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. (2021), 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.

1 Introduction

The global acceleration in 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 global economic recession and a substantial rise in unemployment as a means to fight inflation, the sharp monetary policy tightening worldwide is raising concern 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 a worsening in income distribution. 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. (2021), 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., 2021), 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 can be seen as contributing 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), which is nonetheless mediated by monetary policy. More specifically, we extend the model presented in Rolim et al. (2021) 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).[1]

[1]Given our research question in this paper, a major simplification relative to Rolim et al. (2021) 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.[2] 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.[3]

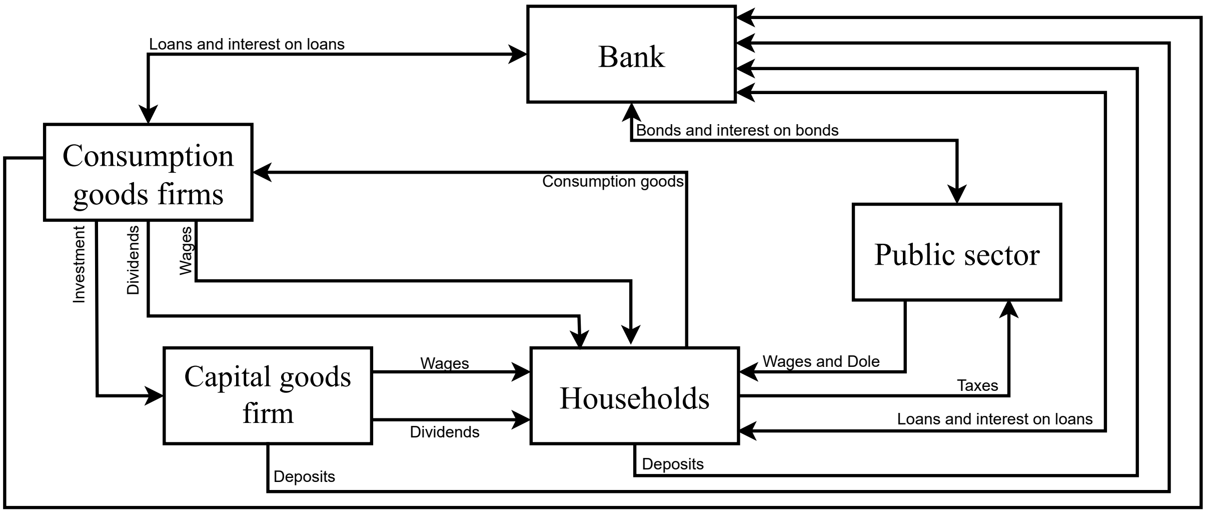


Figure 1: Model structure
Note: arrows point from paying sector to receiver sector.

2.1 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 latter acting as managers and supervisors. The labor demand for each type of workers is given by Equations 1 and 2 respectively:[4]

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

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

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.

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

[3]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.

[4]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.

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

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

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

2.2 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:

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

where $Q^{D}_{c,t-i}$ 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 ($Q^{d}_{c,t}$) is set by also taking into consideration a fixed desired share of inventories (n^{IN}) relative to $Q^{D,e,t}_{c,t}$ 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).[5]

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

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

where $\rho_{2,3} > 0$ are parameters and $L^{dir,fc}_{c,t}$ 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 Zworkers. As reported in Equation 7, the first component ($\mu^*_{c,t}$) depends on the evolution of firms' market share, which contains information with respect to each firm's position relative to its competitors.[6] 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.[7]

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

[5] As explained in Rolim et al. (2021), 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.

[6] 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).

[7] As discussed in Rolim et al. (2021), this specification 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.

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

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 ($1 > \upsilon > 0$). 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 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 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 Households

As in the original model, 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.[8] 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 $t-1$, $T_{h,t}^{w} = 0$). Workers also have a reservation wage, which is the lowest level at which they accept to work and is equal to the unemployment benefit.

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.

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 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:

[8] 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)

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

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 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).[9] Firms use labor surveys to set wages (Bewley, 2007), consulting a random set of workers to consult their desired wage.[10] 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.

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

[10] 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 $j = dir, ind$.

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.

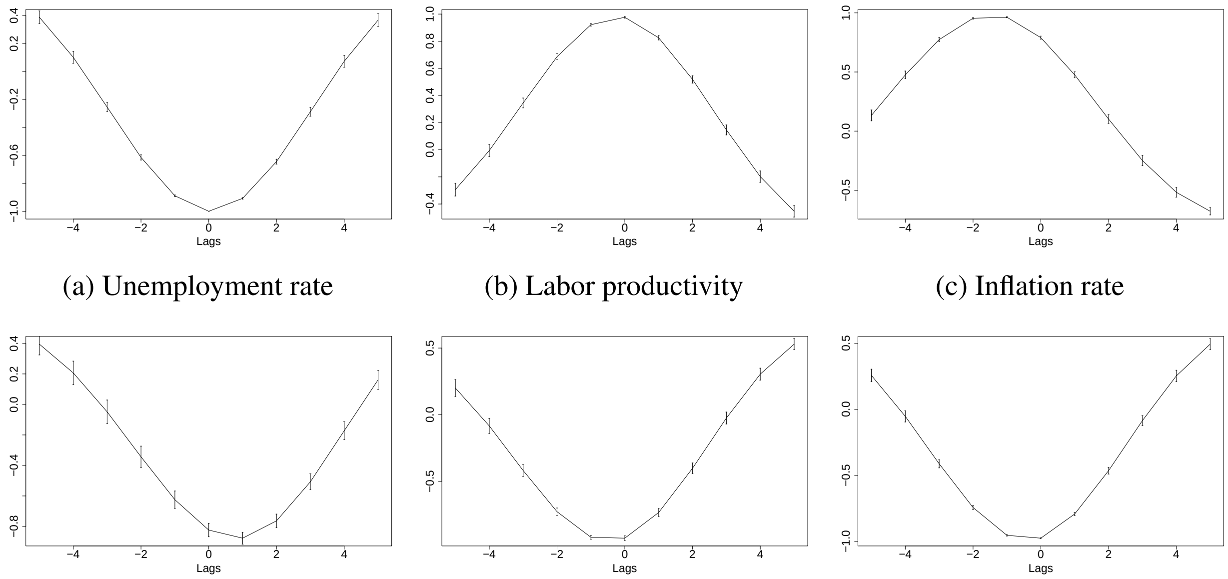
3 The inflation-unemployment-inequality nexus

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).[11] 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 paper, priority is given to stylized facts concerning inflation, inequality, and employment.[12] 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 reduces. 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 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).

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

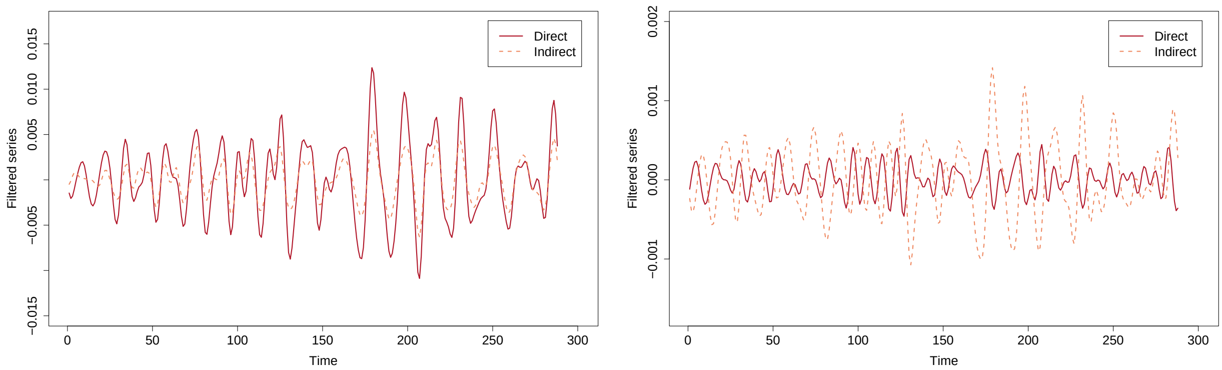
[12] The model structure largely reproduces other empirically observed stylized facts, such as the cyclical fluctuations of output, consumption, investment, and inventories. Given the purpose of this article, we do not report these results and they are available upon reasonable request. See Rolim et al. (2021) for more details on the stylized facts reproduced by the model.



(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). Moreover, when output increases, employment does not increase proportionally because part of employment is overhead and the overall labor productivity increases.[13] Thus, even if the direct labor productivity in the consumption and capital goods sector 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

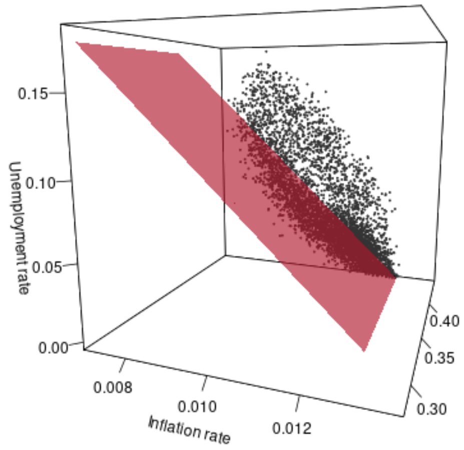
[13]For a formal presentation of this dynamics, see Lavoie (2014, ch. 5). It should be mentioned that a countercyclical wage share is expected to be observed even if firms' mark-up rates are constant and as long as prices are based on unit costs computed at the desired capacity utilization level and overhead labor is present. Another reason for this behavior of the wage share could be labor hoarding.

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. Indeed, 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.

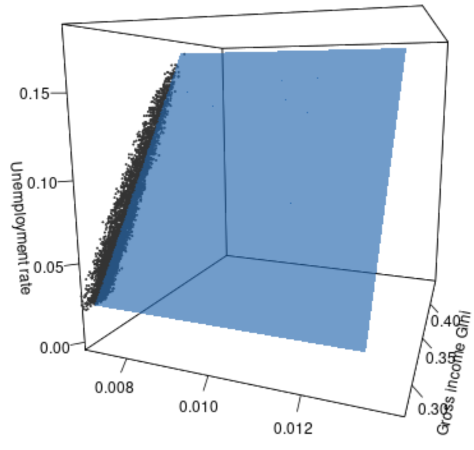
The cyclical dynamics of employment also relates to the inflation dynamics, which is procyclical (Figure 2c), in line with empirical findings (Stock and Watson, 1999).[14] At the peak of the cycle, the lower unemployment rates lead to an increase in workers' bargaining power, which translates into higher nominal wage adjustments. Since mark-ups do not fully absorb the higher costs, price levels grow at a higher rate. This negative relation between the unemployment rate and the inflation rate is a widely observed empirical regularity known as the Phillips curve, which is represented in Figure 4a.[15]

[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. (2021), 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.

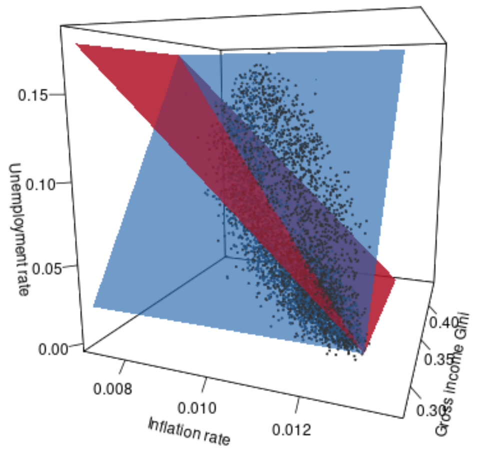
[15]There is a long debate about whether unemployment is related to the level of the inflation rate or to the change in the inflation rate. For a summary of the debate and an analysis of periods in which each type of relation was observed in the USA economy, see Setterfield and Blecker (2022). Also,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



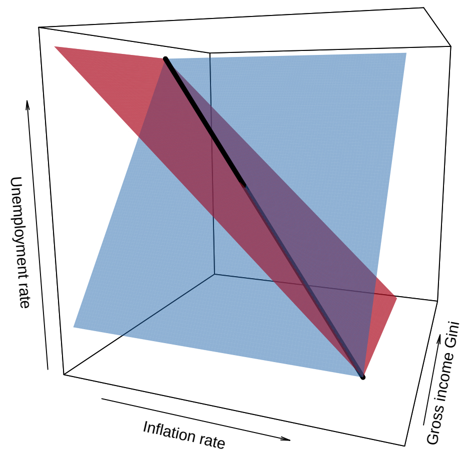
(a) Phillips curve (inflation x unemployment) and its projection to the 3D space



(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 projecting to a three-dimensional space both the Phillips curve, which originally was plotted in the two-dimensional space between the unemployment and inflation rate, and the unemployment-inequality curve, which originally was plotted in the two-dimensional space between the unemployment rate and the gross income Gini coefficient. The intersection between the projections of these two 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]

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 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. 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, as in the work by Setterfield (2005), Setterfield and Blecker (2022), Setterfield and Lovejoy (2006), and Summa and Braga (2020), among others.

In this section, we explore how workers' heterogeneity explains this phenomenon, while also providing an explanation for the increasing wage inequality that is observed in numerous economies. 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,[17] this may be an unrealistic assumption given the institutional changes that may 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,[18] 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.[19]

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

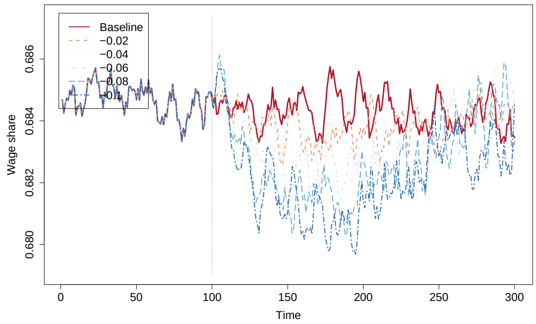
[16] Setterfield and Blecker (2022) highlight that such trade-off also pertains to the functional income distribution. This relationship is also explored in Rolim et al. (2021), wherein there are also implications for the personal income distribution given the nexus between the personal and functional income distributions. The next sections add wage inequality as another dimension of this trade-off.

[17] 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.

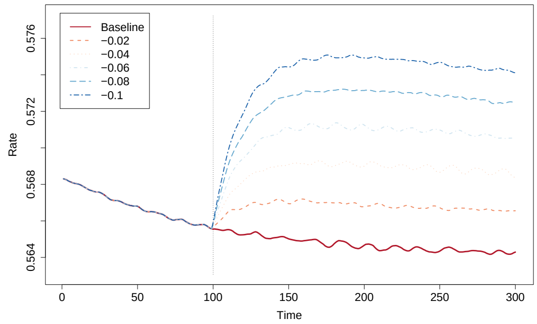
[18] Managers can be considered to be allied to capitalists (Duménil and Lévy, 2015), acting to surpress wages in order to increase shareholder value (Guttmann, 2016). Consequently, managers have succeeded in increasing their own share of income in the form of salaries and executive stock options (Lazonick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

[19] 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.

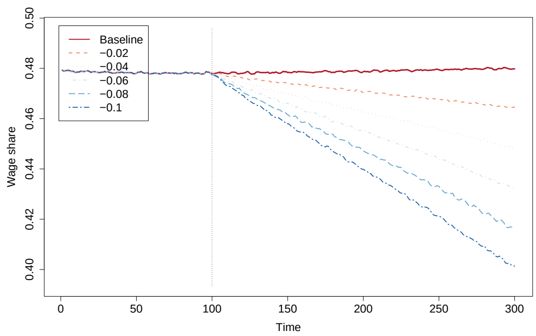
the direct workers' bargaining power to their employment rate (ϕ^{dir}) in Equation 14, while the parameter relative to indirect workers (ϕ^{ind}) is kept constant at the baseline value.[20] In line with the "bargaining power hypothesis", we observe that the negative shocks on the direct workers' bargaining 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).[21] 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).



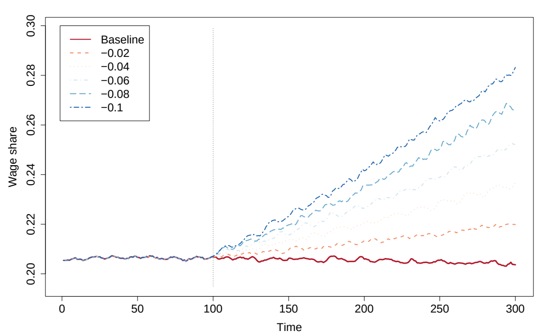
(a) Wage share



(b) Mark-up rate (C sector)



(c) Wage share (direct)



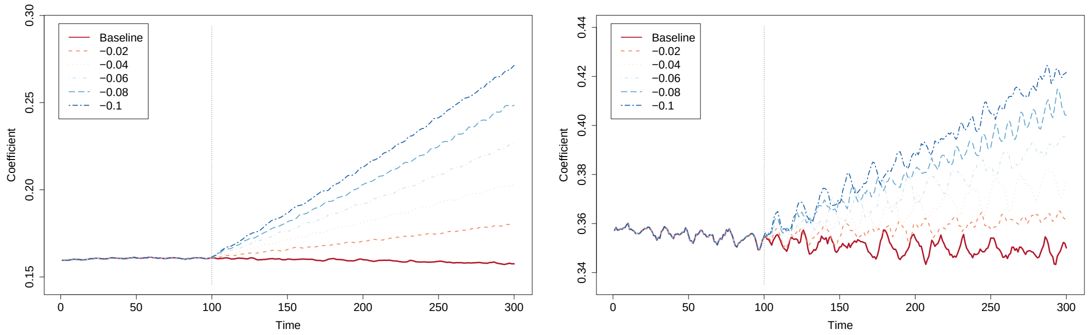
(d) Wage share (indirect)

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.

[20] The experiments values are reported in Table B.2 in Appendix B.

[21] 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 government employment and the wage share within each productive sector.

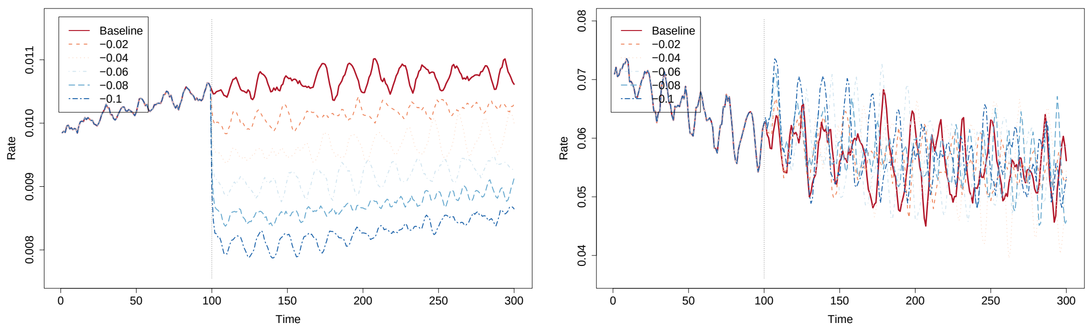


(a) Wage Gini coefficient (b) Income Gini coefficient

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.[22] Yet, this is not observed in our results, since the unemployment rates are rather similar across the simulations (Figure 7b). 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.



(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.

In addition to being an inequality driver, the negative shocks on the direct workers' bargaining power have important consequences for the shape of the Phillips curve. Indeed, Figure 8 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

[22] 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.

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.

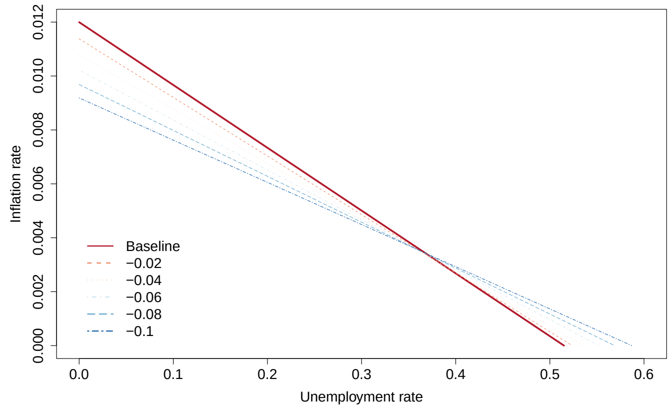


Figure 8: Phillips curve

Note: 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.

Table 1: Intercept and coefficient in Phillips curve

Experiment	Intercept	St. error	Coefficient	St. error
Baseline $(\Delta\phi^{dir}) = 0$	0.012	0	-0.0233	0.0001
$\Delta\phi^{dir} = -0.02$	0.0114	0	-0.0217	0.0001
$\Delta\phi^{dir} = -0.04$	0.0108	0	-0.0202	0.0001
$\Delta\phi^{dir} = -0.06$	0.0102	0	-0.0185	0.0001
$\Delta\phi^{dir} = -0.08$	0.0097	0	-0.017	0.0001
$\Delta\phi^{dir} = -0.1$	0.0092	0	-0.0156	0.0001

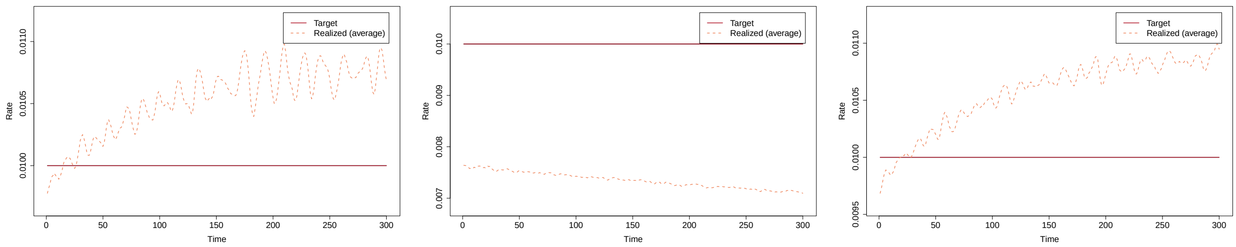
In sum, these results indicate that changes in the institutional framework supporting workers' bargaining power can have major implications for the structural form of the Phillips curve and also to the dynamics of income inequality. Indeed, in an era of "incomes policies based on fear" (Cornwall, 1990, Setterfield, 2005), 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.

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 employment 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 employment (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

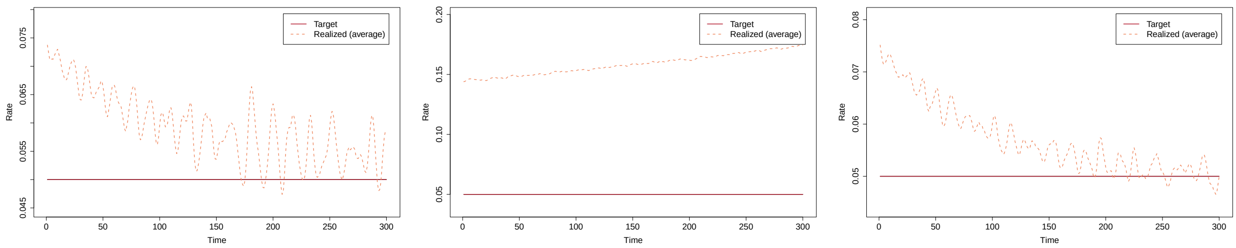
$\lambda_1 = 0$ in Equation 13, monetary policy does not react to the inflation gap, while when $\lambda_2 = 0$ it does not react to the unemployment gap.[23]

Figures 9 and 10 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.[24] Therefore, in this scenario, while monetary policy comes relatively closer to the employment 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 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.[25]



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

Figure 9: Monetary policy rules: target and realized values for inflation rate
Note: Average of 100 Monte Carlo runs.



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

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

The box-plots in Figure 11 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

[23]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 $\phi^{dir} = \phi^{ind}$.

[24]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.

[25]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.

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 worsening in the 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.[26] 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 associated with a slightly higher inflation rate and lower unemployment rate than the baseline scenario, while the income distribution variables are very similar to the baseline scenario. The similarity with the baseline scenario indicates that despite of the dual mandate in this scenario, the weights given to each target tended to prioritize the unemployment rate also in the baseline scenario.

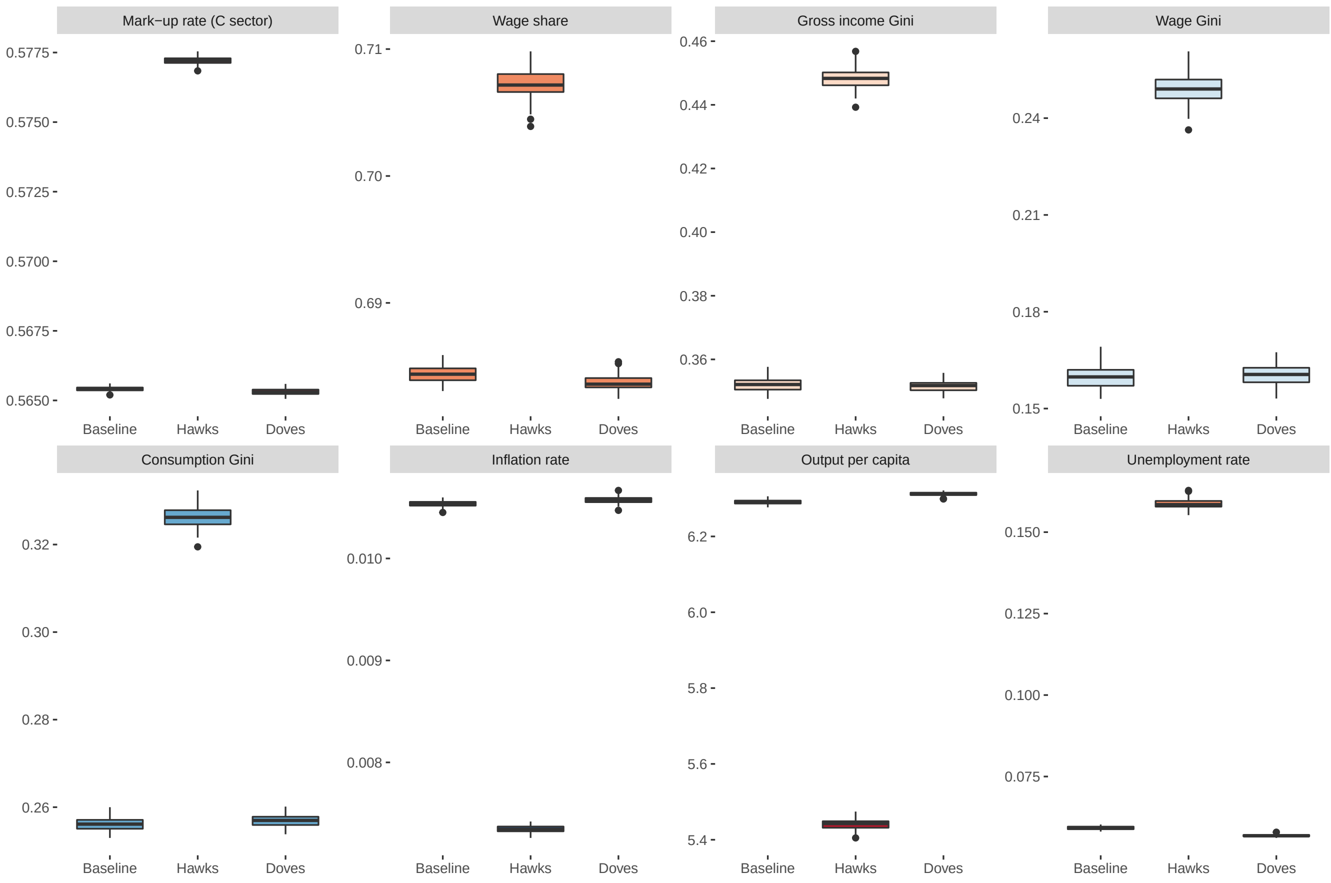


Figure 11: Monetary policy rules comparisons

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. In line with the inequality-augmented Phillips curve, we find that monetary policy rules have important implications for the wage and income inequalities. Thus, a monetary policy rule that prioritizes low inflation rates, such as the Hawks scenario, may come at the cost of higher unemployment and higher inequality.

[26]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 wages dynamics for each type of worker is reflected in the increase in the wage Gini coefficient.

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. 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.

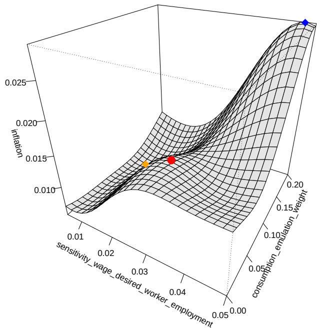
The Sobol decomposition is reported in Table 2. It decomposes the variance of each output in contributions from each input (Sobol, 2001), thus indicating the most important parameters for the dynamics of each variable. The effect of the two most important parameters is analyzed through the Kriging meta-model that follows.

Table 2: Sobol decomposition: direct effects and interactions

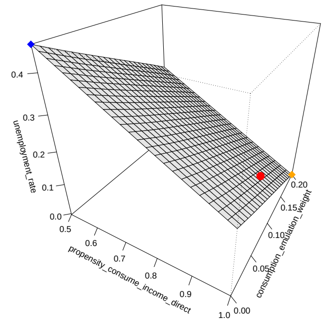
			Inflation rate		Unemp. rate		Wage share		Wage Gini		Gross inc. Gini	
Symbol	Description	Range	Dir.	Int.	Dir.	Int.	Dir.	Int.	Dir.	Int.	Dir.	Int.
c_1	consumption emulation weight	[0, 0.2]	0.190⋆	0.261	0.198⋆	0.002	0.003	0.007	0.039⋆	0.178	0.001	0.266
c_2^{cap}	propensity to consume out of income for capitalists	[0.5, 1]	0.071⋆	0.121	0.19⋆	0.001	0.324⋆	0.540	0.000	0.005	0.001	0.266
c_2^{dir}	propensity to consume out of income for direct workers	[0.5, 1]	0.020	0.004	0.322⋆	0.002	0.000	0.011	0.028	0.171	0.001	0.264
c_2^{ind}	propensity to consume out of income for indirect workers	[0.5, 1]	0.001	0.002	0.113	0.001	0.006	0.002	0.000	0.006	0.048⋆	0.437
λ_1	sensitivity of nominal interest rate to inflation gap	[0, 1]	0.001	0.004	0.012	0.024	0.006	0.007	0.000	0.005	0.000	0.258
λ_2	sensitivity of nominal interest rate to unemployment gap	[0, 0.2]	0.000	0.001	0.001	0.001	0.064⋆	0.047	0.171⋆	0.306	0.000	0.258
ν_3	sensitivity of mark-up deviation to unit costs (C firms)	[0.01, 0.5]	0.001	0.017	0.036	0.032	0.017⋆	0.440	0.000	0.005	0.001⋆	0.268
γ	sensitivity of workers desired wage to employment rate	[0.005, 0.05]	0.256⋆	0.257	0.051	0.002	0.001	0.008	0.000	0.005	0.001	0.266
ϕ^{dir}	sensitivity of workers' bargaining power to employment rate for direct workers	[0.4, 0.8]	0.001	0.003	0.014	0.001	0.001	0.006	0.005	0.008	0.003	0.259
ϕ^{ind}	sensitivity of workers' bargaining power to employment rate for indirect workers	[0.4, 0.8]	0.080	0.052	0.005	0.001	0.009	0.046	0.346⋆	0.248	0.482⋆	0.447

Note: ⋆ denotes the three most important inputs for each output.

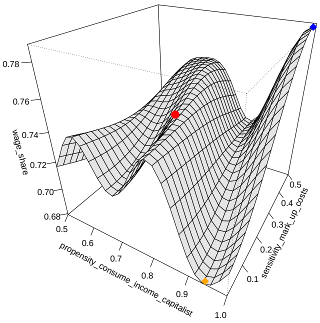
The response surfaces modeled by the Kriging meta-model are reported in Figure 12. These surfaces relate each variable (always in the vertical axis) with the two most important parameters for their dynamics. As reported in Figure 12a, we note that the inflation rate tends to increase with the sensitivity of workers' desired wage to the employment rate (γ), since this is a key variable determining the dynamics of nominal wage adjustments that are then (at least partially) passed on to prices. The inflation rate also grows with the consumption emulation weight (c_1), probably because of its effect on aggregate demand and unemployment, which is another key variable for the nominal wage adjustments. Moreover, the Sobol decomposition suggests a strong interaction between these parameters, which may explain the non-linear response surface for the inflation rate. In line with the behavior of the inflation rate, Figure 12b shows that the unemployment rate decreases with higher values of the consumption emulation weight parameter. Also capturing the interaction between aggregate demand and employment, the unemployment rate tends to be lower when the propensity to consume out of income for direct workers (c_2^{dir}) is higher. The relative importance of the propensity to consume out of income for this specific class most likely reflects the fact that, in the baseline scenario, it is the class with the largest share of income (see figures 5a, 5c, and 5d). Therefore, its propensity to consume will be relatively more important for aggregate consumption.



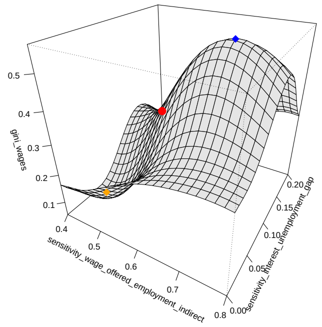
(a) Inflation rate



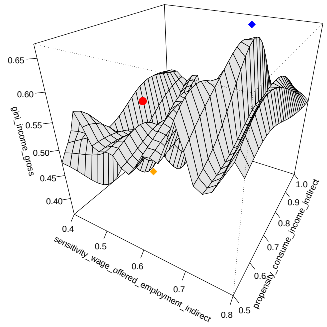
(b) Unemployment rate



(c) Wage share



(d) Wages Gini



(e) Income Gini

Figure 12: Response surfaces in Global Sensitivity Analysis

Note: Average of 100 Monte Carlo runs. Time series refer to simulation effective 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 present more non-linearities than the variables analyzed so far, which reflects the interaction of the many factors driving their dynamics. As described in Figure 12c, the wage share can either grow or decrease when the sensitivity of the mark-up to costs increases (ν_3). Since the only source of growth in costs in the model is nominal wage growth, this non-linear effect simply suggests that if nominal wages are growing (decreasing) more, a higher sensitivity of mark-up to costs leads to a higher (lower) wage share. Thus, the ν_3 parameter's effect on the wage share depends on its interaction with parameters determining the dynamics of nominal wage growth, such as the propensity to consume out of income for capitalists (c_2^{cap}). As with all parameters capturing the propensity to consume out of income, c_2^{cap} tends to be related to higher aggregate consumption and lower unemployment rates. The reduction of the unemployment rate would tend to be associated with a higher wage share, since it leads to an increase in workers' bargaining power. Yet, depending on the resulting increase in the inflation rate, the response of the monetary authority can counteract this effect, increasing the unemployment rate and reducing the wage share. Thus, the interaction between this structural parameter and the response of the monetary authority may provide an economic explanation for the non-linearity in the response of the wage share to the propensity to consume out of income for capitalists.

As reported in Figure 12d, 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 that the minimum wage, which is determined by the 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 12e 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 capitalists (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, 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 Gini coefficient. Also, a higher ϕ^{ind} tends to lead to higher aggregate demand because, in principle, it leads to lower mark-up rates, thus contributing to more equality in the 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 unemployment and inflation through parameters affecting directly the nominal wage adjustments and consumption dynamics. It also confirms the relationship between unemployment and inequality, while suggesting that it is mediated by the monetary policy rule.

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 so-called inequality-augmented Phillips curve as an emerging property of our agent-based model. This curve was plotted in a three-dimensional space between unemployment, inflation and inequality, and highlighted the role of wage inequality as an additional dimension of the traditional Phillips curve. In other words, our results suggest that the widely discussed trade-off between low inflation and low unemployment also involves a trade-off between low inflation and low inequality.

The inflation-inequality-unemployment nexus was investigated further in relation to the role played by inequality dynamics as an explanation for the so-called flattening of the Phillips curve, as identified by different strands of the macroeconomic literature (Stansbury and Summers (2020), Setterfield and Blecker (2022), Svensson (2015)). We showed that this phenomenon can result from a reduction in the low-wage workers' bargaining power and, consequently, that it is associated with a worsening in the wage and personal income distribution.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 in the income distribution.

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. 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. (2021). 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^{dir}_g) 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 $L^{ind}_g = L^{dir}_g \lceil N^{ind}/N^{dir} \rfloor$.

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 $w^{min,\$}_0$ 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

continued ...

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Symbol	Description	Value
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	0.2
$\mu_{c,0}$	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)	0.2
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
$Q_{c,0}^{fc}$	initial full capacity production (C firms)	80
Q_m^{fc}	machines production at full capacity	2.5
R	maximum interest payments to cash flow ratio	0.05
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

continued ...

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Symbol	Description	Value
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	0.2	0	0.2