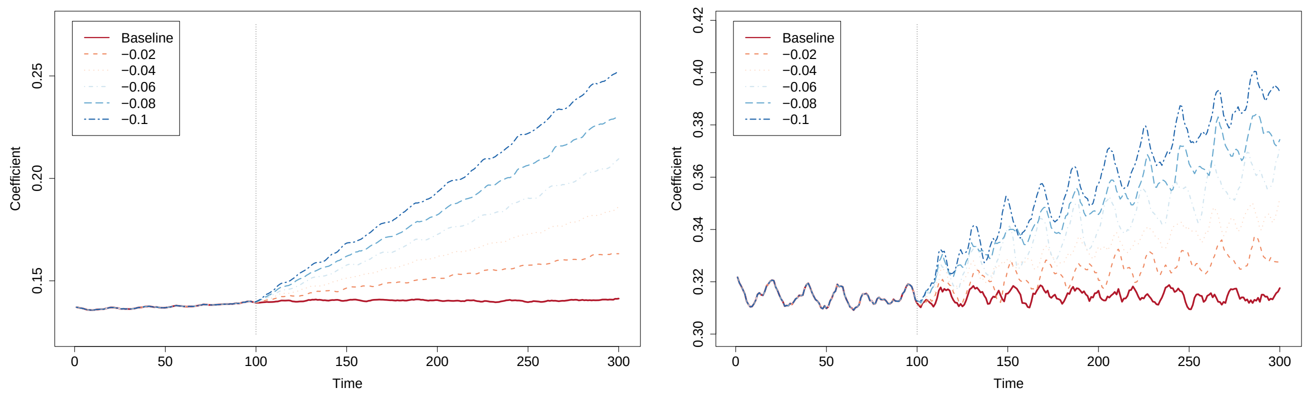


(a) Wage share (b) Mark-up rate (C sector)

(c) Wage share (direct) (d) Wage share (indirect)

Figure 5: Functional income distribution

Note: Average of 100 Monte Carlo runs. Experiment values represent the shocks to the ϕ^{dir} parameter. The vertical line marks the period of the shock.

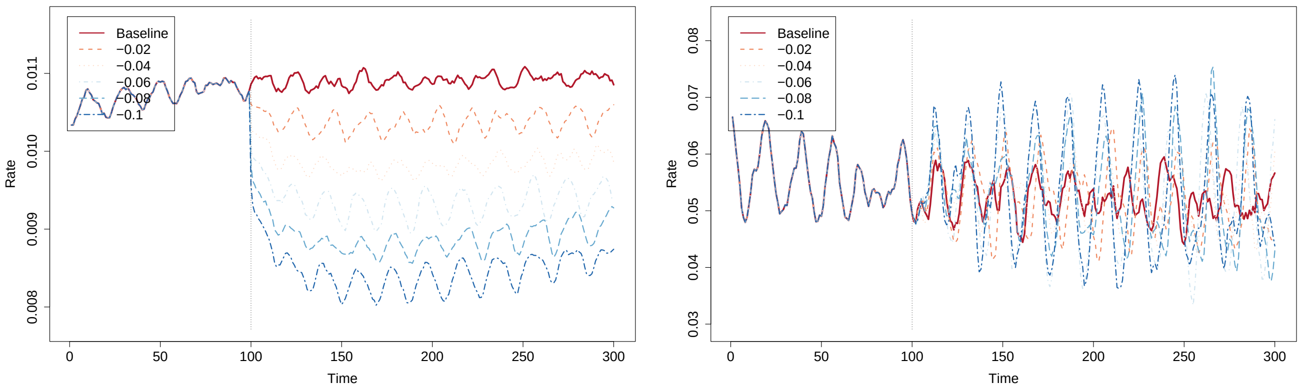


(a) Wage Gini coefficient (b) Income Gini coefficient

Figure 6: Personal income distribution

Note: Average of 100 Monte Carlo runs. Experiment values represent the shocks to the ϕ^{dir} parameter. The vertical line marks the period of the shock.

The macroeconomic implications of these shocks are described in Figure 7. As expected, the negative shocks on the direct workers' bargaining power lead to a strong reduction in the average inflation rate. This occurs because the smaller ϕ^{dir} parameter reduces the growth rate of direct workers' wages and, consequently, reduces the magnitude of cost changes that are passed-on to prices. Since there is an inflation-targeting regime in place and the inflation target is kept constant across the simulations, the lower inflation rates could be associated with higher employment levels. This would be the case because the monetary authority, having reached its targeted inflation rate, would be free to stimulate employment.[24] Yet, this is not observed in our results, since the unemployment rates are rather similar across the simulations (Figure 7b).[25] Indeed, the positive effects of the expansionary monetary policy on output may be counterbalanced by the negative effects of higher inequality levels on aggregate demand, so the net effect on employment is weak and unemployment rates present a mild increase relative to the baseline scenario. Interestingly, the unemployment rate also seems to be more volatile in the scenarios with a smaller ϕ^{dir} parameter.



(a) Inflation rate

(b) Unemployment rate

Figure 7: Macroeconomic data

Note: Average of 100 Monte Carlo runs. Experiment values represent the shocks to the ϕ^{dir} parameter. The vertical line marks the period of the shock.

The decrease of the inflation rate simultaneously to a relatively stable unemployment rate suggests a change in the structural relationship between these variables. Indeed, we find that the negative shocks on the sensitivity of the direct workers' bargaining power to their employment rate is associated with relevant shifts of the inequality-augmented Phillips curve in the three-dimensional space (Figure 8). The curve rotates in the three-dimensional space in the direction of a lower inflation rate, higher unemployment rate and more income inequality and confirms a change in the structural relationship between our three key variables. To understand better how their relationship is altered by the shocks, we analyze also the relationship between pairs of variables.

[24] Actually, in some cases the inflation rate is below the target given by $\hat{p}^T$, so the monetary authority would also operate to increase it in order to reach the target.

[25] Figure C.1 in Appendix C confirms that the unemployment rate is similar between the experiments. Consequently, the output per capita level is also similar between the experiments, as shown in the figure.

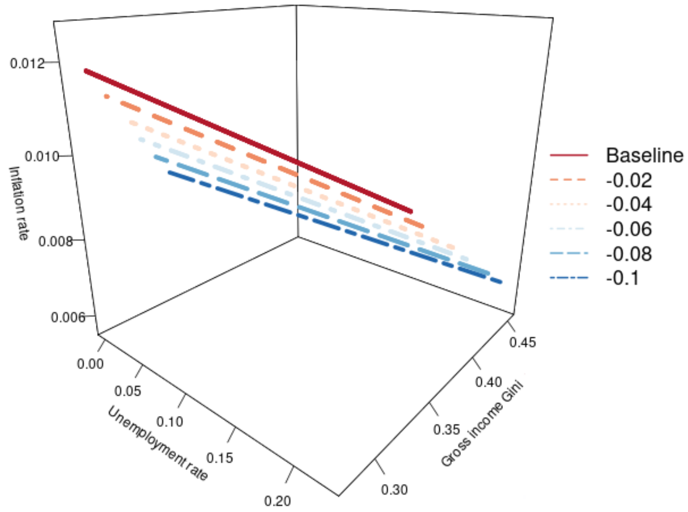
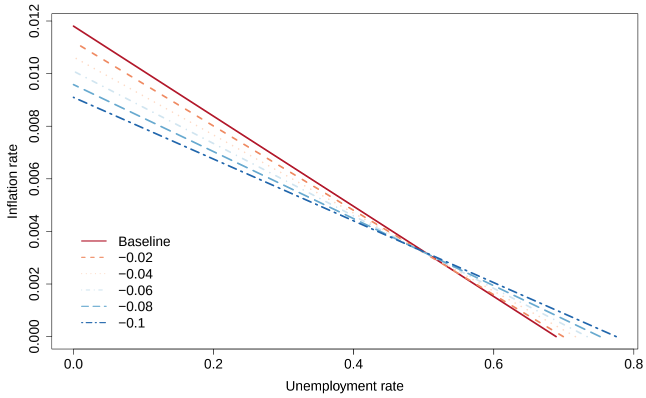


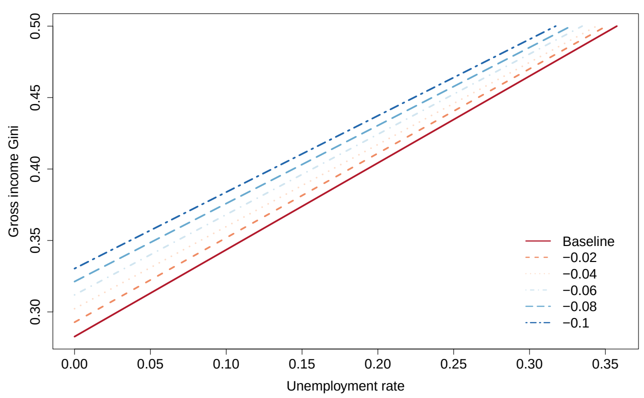
Figure 8: Inequality-augmented Phillips curves

Note: Inequality-augmented Phillips curves estimated using data from 100 Monte Carlo runs over the simulation periods after the shock on ϕ^{dir}. Experiment values represent the shocks to the ϕ^{dir} parameter.

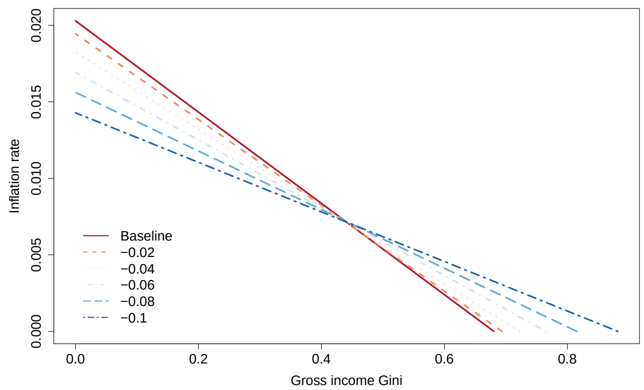
Figure 9a shows that the larger the negative shock on ϕ^{dir}, the flatter the Phillips curve and the smaller the coefficient capturing the sensitivity of the inflation rate to the unemployment rate, as confirmed in Table 1. In line with the dynamics described earlier, the flattening of the Phillips curve results from the lower nominal wage increases for direct workers when unemployment decreases, since the wage set by firms for direct workers does not come as close to the wage desired by workers as it did in the baseline scenario. As a consequence, nominal wage adjustments are less sensitive to the unemployment rate and so is the inflation rate.



(a) Phillips curve



(b) Unemployment-inequality curve



(c) Inflation-inequality curve

Figure 9: Two-dimensional curves

Note: Curves estimated using data from 100 Monte Carlo runs over the simulation periods after the shock on ϕ^{dir}. Experiment values represent the shocks to the ϕ^{dir} parameter.

The negative shocks on the ϕ^{dir} parameter also lead to a change in the relationship between the unemployment rate and the gross income Gini coefficient (Figure 9b and Table 1). The intercept is larger in the scenarios with a larger negative shock, indicating that the same unemployment rate is associated with more inequality. There is also a decrease in the angular coefficient, indicating a weaker relationship between the unemployment rate and the Gini coefficient. This is a direct consequence of the negative shocks, since they reduce the magnitude of the increase in the low wage workers' wages when the unemployment rate decreases, so the reduction in the Gini coefficient also presents a smaller magnitude. In other words, the sensitivity of the Gini coefficient to the unemployment rate reduces with the negative shocks on the ϕ^{dir} parameter.

Table 1: Intercept and coefficients of two-dimensional curves

	Phllips curve				Unemployment-inequality curve				Inflation-inequality curve			
Experiment	Int.	St. error	Coef.	St. error	Int.	St. error	Coef.	St. error	Int.	St. error	Coef.	St. error
Baseline	0.0118	0	-0.0171	0.0001	0.2827	0.0001	0.6077	0.0011	0.0203	0	-0.0298	0.0001
$\Delta\phi dir$ = -0.02	0.0112	0	-0.016	0.0001	0.2928	0.0001	0.591	0.0013	0.0194	0	-0.028	0.0001
$\Delta\phi dir$ = -0.04	0.0106	0	-0.0148	0.0001	0.3023	0.0001	0.5745	0.0016	0.0183	0	-0.0253	0.0001
$\Delta\phi dir$ = -0.06	0.0101	0	-0.0138	0.0001	0.3119	0.0002	0.5619	0.002	0.0169	0	-0.0221	0.0001
$\Delta\phi dir$ = -0.08	0.0096	0	-0.0127	0.0001	0.3212	0.0002	0.5461	0.0024	0.0156	0	-0.0192	0.0001
$\Delta\phi dir$ = -0.1	0.0091	0	-0.0117	0.0001	0.3303	0.0002	0.5348	0.0028	0.0143	0	-0.0162	0.0001

Note: Curves estimated using data from 100 Monte Carlo runs over the simulation periods after the shock on ϕ^{dir}.

Finally, the changes in the relationships between these pairs of variables have important implications to how the inflation rate is related to inequality. Figure 9c represents the relationship between these variables, which is a curve implied by the inequality-augmented Phillips curve. There is also a flattening of this inflation-inequality curve, which is confirmed by the decrease in the magnitude of the negative coefficients and decrease in the intercept values (Table 1). This flattening means that lower levels of the inflation rate are associated with an increase in the Gini coefficient of a smaller magnitude. Since these negative shocks are associated with lower inflation rates, they represent different points along the inflation-inequality curve that combine a higher Gini coefficient and lower inflation rate than in the baseline scenario.

In sum, these result indicate that changes in the institutional framework supporting low-wage workers' bargaining power can have major implications for the structural form of the Phillips curve and also to the dynamics of income inequality. This is represented by the flattening of the Phillips curve, confirming the plausibility of the bargaining power hypothesis (Stansbury and Summers, 2020). We also find that the inequality-augmented Phillips curve shifts in the three-dimensional space, indicating that the relationship between inequality with the unemployment rate and with the inflation rate is structurally different. Moreover, in line with the key insights provided by the inequality-augmented Phillips curve showing that inequality is a third dimension of the traditional Phillips curve, an increase in inequality takes place simultaneously with the flattening of the Phillips curve. This indicates that the lower inflation rates obtained by reducing the bargaining power of workers without the need of generating higher unemployment rates are associated with a significant distributive cost.

5 Monetary policy rules: hawks and doves

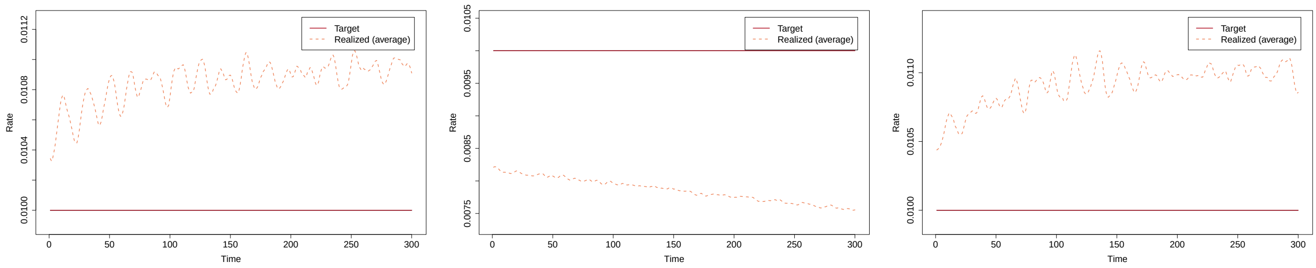
The inflation-unemployment-inequality nexus suggests that monetary policy management has important implications for inequality, especially in a framework such as the inflation-targeting regime. In this section we explore this issue by analyzing the distributive implications of having different degrees of priority given to each monetary policy objective (employment and inflation) in Equation 13. In addition to the baseline scenario, wherein the monetary policy reaction function considers both the inflation and unemployment gaps, we simulate a scenario in which only the inflation gap is considered (a scenario dominated by monetary hawks), and a scenario in which attention would be given only to unemployment (a scenario dominated by monetary doves). The employment and inflation rates targets are the same in all cases, so the difference between the scenarios is only with respect to whether monetary policy aims to reach these targets: when $\lambda_1 = 0$ in Equation 13, monetary policy does not react to the inflation gap, while when $\lambda_2 = 0$ it does not react to the unemployment gap.[26]

Figures 10 and 11 compare the targeted and realized values of the inflation and unemployment rates respectively. In the baseline scenario, where monetary policy reacts to both the inflation and unemployment gaps, the inflation rate fluctuates slightly above the targeted level, while the average unemployment rate slowly converges towards the targeted level.[27] Therefore, in this scenario, while monetary policy comes relatively closer to the unemployment target, it constantly shifts between stimulating economic activity to reduce unemployment and weakening aggregate demand to reduce inflation. In the Hawks scenario, where monetary policy reacts only to the inflation gap, these variables fluctuate less. The inflation rate is kept, on average, below the targeted level, since any increase in the inflation gap leads to a strong reaction by the monetary authority, while the unemployment rate increases significantly. Finally, in the Doves scenario, where monetary policy reacts only to the employment gap, the unemployment rate comes relatively closer to the targeted level, while the inflation rate is constantly above the targeted value. Also in this case the amplitude of the cyclical fluctuations in the unemployment and inflation rates is smaller than in the baseline

[26]The parameter values for each scenario are reported in Table B.3 in Appendix B. Note that these experiments are based on the baseline scenario, wherein $\phi^{dir} = \phi^{ind}$.

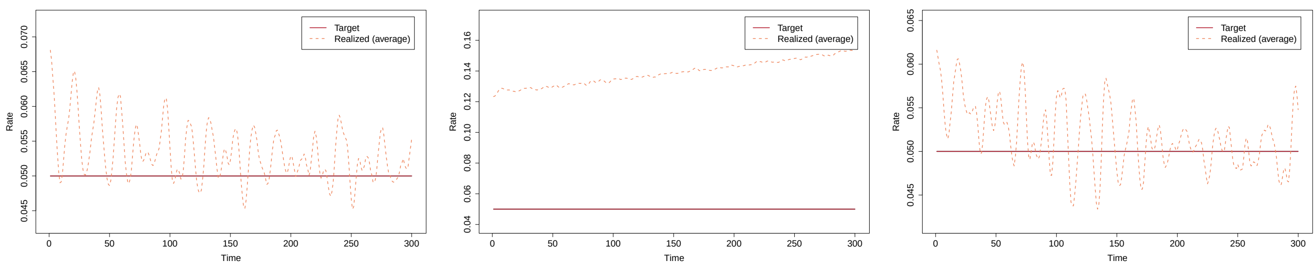
[27]Note that when the average values for the Monte Carlo runs is different from the targeted values for each variable, it does not mean that within each individual simulation the targeted level is never achieved.

scenario, which suggests that a dual mandate for monetary policy may be associated with more fluctuations, especially if there is an incompatibility between the targets.[28]



(a) Baseline (b) Hawks (c) Doves

Figure 10: Monetary policy rules: target and realized values for inflation rate
Note: Average of 100 Monte Carlo runs.



(a) Baseline (b) Hawks (c) Doves

Figure 11: Monetary policy rules: target and realized values for unemployment rate
Note: Average of 100 Monte Carlo runs.

The box-plots in Figure 12 present further information concerning the comparison between the monetary policy rules. These plots confirm that the inflation rate is lower in the Hawks scenario, but this comes at the cost of higher unemployment rates and lower output per capita levels. In line with the inflation-unemployment-inequality nexus and the distributive implications of workers' heterogeneous exposure to business cycle fluctuations, the lower inflation rate in the Hawks scenario is also associated with higher gross income and wage Gini coefficients relative to the baseline scenario. There is also an increase in consumption inequality, meaning that the lower inflation rate is not enough to compensate for the income loss of the lower classes due to the higher unemployment rates and the more concentrated income distribution. Interestingly, this scenario presents a higher wage share than the other scenarios. This increase in the wage share is mostly caused by its counter-cyclical nature and should not be interpreted as an improvement in income distribution: since this scenario is associated with a lower output level while there is a fixed number of indirect workers that are hired independently of the level of aggregate demand, aggregate profits tend to decrease more than aggregate wages. More precisely, profits decrease more than aggregate wages for indirect workers, while direct workers' aggregate wages tend to follow more closely the business cycle (the different wage dynamics for each type of worker is reflected in the higher wage Gini coefficient, higher wage share for indirect workers and lower wage share for direct workers). Thus, despite of a higher mark-up rate, there is an increase in the wage share that is mostly caused by a favorable situation to indirect workers. The Doves scenario is

[28] By incompatibility we mean a situation in which the targeted unemployment rate would be associated with an inflation rate that is above the targeted inflation rate and vice versa. This is also related with the Tinbergen (1952) principle, which states that multiple instruments are required if the government wants to achieve multiple policy targets. See Lima et al. (2013) for a discussion of the inflation targeting regime in light of the Tinbergen principle.

associated with a higher inflation rate and lower unemployment rate than the baseline scenario, while the income distribution variables are slightly smaller than the baseline scenario.

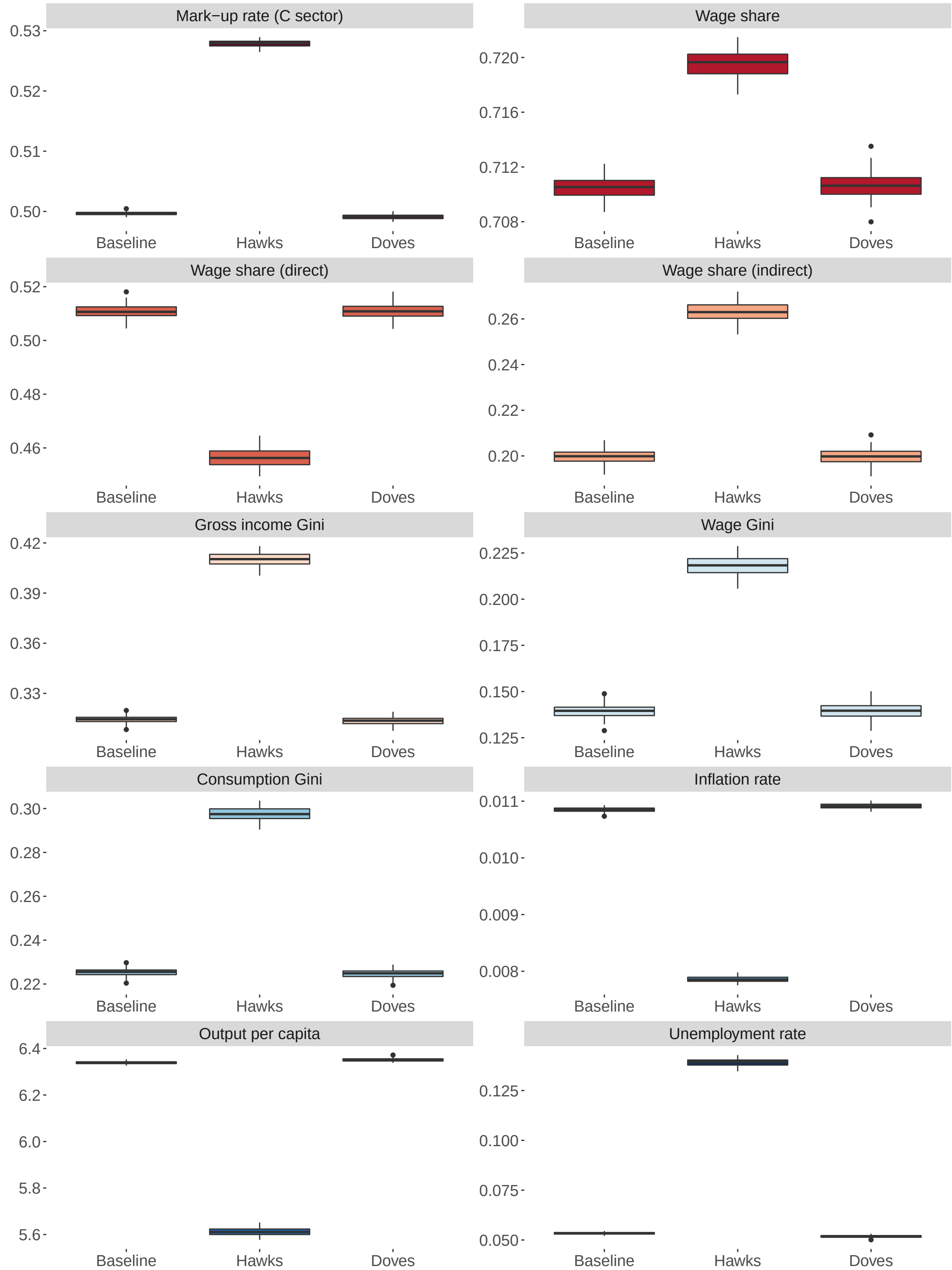


Figure 12: Comparison of experiments (monetary policy rules)
Note: Line represents the median value, box represents the 2nd-3rd quartiles, and whiskers represent the maximum and minimum values among the average for the 100 Monte Carlo runs. Dots are outliers.

These results provide further insights into the effects of monetary policy on inequality, which are strongly mediated by the unemployment dynamics. Since the monetary policy exerts an effect on the unemployment rate, it is also relevant to the dynamics of the wage and income inequality. In terms of the inequality-augmented Phillips curve, these results indicate that a monetary policy rule that prioritizes low inflation rates, such as the Hawks scenario, will tend to move the economy downward along this curve in the direction of higher unemployment rates and higher income inequality. Consequently, the effects of monetary policy can be more perverse than those indicated by the original Phillips curve showing a trade-off between low unemployment rates and low inflation rates.

6 Sensitivity Analysis

In order to further explore the properties of the model, we perform a global sensitivity analysis. This provides further insights with respect to the direct effects of selected parameters, as well as on their interaction. We follow the procedure put forward by Salle and Yıldızoğlu (2014) and make use of the Nearly Orthogonal Latin Hypercube (Cioppa and Lucas, 2007) to have an efficient and parsimonious design of experiments. Afterwards, we construct the Sobol decomposition and estimate a Kriging meta-model that relates the parameters and the variables of interest.

In line with the key aim of this article, which is to explore the inflation-unemployment-inequality nexus, the parameters (inputs) selected for the sensitivity analysis are those closely related to the dynamics of these variables and to their relationship, as well as those related to the monetary policy rules. The specific parameters and range adopted for each parameter are reported in Table 2. The variables (outputs) are the inflation rate, the unemployment rate, the wage share, the wage Gini coefficient, and the income Gini coefficient. The design of experiments for this sensitivity analysis is based on 33 samples and the average of the 100 Monte Carlo simulations for each sample is considered.

The Sobol decomposition is reported in Table 2. It decomposes the variance of each output in contributions from each input (Sobol, 2001), thus indicating the most important parameters for the dynamics of each variable. In the table, we identify those parameters according to their direct effects and interactions. The effect of the two most important parameters for each variable is analyzed through the response surfaces modeled by the Kriging meta-model (Figure 13). These surfaces relate each variable (always in the vertical axis) with the two most important parameters for their dynamics.

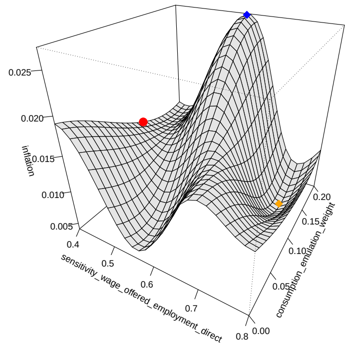
Table 2: Sobol decomposition: direct effects and interactions

			Inflation rate		Unemp. rate		Wage share		Wage Gini		Gross inc. Gini	
Symbol	Description	Range	Dir.	Int.	Dir.	Int.	Dir.	Int.	Dir.	Int.	Dir.	Int.
c_1	consumption emulation weight	[0, 0.2]	0.114*	0.375	0.360*	0.379	0.000	0.001	0.059*	0.163	0.000	0.004
c_2^{cap}	propensity to consume out of income for capitalists	[0.5, 1]	0.147*	0.077	0.166*	0.249	0.015	0.017	0.001	0.002	0.009	0.010
c_2^{dir}	propensity to consume out of income for direct workers	[0.5, 1]	0.001	0.005	0.047*	0.024	0.083*	0.186	0.032	0.157	0.026*	0.140
c_2^{ind}	propensity to consume out of income for indirect workers	[0.5, 1]	0.001	0.005	0.001	0.001	0.014	0.008	0.000	0.003	0.133*	0.288
λ_1	sensitivity of nominal interest rate to inflation gap	[0, 1]	0.000	0.006	0.000	0.002	0.000	0.002	0.000	0.003	0.000	0.006
λ_2	sensitivity of nominal interest rate to unemployment gap	[0, 0.5]	0.000	0.005	0.000	0.001	0.251*	0.324	0.185*	0.254	0.000	0.032
ν_3	sensitivity of mark-up deviation to unit costs (C firms)	[0.01, 0.5]	0.001	0.016	0.001	0.003	0.046	0.015	0.000	0.002	0.000	0.003
γ	sensitivity of workers desired wage to employment rate	[0.005, 0.05]	0.043	0.075	0.002	0.002	0.039*	0.291	0.023	0.073	0.000	0.004
ϕ^{dir}	sensitivity of workers' bargaining power to employment rate for direct workers	[0.4, 0.8]	0.208*	0.398	0.000	0.002	0.010	0.005	0.002	0.002	0.037	0.019
ϕ^{ind}	sensitivity of workers' bargaining power to employment rate for indirect workers	[0.4, 0.8]	0.041	0.027	0.018	0.020	0.050	0.122	0.304*	0.185	0.405*	0.340

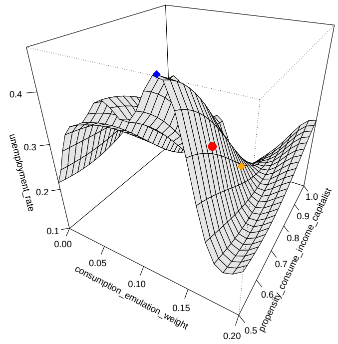
Note: $\star$ denotes the three most important inputs for each output (considering both the direct effect and interactions).

The response of the inflation rate to the two most important parameters for its dynamics, the sensitivity of workers' bargaining power to their employment rate (ϕ^{dir}) and the consumption emulation weight (c_1), is markedly non-linear. This is in line with the high interaction effects reported in Table 2. At very low and very high values of ϕ^{dir}, increases in the c_1 parameter tend to reduce the inflation rate, but for most of the parameter space it exerts a positive effect on the inflation rate. The effect of the ϕ^{dir} parameter, on the other hand, largely depends on its own value and on the value of the c_1 parameter. If c_1 is low (high), increasing the ϕ^{dir} when it is low tends to decrease (increase) the inflation rate, while at high values, further increases increase (decrease) the inflation rate. An economic interpretation to these non-linearities is that they arise from the interaction of these parameters with the inflation-targeting regime. The c_1 parameter tends to stimulate consumption and, consequently employment. This can cause inflationary pressures as well, so its net effect depends on which monetary policy target will drive the dynamics. A similar interpretation can be applied to the ϕ^{dir}, since its relative effect largely depends on the dynamics of workers' desired wages, which is also linked to the unemployment rate. In case this parameter leads to an increase in the wage share, it exerts a feedback effect on the unemployment rate through consumption. Therefore, both parameters have a relevant effect on both the inflation and unemployment rate and their effects are, consequently, dependent on the reactions by the monetary authority.

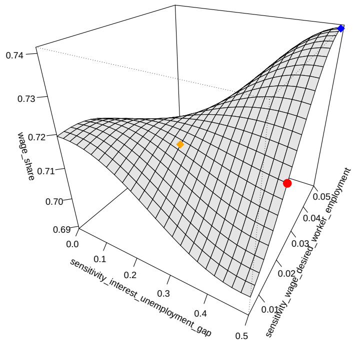
In line with this rationale, Figure 13b shows that the unemployment rate has a non-linear relationship with the consumption emulation weight (c_1). As mentioned, this parameter is important for the dynamics of the unemployment rate through its effect on consumption. It is also important as a transmission mechanism of the monetary policy, since it creates the possibility of desired consumption being above individual incomes, generating a demand for credit. Therefore, its non-linear effect may result from it first allowing monetary policy to be more effective and exert an impact on unemployment, and, after a certain value, stimulating employment through consumption. In addition, the unemployment rate tends to decrease with higher values of the propensity to consume by capitalists (c_2^{cap}) in almost the entire parameter space. This is also an important parameter for the consumption level and, consequently, to economic activity.



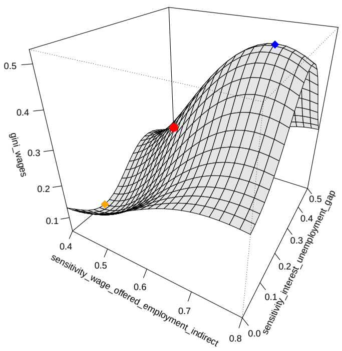
(a) Inflation rate



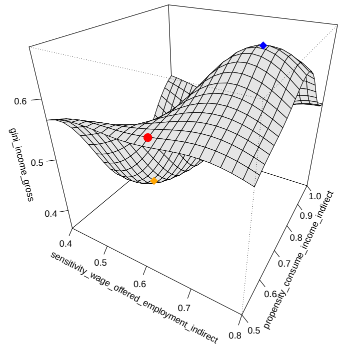
(b) Unemployment rate



(c) Wage share



(d) Wages Gini



(e) Income Gini

Figure 13: Response surfaces in Global Sensitivity Analysis

Note: Average of 100 Monte Carlo runs. Time series refer to simulation considerede periods. Dot identifies baseline specification and squares identify the maximum and minimum values. Input parameters: sensitivity_wage_desired_worker_employment = γ, sensitivity_interest_unemployment_gap = λ_2, sensitivity_mark_up_costs = ν_3, sensitivity_wage_offered_employment_indirect = ϕ^{ind}, consumption_emulation_weight = c_1, propensity_consume_income_direct = c_2^{dir}, propensity_consume_income_indirect = c_2^{ind}, and propensity_consume_income_capitalist = c_2^{cap}. All other parameters are equal to the baseline configuration.

The response surfaces for the distributive variables also reflect the interactions of the many factors driving their dynamics. As described in Figure 13c, there is a non-linear response of the wage share to its two most important parameters: the sensitivity of the interest rate to the unemployment gap (λ_2) and the sensitivity of workers' desired wage to the employment rate (γ). Also in this case, the non-linear responses are associated with significant interaction effects in the Sobol decomposition. The non-linear effect of the sensitivity of the interest rate to the unemployment gap may be associated with the fact that if the unemployment rate is below the target, a higher λ_2 parameter leads to an increase in the unemployment rate and thus reduces the bargaining power of workers, with negative implications for the wage share. Conversely, when the unemployment rate is above the target, a higher λ_2 means a stronger effect of monetary policy to stimulate employment, which exerts a positive effect on the bargaining power of workers. This can be the case when γ is low, for instance, because the inflation rate will tend to be lower and monetary policy will tend to stimulate employment to increase it. With respect to the sensitivity of workers' desired wage to the employment rate, its positive association with the wage share takes place when the λ_2 parameter is high because in this case the inflationary effects caused by the higher γ parameter are not fought against so strongly by the monetary authority since the higher employment rates are being preserved. Consequently, workers' bargaining power is not so badly affected and a higher wage share can be sustained.

As reported in Figure 13d, the wage Gini coefficient presents a relatively linear response to the sensitivity of the wage offered to the employment rate for indirect workers (ϕ^{ind}). This is associated with the key finding discussed in Section 4, which showed that increases in indirect workers' bargaining power relative to that of direct workers is a strong factor driving wage inequality. However, after a certain value, the effect of this parameter become negative, so further increases are associated with a reduction in wage inequality. The economic mechanism that may explain this is the minimum wage: it is possible that, at this point, the wage of direct workers becomes so low relative to that of the indirect workers that the minimum wage, which is determined by the average nominal wage growth (considering both the direct and indirect workers), becomes a binding restriction for most of these workers and, consequently, wage inequality starts to reduce. The wage Gini coefficient also presents a non-linear relationship with the sensitivity of interest rates to the unemployment gap (λ_2). A relationship between the variable and this parameter would be expected due to the importance of cyclical fluctuations in unemployment to the dynamics of wage inequality, which derives from the larger exposure of low-wage workers to business cycle fluctuations. The non-linearity in this relationship likely results from the following rationality: when λ_2 is low, the unemployment rate will tend to be different from the target (probably lower), and thus increases in λ_2 tend to increase the unemployment rate and inequality in wages. This is valid up to a certain point (when the unemployment rate reaches the targeted level), after which further increases in λ_2 tend to reduce the unemployment rate and, thus, reduce inequality in the wage distribution. Thus, the effect of λ_2 is mediated by the sign of the unemployment gap.

Finally, Figure 13e also suggests a strongly non-linear relationship between the income Gini coefficient and the two most important parameters for its dynamics: the sensitivity of the wage offered to the employment rate for indirect workers (ϕ^{ind}) and the propensity to consume out of income for indirect workers (c_2^{ind}). The individual effect of each parameter would be expected to be somewhat linear: since an increase in ϕ^{ind} increases the wage inequality through almost its entire parameter space, it would be expected to increase income inequality as well, while a higher c_2^{ind} would reduce income inequality through its effect on aggregate demand and employment. Thus, the non-linear surface is likely to result from the strong interactions between all parameters, as identified in the Sobol decomposition, and the monetary policy reactions. Indeed, higher c_2^{ind} stimulates economic activity and thus reduces unemployment, but if the reduction in unemployment rates is too strong, the monetary policy response may counteract the positive effects and induce higher levels of the income Gini coefficient. Also, a higher ϕ^{ind} may lead to lower mark-up rates, thus contributing to more equality in the income distribution through changes in the functional income distribution. Yet, since a higher ϕ^{ind} also leads to an increase in wage inequality, the net effect on income distribution may vary widely.

Overall, the sensitivity analysis provides further insights into the complex dynamics of the inflation-unemployment-inequality nexus, while also confirming the main results highlighted in the previous sections. Indeed, the sensitivity analysis favors the link between these variables through parameters affecting directly the nominal wage adjustments and consumption dynamics. In addition, the monetary policy reaction function appears, implicitly and explicitly, as a relevant factor influencing how the other parameters affect our variables of interest. In this sense, the sensitivity analysis confirms the key role played by monetary policy on these variables and their relationship.

7 Conclusion

In this article we discussed the inflation-inequality-unemployment nexus and explored its main distributive and macroeconomic implications. Based on empirical regularities that connect lower unemployment rates with higher inflation rates and lower inequality, we obtained the inequality-augmented Phillips curve as an emerging property of our AB model. This curve was plotted in a three-dimensional space between unemployment, inflation and inequality, and highlighted the importance of inequality as an additional dimension of the traditional Phillips curve. In other words, the inequality-augmented Phillips curve shows that the widely discussed trade-off between low inflation and low unemployment rates also involves a trade-off between low inflation rate and low inequality levels.

The inflation-inequality-unemployment nexus was investigated further in relation to the association of the inequality dynamics with the flattening of the Phillips curve, as identified by different strands of the macroeconomic literature (Stansbury and Summers, 2020, Setterfield and Blecker, 2022, Svensson, 2015)). In particular, we highlighted the role of a reduction in the low-wage workers' bargaining power as an explanation to the flattening of the Phillips curve and an increase in the wage and personal income inequality. Moreover, our model suggests that the existence of this nexus leads to important distributive implications for monetary policy. Our simulations imply that, when the monetary authority gives more priority to inflation control (following the monetary hawks), the higher unemployment rates required to maintain low inflation rates will be associated with more inequality, thus moving the economy downwards along the inequality-augmented Phillips curve.

In sum, our results suggest that income inequality ought to be considered as a relevant dimension when analyzing the macroeconomic effects of monetary policy and the potential trade-offs faced by policymakers when fighting inflation. Indeed, by considering income inequality as an additional dimension, we find that the trade-offs faced by the monetary authorities may be more perverse than what is usually considered. More generally, our findings reinforce the need to expand standard macroeconomic models to consider the role of heterogeneity in labor markets and its distributive implications for a deeper understanding of relevant macroeconomic phenomena observed worldwide.

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Appendix A: Transaction flows matrix

Table A.1: Transaction flows matrix

	Households	Consumption goods firms		Capital goods firm		Bank	Public sector	$\sum$
		Current	Capital	Current	Capital			
Consumption	$-C^{\$}_{H,t}$	$+Q^{s,\$}_{C,t}$						0
Investment			$-I^{\$}_{C,t}$	$+Q^{\$}_{k,t}$				0
Inventories		$+\Delta Q^{IN,\$}_{C,t}$	$-\Delta Q^{IN,\$}_{C,t}$					0
Wages	$+W^{\$}_{H,t}$	$-W^{\$}_{C,t}$		$-W^{\$}_{k,t}$			$-W^{\$}_{g,t}$	0
Profits	$+\Pi^{h,\$}_{H,t}$	$-\Pi^{n,\$}_{C,t}$	$+(\Pi^{n,\$}_{C,t}-\Pi^{h,\$}_{C,t})$	$-\Pi^{n,\$}_{k,t}$	$+(\Pi^{n,\$}_{k,t}-\Pi^{h,\$}_{k,t})$			0
Unemployment dole	$+d^{\$}_{H,t}$						$-d^{\$}_{H,t}$	0
Taxes	$-\mathcal{T}^{\$}_{H,t}$						$+\mathcal{T}^{\$}_{H,t}$	0
Loan interest	$-i_t\Lambda^{\$}_{H,t-1}$	$-i_t\Lambda^{\$}_{C,t-1}$				$+i_t\Lambda^{\$}_{t-1}$		0
Bonds interest						$+iB^{\$}_{t-1}$	$-iB^{\$}_{t-1}$	0
Change in loans	$+\Delta\Lambda^{\$}_{H,t}$		$+\Delta\Lambda^{\$}_{C,t}$			$-\Delta\Lambda^{\$}_{t}$		0
Change in deposits	$-\Delta D^{\$}_{H,t}$		$-\Delta D^{\$}_{C,t}$		$-\Delta D^{\$}_{k,t}$	$+\Delta D^{\$}_{t}$		0
Change in bonds						$-\Delta B^{\$}_{t}$	$+\Delta B^{\$}_{t}$	0
$\sum$	0	0	0	0	0	0	0	0

Note: The subscripts H and C the aggregate values of the households and consumption goods firms sectors respectively. The $+$ sign identifies sources of funds and the $-$ sign identifies uses of funds.

Appendix B: Model initialization and parameter values

The model initialization follows the procedure in Rolim et al. (2023). The number of indirect workers and capitalists depends on the number of direct workers, as follows:

$$N^{ind} = \left\lceil \frac{N^{dir}}{n^{dir}} n^{ind} \right\rceil \tag{B.1}$$

$$N^{cap} = \left\lceil \frac{N^{dir}(1 - n^{dir} - n^{ind})/n^{dir}}{N^c + N^k} \right\rceil (N^c + N^k) \tag{B.2}$$

where N^{dir} is the number of direct workers, n^{dir} and n^{ind} are the proportion of direct and indirect workers respectively. As mentioned, these proportions are calibrated following Mohun (2014). The number of capitalists per firm is equal to $\rho_4 = N^{cap}/(N^c + N^k)$. The number of direct workers as public servants (L_g^{dir}) is given by a multiple n^g of the number of direct workers employed by the private sector in the model's initialization, while the number of indirect workers as public servants is given by $L_g^{ind} = L_g^{dir}\lceil N^{ind}/N^{dir}\rfloor$.

Workers' initial wages are set according to their class, as follows:

$$w^{dir,\$}_{h,0} = \varrho_1 w^{min,\$}_0 \tag{B.3}$$

$$w^{ind,\$}_{h,0} = \varrho_2 w^{dir,\$} \tag{B.4}$$

where $w_0^{min,\$}$ is the initial minimum wage and $\varrho_{1,2} > 1$ are parameters.

Finally, the consumption goods firms start with the same full capacity production level ($Q^{fc}_{c,0}$).

The parameters and initial values of key variables for the baseline scenario are reported below:

Table B.1: Parameters and initial values in baseline scenario

Symbol	Description	Value
γ	sensitivity of workers desired wage to employment rate	0.02
δ	entrant firms' expected sales share of sector average sales (C sector)	0.5
$(1-\eta)^T$	unemployment rate target	0.05
ϑ	employees turnover share	0.05
λ_1	sensitivity of nominal interest rate to inflation gap	1
λ_2	sensitivity of nominal interest rate to unemployment gap	0.5
$\mu_{c,0}$	initial mark-up rate (C firms)	0.6
μ_k	mark-up rate (K firm)	0.5
ν_1	sensitivity of mark-up rate to market share (C firms)	0.01
ν_2	mark-up deviation persistence (C firms)	0.95
ν_3	sensitivity of mark-up deviation to unit costs (C firms)	0.5
ν_4	sensitivity of market share to competitiveness (C firms)	1
ρ_1	managers per direct workers (K firms)	0.16
ρ_2	indirect workers per direct worker (C firms)	0.085
ρ_3	indirect workers per direct worker at full capacity production (C firms)	0.065
ρ_4	number of capitalists per firm*	1
ϱ_1	initial ratio between direct workers wage and minimum wage	2.5
ϱ_2	initial ratio between indirect workers wage and direct workers wage	2.5
τ	tax rate on income	0.05
$\phi^{dir,ind}$	sensitivity of workers' bargaining power to employment rate for direct and indirect workers respectively	(0.4, 0.4)
$\omega_{1,2,3,4}$	sensitivity of expected demand to past demand (C firms)	(0.4, 0.3, 0.2, 0.1)
c_1	consumption emulation weight	0.12
$c_2^{dir,ind,cap}$	propensity to consume out of income (direct workers, indirect workers, capitalists)	(0.95, 0.85, 0.75)
i_0	initial nominal interest rate	0.02
i^{min}	minimum nominal interest rate	1e-07
$L_g^{dir,ind}$	workers hired as public servants*	(230,39)
ms^{min}	minimum market share to stay in the market (C firms)	0.0025
N^c	number of consumption goods firms	200
$N^{dir,ind,cap}$	number of direct workers, indirect workers*, and capitalists*	(1696,286,201)
$n^{dir,ind}$	percentage of direct and indirect workers in total population	(0.844, 0.142)
n^g	proportion of public servants in total initial employment (direct workers)	0.16
n^{IN}	desired share of inventories	0.1
$n^{s,dir,ind}$	proportion of workers in survey	(0.15, 0.3)
n^w	number of hiring rounds per open position	1.5
$\bar{p}^T$	inflation target	0.01
$Q^{fc}_{c,0}$	initial full capacity production (C firms)	80
Q^{fc}_m	machines production at full capacity	2.5
R	maximum interest payments to cash flow ratio	0.05

continued …

...continued

Symbol	Description	Value
s	sensitivity of probability of on-the-job search to difference in wages	5
T^c	number of periods before a new firm can exit the market	10
T^i	number of periods for average variables in monetary policy reaction function	4
T^k	machines lifetime	20
u^d	desired capacity utilization level	0.8
v	expansion investment speed of adjustment	0.2
$w_0^{min,\$}$	initial minimum wage	1
y^c	productivity at C sector	10
y^k	productivity at K sector	10

Note: $\star$ identifies values determined in the model's initialization.

The experiments configuration for section 4 is reported in Table B.2, while the experiments configuration for section 5 is reported in B.3.

Table B.2: Experiments configuration: direct workers' bargaining power shocks

Exp.	1	2	3	4	5	6
$\Delta\phi^{dir}$	0	-0.02	-0.04	-0.06	-0.08	-0.1

Note: experiment 1 corresponds to baseline configuration.

Table B.3: Experiments configuration: monetary policy reaction function parameters

Exp.	Baseline	Hawks	Doves
λ_1	1	1	0
λ_2	0.5	0	0.5

Appendix C: Comparison of experiments

Figure C.1 presents further information concerning the comparison of the experiments discussed in section 4.

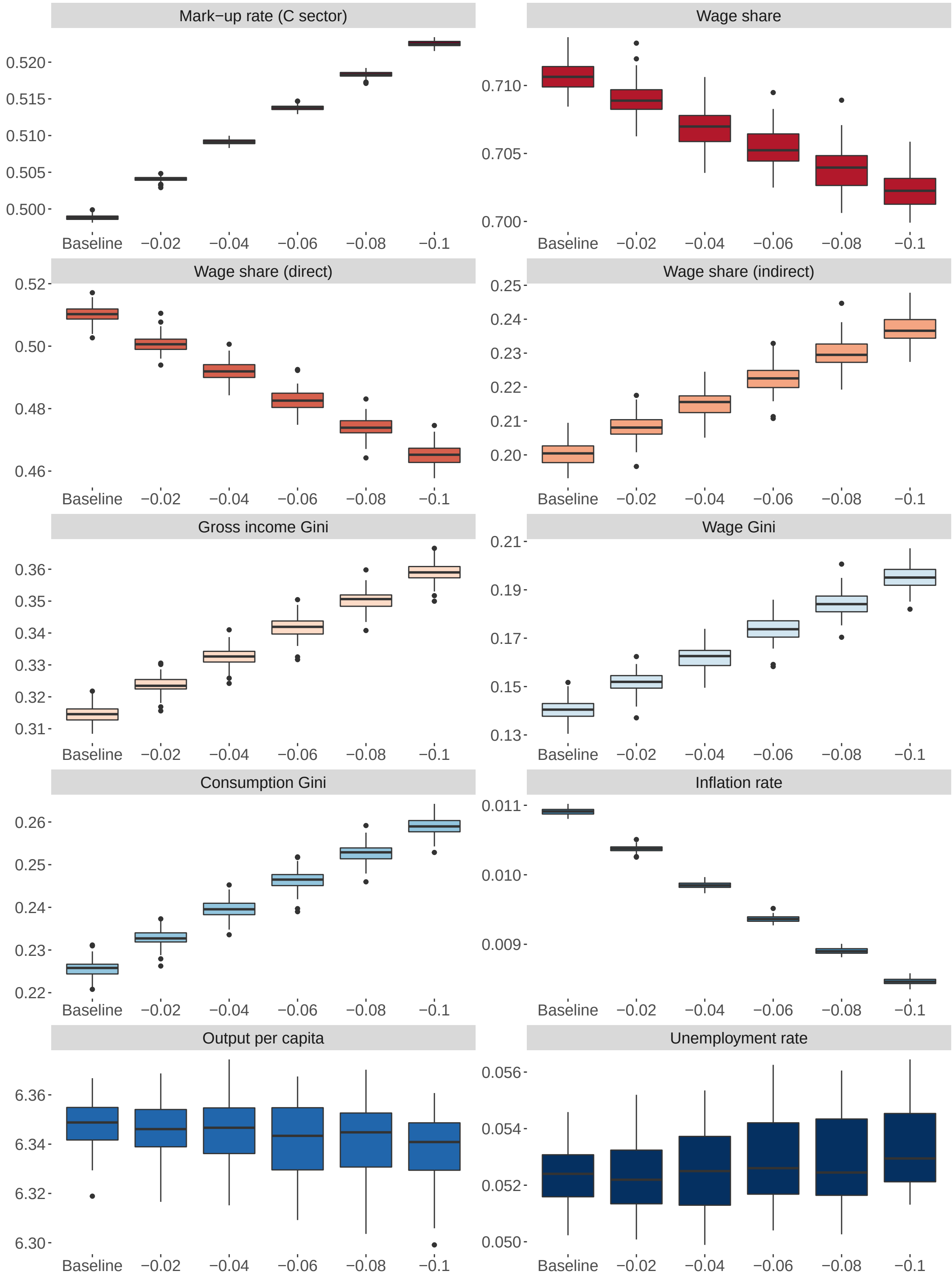

Figure C.1: Comparison of experiments (shocks on the ϕ^{dir} parameter)
Note: Line represents the median value, box represents the 2nd-3rd quartiles, and whiskers represent the maximum and minimum values among the average for the 100 Monte Carlo runs over the simulation periods after the shock on the ϕ^{dir} parameter. Dots are outliers. Experiment values represent the shocks on the ϕ^{dir} parameter