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## Accounting for the Multiple Sources of Inflation: an Agent-Based Model Investigation

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# Accounting for the Multiple Sources of Inflation: an Agent-Based Model Investigation

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**Abstract**

In this work, we develop a macroeconomic agent-based model to study the role of demand and supply factors in the determination of inflation dynamics. The model is characterized by local interactions of heterogeneous firms and households in the labor and goods markets. Imperfect information implies that market selection is imperfect, as it does not depend only on relative prices but also on firm size. We show that our model is able to generate realistic inflation dynamics, as well as a non-linear Phillips curve in line with the empirical evidence. We then find that the traditional demand-led explanation of inflation stemming from a tight labor market only holds when markets are competitive and efficient. Finally, we study the response of inflation to shocks impacting on consumption, labor productivity or energy costs. The results show that only demand shocks lead to wage-led inflation surges. Productivity shocks are entirely passed-through to prices without affecting the income distribution. Energy shocks, instead, induce sellers' inflation after changes in both firms' cost structure and profit margins. This is in line with the recent empirical evidence for the Euro Area.

**JEL Codes:** E31, E32, C63.

**Keywords:** Inflation, agent-based models, market structure, mark-up rates, sellers' inflation.

# 1 Introduction

This paper investigates the multiple sources of inflation surges considering the possible different role played by demand and supply factors. We employ an extended version of the agent-based model by Guerini et al. (2018) which is characterized by local search and matching of heterogeneous firms and workers in the labor and goods markets, which are characterized by imperfect information and selection. In particular, imperfect information implies that prices do not immediately clear the market and firm selection depend on both firms' relative price and size, so that larger companies can enjoy higher monopolistic power. Even in presence of fully flexible price and wages at the firm level, such a market mechanism induces a tighter association between supply-side factors and the inflation rate, possibly leading to a rich dynamics and the emergence of the so-called ”seller's inflation” (see Weber and Wasner, 2023).

The sharp surge in prices witnessed in Europe and in the US since the first semester of 2021 has sparked a vivid debate among economists and policymakers. On the one side, considered inflation surge as an excess-demand phenomenon due to a combination of lax fiscal and monetary policies (Summers, 2021; Bianchi et al., 2023; Cevik and Miryugin, 2023). This view follows is based on the inflation episodes experienced by developed economies since the Seventies and is theoretically grounded upon the standard New-Keynesian, Dynamic Stochastic General Equilibrium models. According to this view, inflation arises as the result of a negative discrepancy between the market interest rate and its natural level, which generates an excess demand that, in turn, accelerates wage growth and inflation (see Galı and Gertler, 1999; Woodford, 2003). On the other side, an opposing view casts serious doubts on the demand-driven origins of the current inflation surge. Among the others, Stiglitz and Regmi (2023) argue that the main determinants of the current inflation ramp-up reside into “*industry-specific problems [...] possibly exacerbated by market power and market manipulation*”, rather than into the labor markets tightness. Similarly, Weber and Wasner (2023) claim that the current inflation spike is likely to be the result of the firms pricing decisions: in their attempt to protect and expand their profit margins, firms propagate and amplify the supply shocks induced by Covid-19 and by the Russian-Ukraine conflict.

From an empirical viewpoint, there are some differences between the inflation of the 1970's and the one we are currently witnessing since the Twenties. First, inflation emerged after the Covid-19 pandemics, a shock originated outside of the economic realm that led to both demand and supply rapid adjustments (see Baqaee and Farhi, 2022). Second, the monetary policy stance was much more expansionary during the 2010's rather than during the 1960's, with the Federal funds effective rate over the two decades averaging respectively 0.61% and 4.18% in the US. Third, during the past three decades a decoupling between productivity and wage growth has also taken place (see Stansbury and Summers, 2018; Baker, 2019; Greenspon et al., 2021). Fourth, the current surge in inflation follows two decades in which most advanced economies have witnessed a rise in both market concentration and average mark-up rates (e.g., De Loecker et al., 2020; Autor et al., 2020), while the post WWII period was characterized by an increase in market competition.

In the past years, empirical works associating the surge of inflation to the rise of profit shares and mark-ups have blossomed. The evidence on the profit shares is uncontroversial. An International Monetary Fund working paper (Hansen et al., 2023) shows a strong association between the 2022-2023 inflation growth and the rise of import prices and domestic profits. Similar results hold true also in Europe: Hahn (2023) find that corporations have more than compensated the increases in non-labor costs, contributing to an acceleration in price growth. Also the OECD Economic Outlook (OECD, 2023) documented a similar trend for unit profits in several advanced economies (see also Glover et al., 2023).

The evidence on the increases of mark-ups is less crystal clear. Andler et al. (2022) and Konczal (2022) highlight how both corporate profits and mark-up have been increasing with prices, while wages have been staying put in the same period. Gerinovics and Metelli (2023) and Arquié and Thie (2023) find a temporary increase in firm mark-ups in 2021-2022 in the US and France respectively. for the US in 2021-2022. In stark contrast, Manuel et al. (2024) document a decline in mark-ups for the UK after the energy shock episodes and Colonna et al. (2023) argue that while profit shares have indeed increased, the mark-ups have been constant in Germany and Italy in 2022. Nonetheless, the President and the Chief Economist of the European Central Bank, respectively Lagarde and Lane, release official declarations indicating that the current inflation surge is also a result of the increase in the profit margins (Lagarde, 2023; Lane, 2023).

To shed light on the possible multiple sources of inflation surges, we develop an Agent-Based Model (ABM). Agent-Based Models represent the economy as a complex, evolving system populated by heterogeneous and interacting agents (see Dawid and Gatti, 2018; Fagiolo and Roventini, 2017; Dosi and Roventini, 2019). The model extends the work by Guerini et al. (2018) and it is populated by heterogeneous firms and workers which locally interact in imperfectly competitive labor and goods markets. As the markets are characterized by deep uncertainty, firms fix prices and wages following heuristics (Dosi et al., 2010, 2020). More specifically, firms set wages according to the previous period gap between opened and filled vacancies (a measure of the perceived excess demand for labor). Prices are fixed according to a mark-up rule, wherein the latter is an increasing function of the market share growth (the individual firm's perceived market power). Agents' interactions in the labor and goods markets are governed by local search and matching protocols. In the labor market, the probability of a worker to match a firm is an increasing function of the wage posted by the latter. In the goods market, we extend the model in Guerini et al. (2018)[1] assuming that the probability of matching between a consumer and a firm is both a decreasing function of the price posted by the firm and an increasing function of the firm size. The dependence of the latter matching probability on firm size captures the imperfect selection in the market for goods in the spirit of customer market models (see Phelps and Winter, 1970; Greenwald and Stiglitz, 2005, among the others) and it mimics the search and matching algorithm introduced in Fontanelli et al. (2023). The assumption that the probability of matching increases with firm size, *ceteris paribus* generates an advantage for larger firms as it implies that, given the prices, they will be able to attract more customers. Note that our model provide a *Tobinesque* interpretation of inflation as a disequilibrium phenomenon emerging out of the interaction occurring among heterogeneous agents in different segmented markets (Tobin, 1972) [2]

Our work adds up to the small but quickly expanding agent-based literature centered on the investigation of inflation dynamics as well. A conspicuous number of ABM Macro models address price dynamics indirectly while investigating contiguous topics like monetary policy (Salle et al., 2013), business cycles (Riccetti et al., 2015), or financial instability (Assenza et al., 2015). However, relatively few contributions in the literature focus directly on inflation and its determinants (Seppecher et al., 2018). Ashraf et al. 2016 focuses on decentralized interaction and customer markets, while Gualdi et al. 2017; Knicker et al.

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[1] We also enrich the model by introducing a banking sector which provides credit to firms, and a central bank that fix the reference interest rate according to a pure inflation-targeting Taylor rule.

[2] The interpretation of inflation outlined above is complementary, and not exclusionary, to those views that trace back the roots of inflation to conflicting claims over real income by different groups of economic agents (see for example Lorenzoni and Werning, 2023; Hein, 2023; Lavoie, 2024) .

2023 draw policy implications from a stylized macroeconomic ABM with aggregate consumption. At the same time, some papers in the agent-based literature focus on inflation dynamics in open economies, addressing the impact of price shocks on expectations (Alvarez et al., 2020) and on income distribution (Rolim et al., 2022). Finally, Poledna et al. 2023; Hommes et al. 2022 develop a behavioral agent-based model with an emphasis on forecasting performance and use it to explain the macroeconomic impact of the COVID-19 pandemic for Austria and Canada, respectively.

Extensive Monte Carlo simulations show that the model is able of generate realistic inflation dynamics and a non-linear Phillips curve in tune with the empirical evidence (Gagnon and Collins, 2019; Benigno and Eggertsson, 2023). We find that the nature of inflation strongly depends on the characteristics of selection in the market for goods. When selection in that market is close to perfect - and therefore competition is largely driven by price differences among firms - the market structure becomes less concentrated. In such a scenario, higher aggregate demand and widespread labor shortages push the money wages upwards increasing their pressure on prices. This is consistent with the traditional "demand-led" explanation of inflation. In contrast, as market selection becomes more and more imperfect, the allocation of market shares is increasingly affected by the size of the firms which gain monopolistic power. In such a scenario, the variability in mark-ups explains the rise of inflation with the emergence of a profit-price spiral (see also Tobin, 1972).

Finally, we analyze the impact of demand, productivity and energy shocks on aggregate output, inflation, and market structure dynamics. After a positive demand shock, the increased production leads to a scarcity of labor which pushes up wages and prices. This leads to a temporarily higher inflation rate which is accompanied by a moderate fall in marks-ups and profit shares. A negative supply shock to labor productivity increases inflation, as firms are able to completely pass through the shock to the consumers, but it does not substantially impact either on the marks-ups or on the profit shares. On the contrary, a positive shock to energy costs endogenously generate profit-led inflation (Weber and Wasner, 2023), which stems from both changes in firms' relative cost structure and higher market concentration [3]. The former channel leads to an increase in the profit shares, as wages do not respond to the increased energy costs (in line with Manuel et al., 2024; Colonna et al., 2023). The second channel dampens market competition thus spurring firms' profit margins (Konczal, 2022; Gerinovics and Metelli, 2023). Our re-

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[3] ee (Weber et al., 2024) for a representation of the cost-price relationships during the Ukraine war inflation in the US.

sults replicate the recent empirical evidence on the surge of profit-led inflation in the Euro Area (Hansen et al., 2023).

The rest of the paper is structured as follows: Section 2 introduces the model, while Section 3 presents the results of the first set of Monte-Carlo which show the explanatory capability of the model. Section 4 explores the impact of different demand and supply shocks on macroeconomic dynamics. Finally, Section 5 concludes.

# 2 The Model

We consider a closed economy populated by $F$ firms, $H$ households, a bank, and a central bank. Time is discrete, indexed by "weeks" t = 1, ..., T. There are 52 weeks per "year". Firms produce a homogeneous consumption good using a linear technology that employs only labor. Households supply labor inelastically and consume the final good using the income received by firms and their stock of liquid wealth. In the good and labor markets, firms and households locally interact via decentralized protocols. The commercial bank collects deposits from households and it provides loans to firms, charging the relative interest rates. The central bank adopts a single-mandate Taylor Rule in order to steer the economy towards an inflation target.

## 2.1 Timeline of events

In any given time period *(t)*, the following microeconomic decisions take place in sequential order:

1. Financial state variables are updated. Firms and bank update their balance sheets and households update their wealth.
2. The central bank fixes the reference rate of interest. Inflation expectations by households and firms are updated.
3. Bankrupted firms exit from the economy and are replaced by new ones on a one-to-one basis.
4. Firms set their mark-up rate, the offered wage and their production target; they compute their demand for labor and selling price accordingly.

5. Firms compute their loan demand and the bank decides whether or not to grant credit.
6. Households compute their desired consumption levels.
7. The labor market opens. Employers and employees are matched. Production takes place. Households receive their wages.
8. The goods market opens. Firms and consumers are matched.
9. Firms and the bank compute their profits and distribute dividends to households. Households calculate their realized consumption expenditure and their savings.
10. At the end of each time step, aggregate variables (e.g. GDP, investment, employment) are computed summing over the corresponding microeconomic variables.

## 2.2 Central bank policy

The weekly inflation rate is defined as:

$$\pi_t = \frac{\bar{P}_t - \bar{P}_{t-1}}{\bar{P}_{t-1}}, \tag{1}$$

where $\bar{P}_t = \sum_{f=1}^{F} P_{f,t} s_{f,t}$ is the average price set by firms at time $t$, weighted by their market shares $s_{f,t}$. Every six weeks the central bank computes the average inflation rate of the past year ($\tilde{\pi}_t = \frac{\sum_{k=1}^{52} \pi_{t-k}}{52}$), and it plugs it into a single mandate Taylor Rule to set the reference rate of interest $\rho_t^0$ in order to steer the economy towards a target inflation level $\pi^*$:

$$\rho_t^0 = \rho^* + \phi(\tilde{\pi}_t - \pi^*), \tag{2}$$

where $\rho^* > 0$ is a "target" interest rate and $\phi > 0$ represents the intensity of the policy.[4]

## 2.3 The expectations formation process

We assume that inflation expectations by firms and households are a linear combination between realized inflation during the last week and an inflation "anchor" which is exogenously set, along the lines of Salle

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[4] The values we assume for these as well as all others parameters in our baseline parametrization of the model are reported in Table 1.

et al. (2013).[5] Formally, each agent forms her inflation expectation as a weighted average between the inflation anchor $\pi^*$ and past inflation $\pi_{t-1}$.

$$\hat{\pi}_{f,t} = \chi\pi^* + (1-\chi)\pi_{t-1} \tag{3}$$

The weight parameter $\chi \in [0,1]$ is assumed to be common across all agents, and it can be interpreted as the degree of anchoring private expectations to some long-term inflation rate.

### 2.4 Production, wages, and prices

In each period firms set their production level and the price and wage they offer to workers. At the same time, households set their desired consumption. Output is perishable and cannot be stored for the next period.

The production of the consumption good takes place by means of a linear production function employing only labor ($n_{f,t}$) as input:

$$q^s_{f,t} = a_{f,t}n_{f,t}, \tag{4}$$

where $a_{f,t}$ is the firm-specific labor productivity, which we assume to be subject to idiosyncratic mean zero random shocks.

In the second experiment of Section 4 we hit the economy with a 5% reduction of labor productivity $a_{f,t}$ at $t = 1600$, in order to study the impact of this kind of shock on the model dynamics. We consider a negative, uniform change in the value of household consumption at time t*. The dynamics of the shock is the following:

$$a_{f,t} = a_{f,t*}(1-\eta_t) \text{ where } \begin{cases} \eta_t = 0 \text{ if } t < t^* \\ \eta_t = \mu_\eta \text{ if } t \in (t^*, t^*+3) \\ \eta_t = \rho_\eta \eta_{t-1} \text{ if } t > t^*+3 \end{cases} \tag{5}$$

Firms' labour productivity decreases by an amount $\mu_\eta$ for a 4-weeks period. Starting from the fifth

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[5] The relevance of past inflation for the expectation formation process has been recently highlighted by Candia et al. (2023). Furthermore, the expectation formation rule here adopted is grounded on the laboratory experiments by Anufriev and Hommes (2012) and Assenza et al. (2021) among the others.

week, the shock starts to decay at a rate $\rho_\eta$. (we set $\mu_\eta = 0.05$ and $\rho_\eta = 0.95$).

Firms set their desired production ($\widehat{q}_{f,t}$) according to:

$$\widehat{q}_{f,t} = \tilde{q}_{f,t} + \alpha^g z^{good}_{f,t-1}, \tag{6}$$

with $\alpha^g > 0$. The term $\tilde{q}_{f,t}$ captures the reference or "normal" production level, in line with the insights from behavioral economics about reference-dependence and satisficing behaviour by firms (see e.g. Cyert and March, 1963; Simon, 1955). The above rule implies that deviations from the reference level of production are due to past excess demand. The reference level itself evolves adaptively with past sales:

$$\tilde{q}_{f,t} = \tilde{q}_{f,t-1} + \alpha^g(q_{f,t-1} - \tilde{q}_{f,t-1}) \tag{7}$$

Each firm $f$ sets the money wage $W_{f,t}$ as follows:

$$W_{f,t} = W_{f,t-1}(1 + \hat{\pi}^+_{f,t})^{\beta^l}(1 + z^{lab}_{f,t-1})^{\alpha^l}, \tag{8}$$

with $\beta^l > 0$, $\alpha^l > 0$ and $\hat{\pi}^+_{f,t} = max\left\{\hat{\pi}_{f,t}, 0\right\}$. More precisely, we assume that the firms use the monetary wage posted the previous week as a benchmark, and they adjust it according to the expected current inflation level (if positive) to account for formal and informal indexation mechanisms operating in the wage formation process. Moreover, the wage is influenced by the state of the labor market through the term $z^{lab}_{f,t-1}$, which represents the ratio between the vacancies left unfilled in the previous period and the total opened vacancies. This implies that a gap between open and filled vacancies will push a firm to increase its wage in order to attract more workers (see e.g. Mortensen and Pissarides, 1999; Diamond, 1982). This formulation can be seen as a formal representation of the idea expressed by Tobin (1972) of wage growth being the sum of two components, an equilibrium component (represented in the model by anchored inflation expectations), or the rate at which wages would grow with no vacancies, and a disequilibrium one, which can be seen as a function of excess demand. Note that the rate of unfilled vacancies at each period $z^{lab}_{f,t}$ can only take non-negative values; this implies a downward nominal rigidity in our model. Firms react to labor shortages by increasing the money-wage and to excess employment by reducing the number of jobs. This feature of the model finds justification on the overwhelming macro- and individual-level evidence supporting the existence downward money wage rigidity.[6]

The assumption of downward money-wage rigidity does not prevent real wages from adjusting. On the contrary, even if money wages cannot be compressed, the firm has always the power to set prices above wages with the rate of profit margins being determined by the market structure (see below Equation 10). Therefore, real wage can fall, but this happens by upward movements in prices, instead than by downward movements in money-wages. This makes our model substantially different from New-Keynesian models that generate involuntary unemployment by assuming real wage rigidities - e.g. Blanchard and Galí (2006). In other words, in line with Tobin (1972), our economy has an "inflationary bias", displaying positive long-run inflation as a natural outcome when the economy is close to full employment, breaking therefore the "divine coincidence" feature of New Keynesian models (Blanchard and Galí, 2007).

Firms employ a full cost pricing heuristic (see e.g. Hall and Hitch, 1939) to set their prices. Being labor the only factor of production, the unit production cost $C_{f,t}$ of a firm is equal to:

$$C_{f,t} = \frac{W_{f,t}}{a_{f,t}} \tag{9}$$

Firms apply a variable mark-up ($\mu_{f,t}$) over their unit costs of production. The price ($P_{f,t}$) posted by the firm therefore is:

$$P_{f,t} = C_{f,t}\left(1 + \mu_{f,t}\right). \tag{10}$$

Mark-up rates change over time according to the variation in firm's market share $s_{f,t} = \frac{q_{f,t}}{\sum_g^F q_{g,t}}$:

$$\mu_{f,t} = \mu_{f,t-1} + \nu(s_{f,t-1} - s_{f,t-2}), \tag{11}$$

with $\nu > 0$. Such a rule implies that firms consider the variation of their market shares as a proxy of the degree of their market power (as in Dosi et al., 2010, 2013). In addition, the above rule is in line with the recent empirical evidence indicating that industries with larger firms and more concentrated market structures are associated to higher mark-up rates (see e.g. Autor et al., 2020; De Loecker et al., 2020).

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[6] For the U.S., see Akerlof et al. (1996), Kahn (1997) and Daly and Hobijn (2014), among many others. Individual-level evidence for a large number of countries is in Dickens et al. (2007). Kahneman et al. (1986), Bewley (1999, 2007) provide extensive anecdotal and survey evidence on downward nominal wage rigidities in the United States and Germany. Holden and Wulfsberg (2008) provide multi-country evidence from industry-level data.

### 2.5 Consumption

We assume that households set their desired consumption $\widehat{c}_{h,t}$ according to a buffer-stock consumption rule, analogous with the one implied by Carroll et al. (1992) and Carroll (1997). In particular, households make their consumption decisions by targeting a given "cash-on-hand ratio", defined as the wealth as a proportion of "normal income" (i.e., $\frac{A_{h,t}}{\bar{Y}_{h,t}}$) (see Carroll, 2001). $A_{h,t}$ indicates the household's stock of wealth, which evolves according to the past flow of the household's savings (see equation 23). The "normal income" $\bar{Y}_{h,t}$ evolves adaptively according to past realized income which includes both wage and dividends (cfr. equation 14 and 23):

$$\bar{Y}_{h,t} = \left[\bar{Y}_{h,t-1} + \alpha_y \left(Y_{h,t} - \bar{Y}_{h,t-1}\right)\right](1 + \pi_{t-1}) \tag{12}$$

with $\alpha_y > 0$ being a parameter that captures the speed of adjustment. Households desired consumption then writes:

$$\widehat{c}_{h,t} = \bar{Y}_{h,t}\left[1 + \delta_0\left(\delta_1 \frac{A_{h,t}}{\bar{Y}_{h,t}} - 1\right)\right] \tag{13}$$

with $\delta_0 > 0$ and $\delta_1 > 0$ representing respectively the consumption adjustment and the cash-on-hand ratio sensitivity. If actual cash-on-hand ratio is greater than the target, the agent has been "over cautious" and will consume more; if cash-on-hand is below the target instead, the the household will save save more in order to bring the wealth ratio back toward the target $\frac{A_{h,t}}{\bar{Y}_{h,t}}$. Finally, if the real wealth $\frac{A_{h,t}}{\hat{P}_t}$ of an household is not sufficient to cover for the planned expenses (i.e., the desired consumption is outside the feasible consumption set), the household consumes all its real wealth without any form of saving.

The main difference between Carroll's buffer-stock saving rule and our setup is that we assume households to have adaptive expectations about normal income (cfr. equation 12) instead of facing a given income distribution centered around a "permanent" income mean. In line with the empirical evidence about excess smoothness (Flavin, 1993), our assumption implies that after an income shock, an household needs some weeks to adjust to the new level of consumption.

Total savings, computed at the end of the period, are equal to the difference between effective nominal consumption and income, represented by the earned wage $W_{h,t}$, the fraction of firms and bank profits paid as dividends, $D_{h,t}$, and returns on deposits $\rho_t^d A_{h,t}$:

$$S_{h,t} = W_{h,t} + D_{h,t} + \rho_t^d A_{h,t} - \sum_{f=1}^{F} P_{f,t} c_{h,t} \tag{14}$$

## 2.6 The credit market

The banking sector is constituted by one commercial bank. Analogously to Popoyan et al. (2017), we assume the interest rate on deposit to be equal to the reference rate fixed by the central bank, i.e. $\rho_t^d = \rho_t^0$, while the interest rate on loans is $\rho_t^l = \rho_t^0 + \varsigma$, with $\varsigma > 0$ being a fixed positive spread. The bank has a positive initial net worth $NW^b$ and, as the firms, it redistributes a fixed share of its profits to households at each period.

The demand for credit stems from firms' production plans. More specifically, each firm computes its demand for credit ($L_{f,t}^d$) as the difference between the production costs it expects to sustain in the next period and its own internal financial resources, that is $L_{f,t}^d = max\left\{n_{f,t}W_{f,t} - NW_{f,t}, 0\right\}$.

As a firm applies for credit, the bank checks its loan-to-value ratio ($\frac{L_{f,t}^d}{NW_{f,t}}$) and fully satisfies firms' credit demand if $\frac{L_{f,t}^d}{NW_{f,t}} \leq \mathscr{E}_t$. Otherwise, the bank provides credit just up to $\mathscr{E}_t NW_{f,t}$, and the rationed firm is forced to scale down its production accordingly. The threshold $\mathscr{E}_t > 0$ is time varying and it is a decreasing function of the real interest rate, in accordance with the literature on the bank-lending channel of monetary policy (Bernanke, 2007; Disyatat, 2011):

$$\mathscr{E}_t = \mathscr{E}[1 - \theta(\rho_t^0 - \pi_t)], \tag{15}$$

where $\theta > 0$ represents the sensitivity of the threshold to the weekly real interest rate ($\rho_t^0 - \pi_t$). The variable $\mathscr{E}$ represents the baseline threshold level (that is, the maximum credit ratio the bank would be willing to accord if the real interest rate was zero). The intuition behind this relation is that the perceived strength of the bank's balance sheets affects its willingness to supply loans. Whenever an indebted firm is unable to repay the loan and goes bankrupt, the bank absorbs the corresponding "bad debt". As a rise in interest rates reduce the capability of firms to pay bank their loans, the bank tightens its credit supply in order to hedge against the increasing default probability. Although this mechanism is not modeled explicitly here, our assumption is in line an ample evidence showing that banks react to monetary tightening by decreasing lending (Altunbaş et al., 2002; Gambacorta, 2005; Gambacorta and Marques-Ibanez, 2011) conditional to their capitalization, risk profile ad liquidity.

## 2.7 The search and matching process in the labor and goods markets

Firms and workers interact locally in both the goods and labor markets according to a search and matching protocol similar to the one introduced in Guerini et al. (2018). We first describe the search and matching process in the labor market and, next, the one in the market for goods.

### 2.7.1 The labor market

Firms in the labor market needs to hire workers to fulfill their production plans. Labor demand ($n^d_{f,t}$) is equal to:

$$n^d_{f,t} = \frac{\widehat{q}_{f,t}}{a_{f,t-1}} \tag{16}$$

Each worker supplies one unit of labor inelastically and has a zero reservation wage.

The matching between firms and workers is local. Firms post their vacancies and wage quotes. Workers sort firm randomly and sequentially decide whether to queue up or not for the open positions with a probability that is increasing in the offered salary. More formally, a worker decides to queue up or not for a job according to a binomial draw with probability $p^{LM}_{f,t}$:

$$\Phi^{LM}_{h,t} = \begin{cases} 0 \;\; \text{with probability} \;\; 1 - p^{LM}_{f,t} & \text{(not queuing up)} \\ 1 \;\; \text{with probability} \;\; p^{LM}_{f,t} & \text{(queuing up)} \end{cases} \tag{17}$$

The probability of queuing $p^{LM}_{f,t}$ is proportional to the wage offered by the firm, relative to the market-average one:

$$p^{LM}_{f,t} = 1 - \varrho^{LM} \left[ 1 - \left( \frac{W_{f,t} - \bar{W}_t}{\bar{W}_t} \right) \right]. \tag{18}$$

$\bar{W}_t$ is the market average wage and $\varrho^{LM} \in (0,1)$ is a parameter determining the degree of search frictions and imperfect information in the labor market. Note that the probability of queuing is an increasing function of $\varrho^{LM}$. Therefore, the lower the value of $\varrho^{LM}$, the higher the probability that workers will queue up for any given difference between the firm's wage and average one. When a firm has filled all of its vacancies, workers stop looking for jobs at that specific firm regardless of the wage posted.

Finally, the effective units of labor at the firm level ($n_{f,t}$) are determined by the short side of the market according to:

$$n_{f,t} = min(n^d_{f,t}, n^s_{f,t}) \tag{19}$$

Notice that decentralized matching implies that frictional unemployment (or labor rationing) may arise even when the notional aggregate labor demand and aggregate labor supply are equal.

### 2.7.2 The goods market

Right after the labor market closes and workers have been allocated to the firms, the production of goods take place by means of the linear production process specified in Eq. (4).

The allocation of total consumption demand across firms is determined by a local search and matching process similar to the one described above for the labor market. The main difference is that consumers do not sort firms randomly but according to their market share, and they start looking for sellers with a preferential attachment to largest companies.[7] The assumption that consumers sort firms according to their size in the above matching protocol proxies the fact that larger firms have also better distribution channels and are therefore more visible to customers and able to grow. It also implies that the selection process of firms in the goods market is imperfect as it does not just depend on prices but also on other firm variables (like firm size). Finally, it generates dynamic increasing returns in market selection, as larger firms are able to match with more customers for any given price posted (see Fontanelli et al., 2023, for a similar approach to the analysis of international trade dynamics). The above micro-foundation of market selection builds on customer market models with imperfect competition and stochastic matching between consumers and producers (see for example Phelps and Winter, 1970; Bils, 1989; Rotemberg and Woodford, 1991; Greenwald and Stiglitz, 2005). Furthermore, the presence of dynamic increasing returns in market selection is in line with several evolutionary models of market dynamics (see e.g. Arthur, 1989; Dosi and Kaniovski, 1994; Pagano and Schivardi, 2003; Dosi et al., 2019).

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[7] The preferential attachment process has been largely empirically verified over several domains. See e.g. Barabási and Albert (1999) among many.

Once firms are sorted according to their size, consumers decide whether to queue up or not for the goods sold by the firms in their list with a binomial trial with probability $p^{GM}_{f,t}$.

$$\Phi^{GM}_{h,t} = \begin{cases} 0 \text{ with probability } 1 - p^{GM}_{f,t} & \text{(not queuing up)} \\ 1 \text{ with probability } p^{GM}_{f,t} & \text{(queuing up)} \end{cases} \tag{20}$$

A household queues up at one firm only, demanding $\widehat{c}_{h,t}$ units of the good.[8] The probability of queuing is proportional to the price posted by the firm relative to the market average one:

$$p^{GM}_{f,t} = \rho^{GM} - \frac{P_{f,t} - \bar{P}_t}{\bar{P}_t} \tag{21}$$

With $\rho^{GM} \in (0, 1)$. Once all the households have queued up, the effective amount of product sold by a firm is determined by the short side of the market.

Note that by varying the value of the parameter $\rho^{GM}$ in Equation 21, one can tune the intensity of the firm size advantage in the matching process between firms and customers and therefore the degree of imperfection in the market selection process. In particular, higher values of $\rho^{GM}$ imply a higher probability of matching for any given price, capturing a higher advantage for larger firms (i.e., those that can exploit their ”prominence” on the market and are sorted first by consumers). In the simulation analyses in sections 3 and 4 we exploit the above properties intensively and we present results for different values of $\rho^{GM}$, which capture scenarios where market selection is more or less imperfect.

The above assumptions about how firms and customers interact allows us to keep an important property of the model by (Guerini et al., 2018), namely the emergence of coordination failures in labor and goods markets which, through the amplifying role of positive demand feedbacks, is able to generate involuntary unemployment even when real wages are falling.

At the end of the matching algorithm, a household consumes a quantity $c_{h,t}$. According to the scenario analyzed (see Section 3.1 and 4), final consumption can be shocked, in order to simulate a rise or a fall of personal consumption expenditure.

More precisely, we consider a uniform change in the value of household consumption at time $t^{\star}$. The

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[8] This also implies that, if a firm is not able to satisfy the demand of a consumer, then the consumer gets rationed.

dynamics of the shock is the following:

$$c_{h,t} = c_{h,t^\star}(1+\eta_t) \qquad \text{with} \begin{cases} \eta_t = 0 & \text{if1} \quad t < t^\star \\ \eta_t = \mu_\eta & \text{if } t \in (t^\star, t^\star + 3) \\ \eta_t = \rho_\eta \eta_{t-1} & \text{if } t > t^\star + 3 \end{cases} \tag{22}$$

Households increase their personal consumption by an amount $\mu_\eta$ for a 4-weeks period. Starting from the fifth week, the shock starts to decay at a rate $\rho_\eta$.

## 2.8 Financial conditions, exit and entry

After the matching process in the goods market is concluded, households determine their effective real consumption $c_{h,t} \leq \widehat{c}_{h,t}$ and their consumption expenditures $\sum_{f=1}^{F} P_{f,t} c_{h,t}$. They also compute savings, as the difference between income and effective nominal consumption. Households' income is represented by the earned wage $W_{h,t}$, the fraction of firms and bank profits paid as dividends, $D_{h,t}$, and returns on wealth $\rho_t^d A_{h,t}$. Households update their wealth ($A_{h,t+1}$) according to:

$$A_{h,t+1} = A_{h,t} + S_{h,t} \tag{23}$$

Households store at each time step all of their savings in the form of deposits.

Firms' profits $\Pi_{f,t}$ are equal to total sales revenues net of labor costs and interest payment:

$$\Pi_{f,t} = q_{f,t} P_{f,t} - n_{f,t} W_{f,t} - \rho^l L_{f,t} \tag{24}$$

Whenever profits are positive, firms distribute a fraction $\omega_1$ as dividends to households, and then a fraction $\omega_2$ to a fund that bails in bankrupted firms (firms' bankruptcy protocol is illustrated in the next paragraph) The law of motion of the firm's net worth is therefore:

$$NW_{f,t} = \begin{cases} NW_{f,t-1} + (1-\omega_1)(1-\omega_2)\Pi_{f,t} & \Pi_{f,t} \geq 0 \\ NW_{f,t-1} + \Pi_{f,t} & \Pi_{f,t} < 0 \end{cases} \tag{25}$$

As firm ownership is symmetric, each household receives a fraction $1/H$ of the dividends paid by each firm and by the bank. If profits are negative, firm's net worth is reduced accordingly. A firm is declared bankrupt whenever its net worth becomes negative. In such a situation, the firm exits the market and it is replaced by a new entrant. The net worth of the new firms is drawn from a bail-out fund and it is equal to its initialization value (indexed by price level), while bad debt is absorbed by the bank. The bailout fund is financed through a contribution by incumbent firms, that put a share of profits $\omega_2 > 0$ into the fund every week they realize a positive profit. [9]. Households own an equal share of the new firm, receiving its future dividends (if any). Finally, prices, wages and desired production of the entrant are computed as the weighted (by market shares) average of the incumbents.

**Table 1:** Baseline parametrization

| | **Parameter Description** | **Parameter Value** |
|---|---|---|
| $T$ | Simulation length | 2000 |
| $MC$ | Number of MonteCarlo Simulations | 100 |
| $H$ | Number of households | 500 |
| $F$ | Number of firms | 50 |
| $X$ | Expectation Anchoring | 0.5 |
| $\alpha^l$ | Wage adjustment | 0.1 |
| $\alpha^g$ | Supply adjustment | 0.1 |
| $\nu$ | Mark-up sensitivity to market shares | 0.5 |
| $\beta^l$ | indexation parameter | 1 |
| $\delta_0$ | Consumption adjustment | 0.5 |
| $\delta_1$ | Consumption - Cash-on-hand ratio | 0.2 |
| $\alpha_y$ | Consumption - Permanent income adjustment | 0.5 |
| $\mathscr{E}$ | Debt to Equity threshold | 10 |
| $\theta$ | Real interest rate effect on credit | 300 |
| $\pi^*$ | Inflation target | 0 % |
| $\rho^*$ | Baseline weekly deposit rate | 0.02 % |
| $\rho^1$ | Baseline weekly loan rate | 0.05 % |
| $\phi$ | Monetary policy intensity | 0.5 |
| $\gamma^{LM}$ | Matching friction labor | 0.25 |
| $\rho^{GM}$ | Incumbent advantage effect | 0.4 |
| $\omega_1$ | Firm share of profit distributed to households | 0.5 |
| $\omega_2$ | Firm share profits distributed to ”bailout fund” | 0.5 |

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[9] The bail-out fund makes the model stock-flow consistent, in the sense that all the resources needed to finance firm entry are drawn from firm profits within the model (see Godley and Lavoie, 2006, for an extensive illustration of stock-flow consistency.)

# 3 Simulation Results

We analyze the model described in the previous section through extensive Monte Carlo simulations. More precisely, we perform $MC = 100$ Monte Carlo runs for the baseline parametrization of the model (see Table 1). Each Monte Carlo run is iterated over 2000 periods (or ”weeks”) which are enough for the model to converge to a statistical equilibrium for all the aggregate variables of interest.[10] We calibrate our model selecting a vector of parameters which is able to approximately match empirical evidence on our main variable of interests (Fagiolo and Roventini, 2017; Fagiolo et al., 2019). In table 2 we compare the average values of the main macroeconomic variables obtained in our baseline calibration with real-world data from the United States and the European Union. For inflation rates, unemployment we take the simple average of FRED time series, while for mark-ups we borrow from the manufacturing sectors mark-ups estimated in (Christopoulou and Vermeulen, 2012). Our simulations results are in line with empirical evidence and slightly closer to EU data rather than US ones, especially for mark-up.

**Table 2:** Baseline output validation

| Variable | Model | US data | EU data |
|---|---|---|---|
| Inflation | 2.2% | 2.49% | 2.24% |
| Unemployment | 6.25% | 5.9% | 8.8% |
| Mark-up | 16.2% | 28% | 18% |

Inflation: FRED average for 2000-2022.
Unemployment: FRED average for 2000-2022.
Mark-up rates: Christopoulou and Vermeulen (2012) for 1981-2004.

In Figure 1, we show the dynamics of a typical run of the model for key macroeconomic variables: output, inflation, mark-up and unemployment. In order to facilitate comparisons with real world data, we apply a centered moving average (MA) filter of order 12 to consolidate the weekly data points into quarterly data, thus getting rid of higher-frequency variability. The time series show the emergence of endogenous business cycles of varying amplitude and duration. Next, we compute cross-correlation functions in order to studying the relationships between the macro variables across business cycle frequencies. The results are reported in Figure 2. In accordance with the empirical literature (Stock and Watson, 1999; Napoletano et al., 2006), we find that unemployment is counter-cyclical, while inflation

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[10] The first 1500 simulated periods are then discarded from the analysis in order to allow the model to exit from the transition phase.

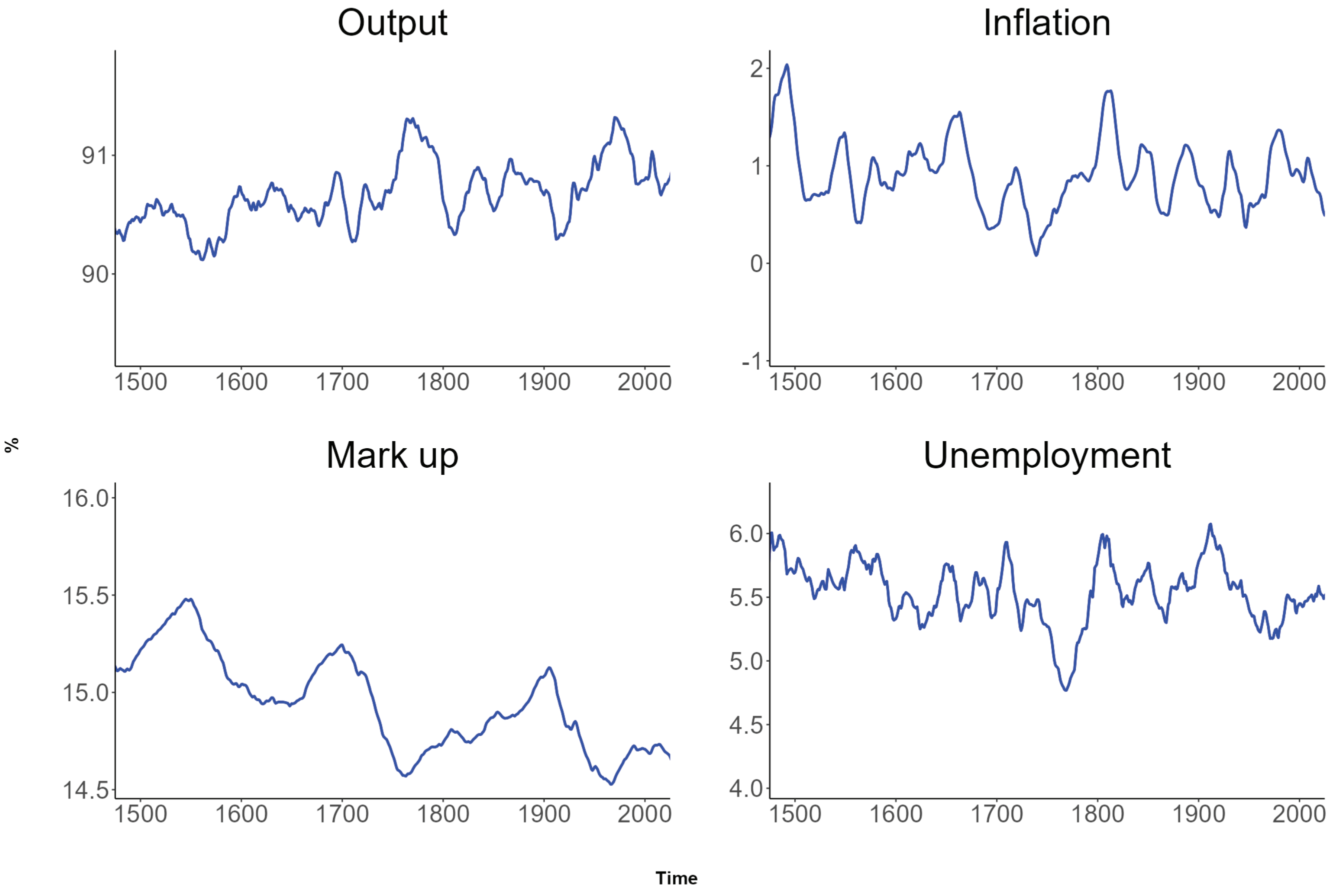

**Figure 1:** A typical run of the model for key macroeconomic variables: output (top-left), inflation (top-right), mark-up rate (bottom-left) and unemployment rate (bottom-right) as a function of simulation time.

is pro-cyclical and lags the business cycle. Moreover, in tune with the evidence provided by Bils et al. (2018), the mark-up is counter-cyclical.

In what follows, we will study the different source and drivers of inflation dynamics both at the macro and at the micro levels. Such analysis will explicitly take into account how the efficiency of goods market selection affect firms' market power and, in turn, inflation dynamics. In the model, the intensity of market selection, which stem from imperfect information and other frictions, can be controlled by changing the parameter $\rho^{GM}$ in Equation 21. Indeed, let us recall that low values of $\rho^{GM}$ capture a scenario in which market selection has less frictions since firm size plays a smaller role in the matching process between firms and customers. In this case, competition among firms is mostly driven by price (efficiency) differences. On the contrary, if $\rho^{GM}$ is higher, market frictions are pervasive and large firms can capture larger market shares even when they are less efficient than their smaller competitors.

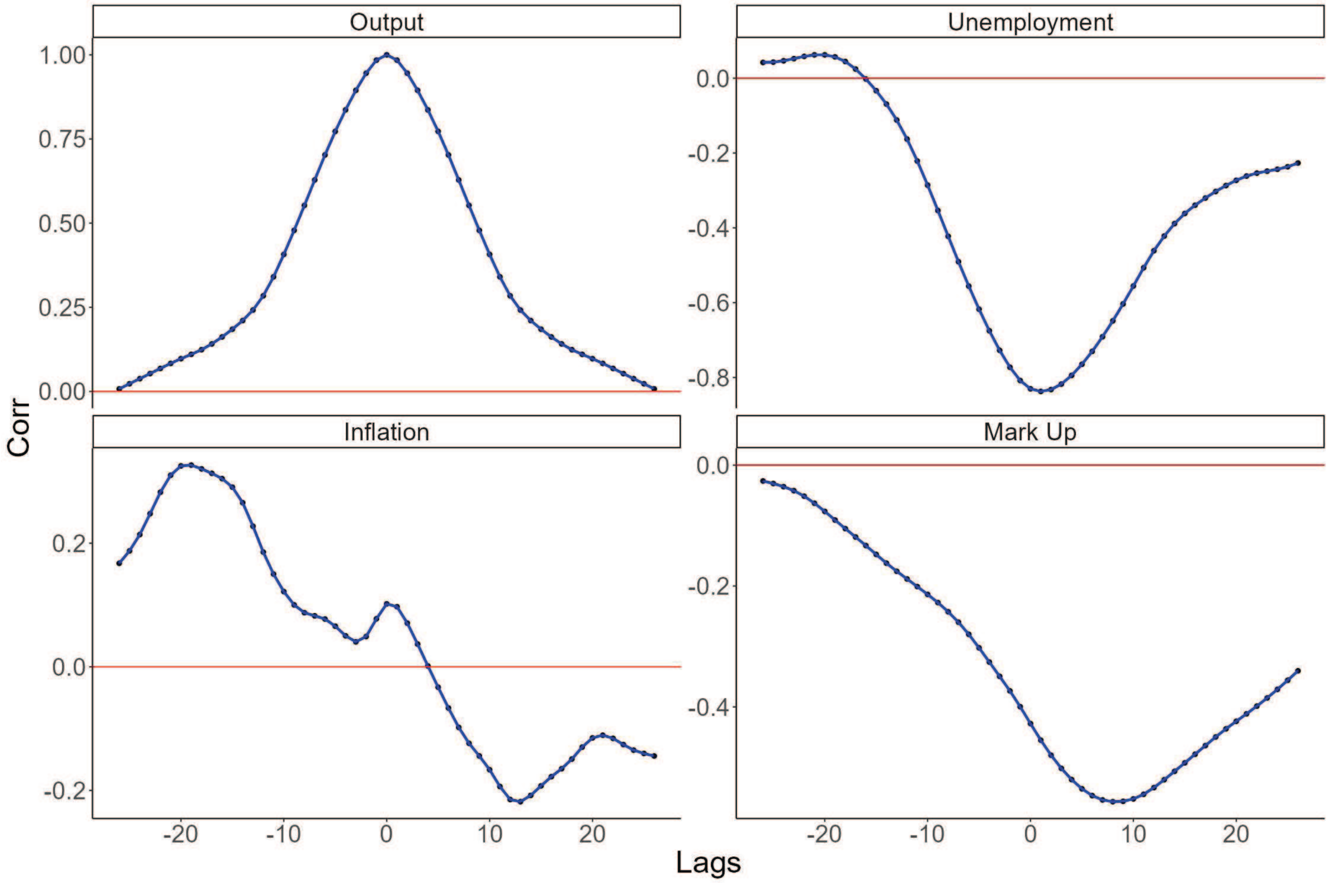

**Figure 2:** Autocross-correlations ($corr(x_t, y_{t+k})$) between output and unemployment, inflation, mark-up.

## 3.1 Aggregate evidence on inflation

In this section, we hit the model under the baseline parameterization with different shocks in order to study how inflation respond to demand and supply fluctuations. In all the experiments, we run 100 Monte Carlo simulations.

### Labor market tightness and inflation

We first consider aggregate demand shocks. More specifically, we consider a shock to household consumption of the type illustrated in Equation 22, setting $\mu_\eta = -0.15$ and $\rho_\eta = 0.95$. By exploiting the variation generated by this shock, we can assess the association between inflation and unemployment over a wider domain with respect to the normal "business cycle" fluctuations that are endogenously generated in the model. Under this setting, and in line with the empirical evidence documented by Gagnon and Collins (2019); Benigno and Eggertsson (2023) among others, the model shows the emergence of a non-linear Phillips Curve, jointly with a non-linear Beveridge Curve (see Figure 3 and Table 3).[11] The negative association between unemployment and inflation is stronger when the economy is close to full employment and the labor market is tight. However, it flattens out as the unemployment rate increases and the labor market loosens.

The explanation for this result can be traced back to two key features of the model. On the one hand, and analogously to Guerini et al. (2018), Keynesian coordination failures between the good and labor markets stemming from the decentralized matching protocols are responsible for the price-unemployment co-evolution. When aggregate demand is strong in the goods market, firms respond by increasing production targets instead of prices; this brings about labor scarcity. Firms then struggle to fill the vacancies they open to meet their desired production and this pushes upward money-wages and then prices. When demand is weak, firms revise their production plans downwards and subsequently fire employees; an ease in the labor market is therefore followed by disinflation.

On the other hand, our assumptions on wage setting explain why the Phillips Curve "bends" at high levels of unemployment. In fact, recalling Equation 8, labor scarcity generates a demand-pull inflationary pressure when the labor market gets tight, that does not compensate in the opposite direction when the labor market gets looser.[12] In the left panel of Figure 3, the rate of vacancies left unfilled over total is confronted with the rate of unemployment. It is very clear how, with lower and lower unemployment rates, firms are increasingly struggling to fill their job openings. This maps directly in an increase in prices through the channel of higher wage demands.

### Supply shocks and stagflation

Next, we analyse the response of the model to a negative supply shock due to a sudden decrease in the productivity of labour. We consider a shock of the type illustrated in Equation 5, with $\mu_\eta = 0.05$ and $\rho_\eta = 0.95$. Under this setup the model generates a positive relationship between unemployment and inflation, with the emergence of a positively-sloped Phillips Curve (Panel 2 in Figure 4). Notice that,

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[11] Note that we estimate the Phillips curve using the inflation rate rather than its variation, because the expectations in the model are anchored. See also, Blanchard (2016). See also Figure 14 and Table 6 in Appendix B for an alternative non-linear specification.

[12] This is also in line with Tobin (1972).

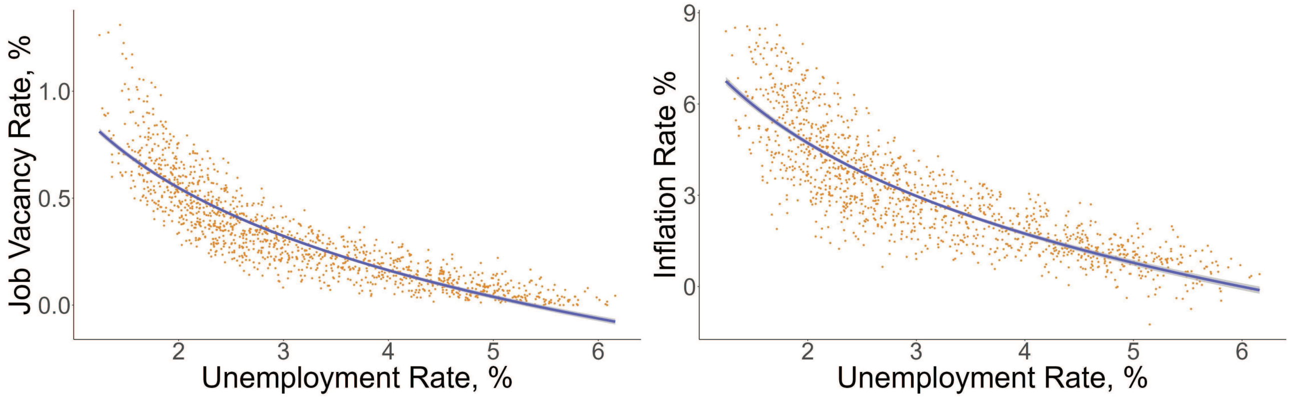

**Figure 3:** Level-log estimations of the Beveridge Curve (left panel) and Phillips Curve (right panel) with an aggregate demand shock. Asymmetries in wage-setting generate a non-linear relationship between unemployment and price growth.

| | **Beveridge Curve** | **Phillips Curve** |
|---|---|---|
| $Const.$ | $0.93^{***}$ | $7.70^{***}$ |
| | (0.001) | (0.083) |
| $log(u)$ | $-0.55^{***}$ | $-4.29^{***}$ |
| | (0.008) | (0.072) |
| $Nobs.$ | 1300 | 1300 |
| $R^2$ | 0.76 | 0.73 |

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

**Table 3:** Coefficients of the level-log regressions for the Beveridge and Phillips Curves with an aggregate demand shock. Standard errors are reported in parentheses.

while we assist to this inversion of the Phillips Curve, the Beveridge Curve (Panel 1 in Figure 4) maintains its natural downward-sloping structure. This implies that for this specific type of shock, the underlying dynamics of the labour market is left unaffected. In this case, the surge in inflation is driven by the sharp increase in costs generated by the labour productivity shock. In short, and in line with standard theory (e.g. Blinder and Rudd, 2013), a large productivity shock generates a ”stagflation” outcome with joint increase of unemployment and prices due to the joint increase in costs and reduction in productive capacity.

### Demand & supply shocks and inflation

Finally, in the third simulation exercise, we simultaneously shock the system with both the demand and supply shocks described above. In this third battery of simulations, the standard downward-sloped

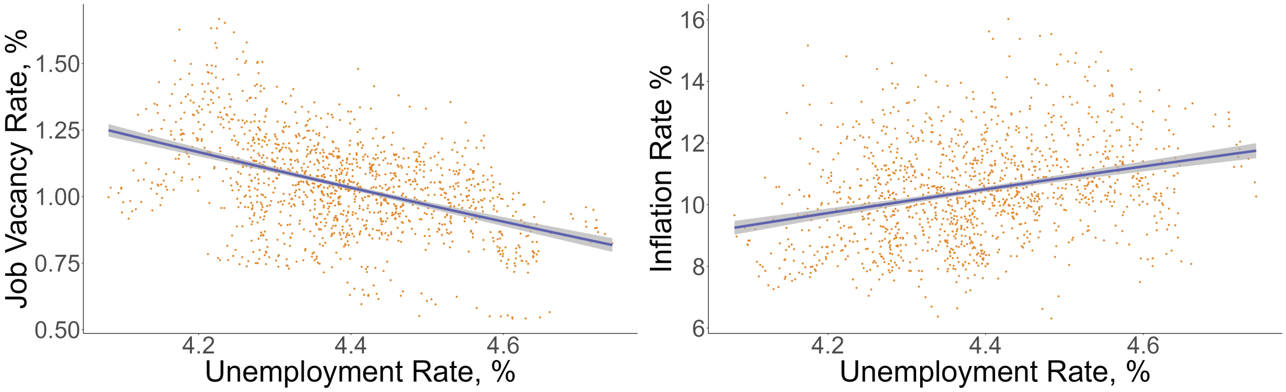

**Figure 4:** Level-log estimations of the Beveridge Curve (left panel) and Phillips Curve (right panel) In presence of an aggregate supply shock.

| | **Beveridge Curve** | **Phillips Curve** |
|---|---|---|
| $Const.$ | $5.28^{***}$ | $-14.15^{***}$ |
| | (0.22) | (2.18) |
| $log(u)$ | $-2.87^{***}$ | $16.64^{***}$ |
| | (0.15) | (1.47) |
| $Nobs.$ | 1300 | 1300 |
| $R^2$ | 0.20 | 0.08 |

* p < 0.1, ** p < 0.05, *** p < 0.01

**Table 4:** Coefficients of the level-log regressions for the Beveridge and Phillips Curves with an aggregate supply shock. Standard errors are reported in parentheses.

Phillips Curve is restored, even if the non-linearities have disappeared (the logarithmic fit line is almost flat) and the unemployment variation is able to explain only a residual part of the variability in inflation (see the lower R squared in Table 5). In other words, the overlap of demand and supply shocks is able to partly ”hide” the structural Phillips Curve relationship in the model, leading to a weaker price-unemployment nexus then the one we would observe in the absence of supply shocks. This result could provide an explanation to the flattening of the Phillips Curve observed in many countries across the world resonating with, for example, Hobijn (2020): when economic fluctuations are mainly driven by supply shocks, the downward demand-side pressures on prices are (totally or partially) offset by the supply-side upward pressures.

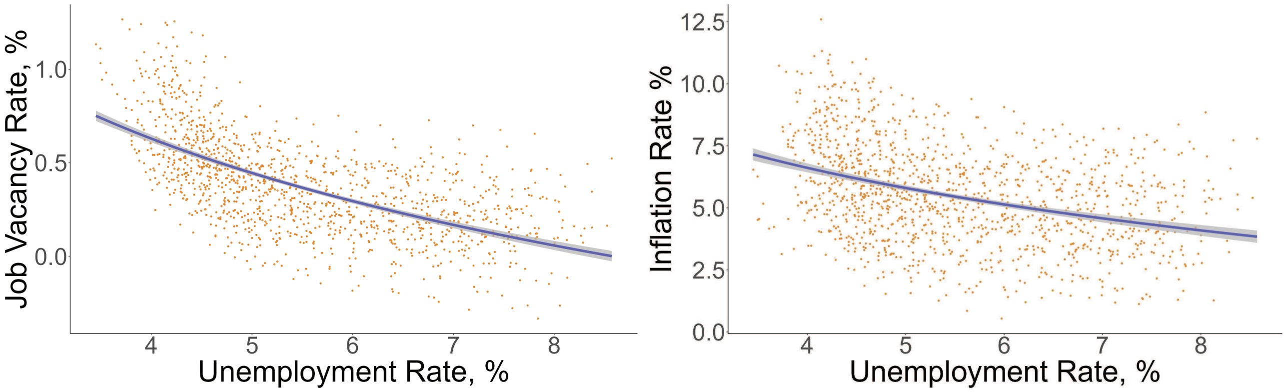

**Figure 5:** Level-log estimations of the Beveridge Curve (left panel) and Phillips Curve (right panel) In presence of an aggregate demand and supply shock.

| | **Beveridge Curve** | **Phillips Curve** |
|---|---|---|
| $Const.$ | $1.77^{***}$ | $11.65^{***}$ |
| | (0.05) | (0.42) |
| $log(u)$ | $-0.82^{***}$ | $-3.64^{***}$ |
| | (0.03) | (0.25) |
| $Nobs.$ | 1300 | 1300 |
| $R^2$ | 0.39 | 0.13 |

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

**Table 5:** Coefficients of the level-log regressions for the Beveridge and Phillips Curves with an aggregate demand and supply shock. Standard errors are reported in parentheses.

## 3.2 Goods market imperfections and inflation

Now that we have described the basic properties of inflation in our model conditional on different shocks, we proceed to assess the role of market imperfections on the aggregate properties of the model. To carry out this task, we simulate the model under the same sequence of random draws, but varying the parameter affecting the degree of goods market imperfections . Figure 6 displays the median value (across Monte Carlo) of four aggregate variables for different values of the market selection parameter.

Our analysis reveals a non-monotonic relationship between the degree of market imperfection and the level of inflation. Indeed, even if for all the parameter values inflation converges to a stationary state characterized by a strictly positive inflation rate, we record a lower average inflation rate for good markets with low and high levels of frictions ($\rho^{GM} \leq 0.11$ and $\rho^{GM} \geq 0.33$). In contrast, there is a monotonically increasing relationship between the degree of imperfections in the market selection process and the un-

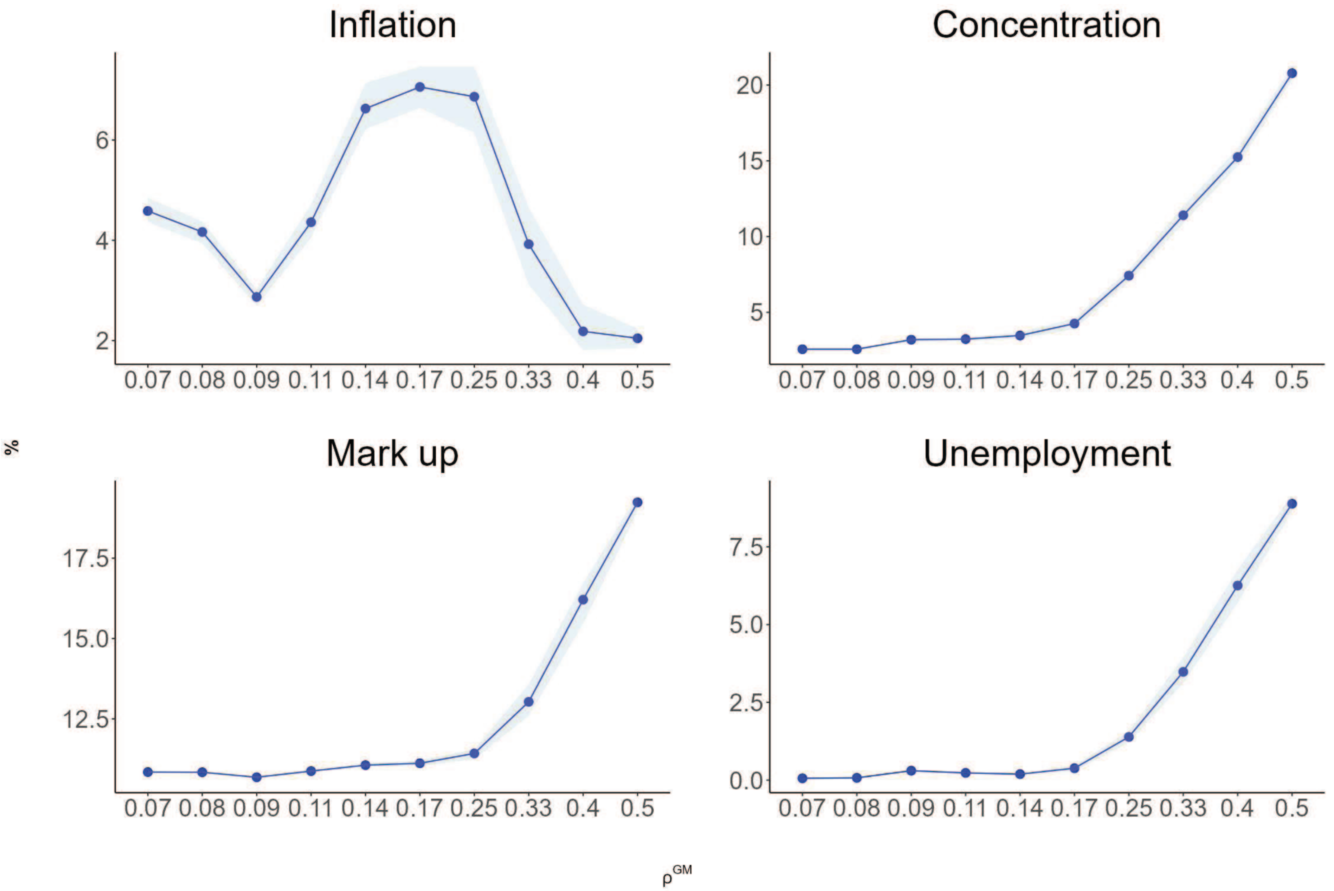

**Figure 6:** Median value (blue dot) of the Monte Carlo distribution for inflation rate (top-left), market concentration (top-right), mark-up rate (bottom-left) and unemployment rate (bottom-right) as a function of the degree of imperfection in the goods market, $\rho^{GM}$. For each value of $\rho^{GM}$, the shaded area is defined by the 10th and 90th percentile values values out of 100 Monte Carlo simulations.

employment rate, the degree of market concentration, and the firms market power. In particular, less selective markets give rise to a more concentrated economy with higher profit margins. This last result is due to the presence of dynamic increasing returns and imperfect information in demand allocation which is a feature of our matching protocol, as explained in Subsection 2.7.2. In turn, higher mark-ups imply lower labor shares, lower consumption (only a fractions of profits is distributed back to households as dividends) and production, and higher unemployment. This explains the non-monotonicity in the relationship between market frictions and the inflation rate in the first Panel of Figure 6. In the left side of the graph, the economy is almost in full employment and an increase in the degree of imperfection leads to a higher inflation rate. However, in the right part of the graph, a raise in market imperfection leads to a decline in inflation due to the decline in aggregate demand associated to larger unemployment rates.

## 3.3 A closer inspection on the sources of inflation

To sum up, the model shows that negative productivity shocks lead to inflation surges. At the same time, the model can generate a non-linear Phillips Curve which arises from downward nominal wage rigidities and Keynesian demand feedbacks due to coordination failures. Finally, changes in market selection intensity can jointly explain the emergence of higher mark-ups (and decreasing labor shares) and higher market concentration documented by the empirical literature for the United States (see e.g Stansbury and Summers, 2020; De Loecker et al., 2020), as well as declining employment trends (e.g. Abraham and Kearney, 2020).

We can now exploit our wage and price setting mechanisms (see Section 2.4) to decompose price changes along different dimensions in order to shed further light on the drivers of inflation. In particular, we carry out two different decomposition exercises. The first one breaks the aggregate price variations into a *within firms* component, which originates in the price adjustments operated by the single firms, given their market share; and a *between firms* component, stemming from the continuous reallocation of market shares between firms which affect the aggregate price through their market weights for given firm prices. The second decomposition, instead, focuses on price changes at the individual firm level and on their possible drivers, i.e. state of the labor market, firm market power and wage indexation.

### The between and within inflation decomposition

The aggregate price index of our model is defined as a market-shares weighted average of the individual firm prices. In logs, this writes:

$$log(P_t) = \sum_{f=1}^{F} s_{f,t} log(P_{f,t}) \tag{26}$$

Exploiting this definition, the changes in the aggregate price index can be decomposed as follows (see also Baily et al., 1992):

$$log(P_t) - log(P_{t-1}) \approx \sum_{f=1}^{F} s_{f,t-1} \Delta log(P_{f,t}) + \sum_{f=1}^{F} \Delta s_{f,t} log(P_{f,t}) \tag{27}$$

On the right hand side of the equation, the first term measures the counterfactual inflation if the individual firm share would be held constant (*within effect*), while the second term measures inflation through changes in market shares (*between effect*).

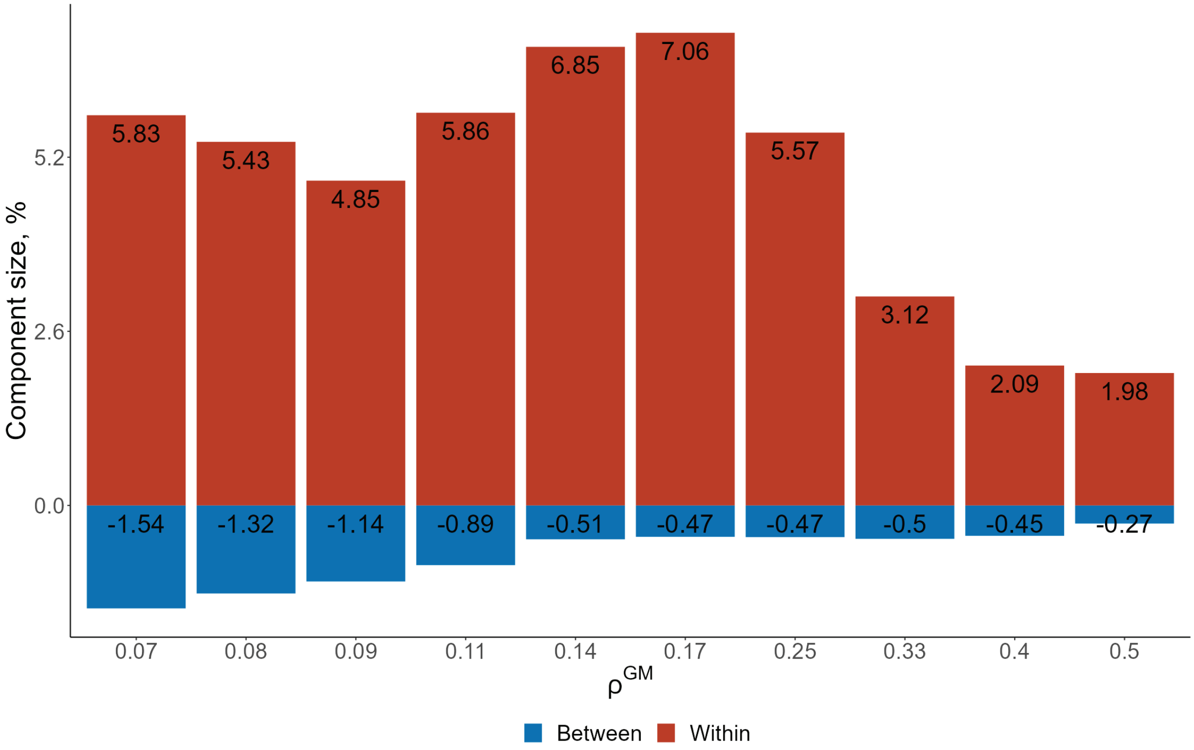

**Figure 7:** Monte Carlo averages of within and between firm components of aggregate price changes as a function of the degree of imperfection in the market selection process in the goods market. Higher values of $\rho^{GM}$ imply a more imperfect market selection process. Numbers on bars indicate the magnitude of each component

We perform the aforementioned decomposition for different degrees of imperfection in the goods market selection. Monte Carlo averages are presented in Figure 7. Three main insights result from the analysis. First, and unsurprisingly, the within effect is positive and the between effect is negative for all the considered market imperfection regimes. This stems from the fact that households continuously strive to reallocate their expenditures towards the firms posting lower prices, even when prices are generally rising. Second, the between effect is always smaller in absolute value than the within effect, implying a positive inflation rate for all values of market imperfections. Third, the absolute magnitude of the between component decreases with the imperfection of the goods market selection process. Therefore, in markets with relatively efficient selection, the customers quickly switch from firms charging higher prices to the ones with lower prices. When selection is imperfect, customers are less sensitive to price differences across firms, and big firms can increase their profit margins without significant repercussions on their market share. This result is consistent with a number of contribution linking market competition and inflation (see Janger et al., 2010; Przybyla and Roma, 2005; Torun and Yassa, 2023).

### Dissecting firm inflation drivers

Starting from the equations of firms price and wage setting behavior, we can decompose price changes at the individual firm level according to different sources. Let us start by deriving a "reduced form" equation for firm-specific price growth by simply taking the log-difference of the price setting Equation 10. This boils down to:

$$\pi_{f,t} = \log(W_{f,t}) - \log(W_{f,t-1}) - (\log(a_{f,t}) - \log(a_{f,t-1}) + (\mu_{f,t} - \mu_{f,t-1}) \tag{28}$$

After substituting the wages with the wage setting Equation 8, we obtain:

$$\pi_{f,t} = \alpha^l z^{lab}_{t-1} + \beta^l \hat{\pi}_{f,t} - \Delta \log(a_{f,t}) + \Delta\mu_{f,t} \tag{29}$$

This decomposition shows the four fundamental channels through which firms increase their prices. The first driver of inflation is excess demand in the labor market, captured by $\alpha^l z^{lab}_{t-1}$. Whenever the local labor market is tight, firm has to increase the offered nominal wage and this leads to price growth in the following period. The first inflation driver is akin to the standard interpretation of "demand-pull" inflation (see Lipsey, 1960, among the others). The second cause of inflation is captured by the wage indexation $\beta^l \hat{\pi_{f,t}}$, which is intimately linked to expectations and act as a propagation channel by linking today's firm-level price adjustments to past realized inflation at the aggregate level. Third, inflation can arise from productivity shocks $\Delta \log(a_{f,t})$ which have an immediate impact on the unit cost of output $\frac{W_{f,t}}{a_{f,t}}$ and, therefore on prices. This is the so-called "cost-push" source of inflation (Porter, 1959). The fourth and final driver of inflation is the mark-up rate variation $\Delta\mu_{f,t}$ which implies that firms' market power affect the level of the statistical equilibrium of inflation. [13] The idea that market power affects firms'

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[13] It is not necessary to have a time-increasing aggregate mark-up rate to have positive trend inflation, as long as we assume asymmetries in the money-wage adjustment process. Even if firms' mark-ups oscillate symmetrically around a fixed average due

pricing behaviour can be traced back to the administered price literature (Means, 1972; Blair, 1974) Note that the cost-push and mark-up components can take either positive or negative values, while the excess demand and expectations component can only take non-negative ones.

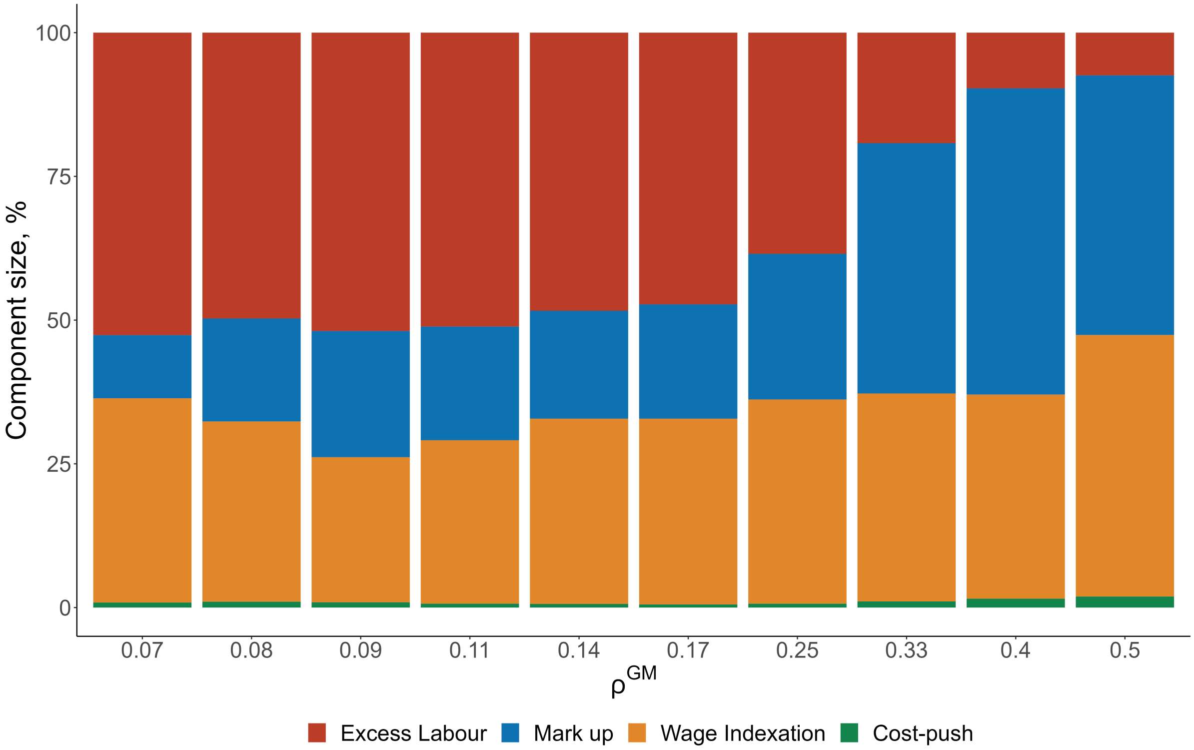

**Figure 8:** Absolute value of the Monte Carlo averages of the components of firm-level price growth s a function of the degree of imperfection in the market selection process in the goods market. Higher values of $\rho^{GM}$ imply a more imperfect market selection process.

Figure 8 highlights the relative importance of the four identified factors by displaying a bar plot with their relative values (rescaled in order for the components to sum up to 100%), for different degrees of imperfection in the goods market selection. The decomposition reveals that, as long as market selection is sufficiently efficient (i.e., for low values of $\rho^{GM}$) the excess labor demand plays a prominent role in determining inflation and the model behaves as standard New-Keynesian models with inflation being characterized as a demand pull phenomenon. These scenarios are also characterized by low concentration, high aggregate demand and low unemployment (see Section 3.2). However, such results are

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to continuous disequilibrium adjustments, wages will respond more to increases in the price index than they do to decreases, resulting in positive long-run inflation rates.

substantially reverted as market imperfections become more pervasive (i.e., for high values of $\rho^{GM}$) and selection processes weaken. Here the excess labor demand component becomes less and less important and inflation is mostly driven by variation in the mark-up rates, and in turn in firms' profit margins. Therefore, when goods market imperfections are relevant, inflation is mainly drive by *firms' market power*.

### Taking stock

Overall, all the previous results show that the nature of inflation depends on the efficiency of market selection in the goods market which stems from the local interactions of heterogeneous firms and household in an environment characterized by imperfect information and other frictions. This is in contrast with the traditional explanation of inflation as a phenomenon generated by an excessive level of demand and a tight labor market. This simplistic view holds only as long as the reallocation of market shares across firms is rapidly guided by the price signals, i.e. if markets are competitive. In such a scenario, the fast reallocation of market shares (between effect) significantly influences inflation at the macro level, while, at the micro level, inflation is mostly driven by excess demand in the labor market.

In stark contrast, when goods market selection is less efficient due to pervasive imperfections, the signaling role of prices is weakened and larger firms get a competitive advantage in the local interactions with consumers. In this case, aggregate inflation becomes a phenomenon driven by changes in price at the firm level (within effect) mostly driven by increases in mark-up rates. The latter effect is in particular determined by the fact that larger firms are able to increase market shares even if they practice prices that are not below their competitors prices due the inefficient selection of markets. In this setting, where there are no exogenous shocks to production costs, the role of the cost-push component is marginal. We investigate more in detail the importance of cost-push shocks in the following section.

The inability of customers to select the most price-competitive producer via localized interaction highlights one interesting property of the model: the emergence of finite, heterogeneous demand elasticities among firms due to their non-price characteristics (in this case, size). Larger firms are rewarded by the imperfect matching protocol and can post relatively higher prices without fear of losing customers. Conversely, smaller firms are bound to compress profit margins in order to attract demand which otherwise would be drawn towards the market leaders. Imperfect information as outlined in our search and matching protocol therefore provides a plausible microfoundation to the emergence of market power in the long run, in analogy with results from imperfect information theory (e.g Stigler, 1961; Phelps, 1969). The protocol assumptions lead, therefore, to the emergence of a long run price distribution, in continuity with standard imperfect information models (Stiglitz, 1979, 1989), even assuming homogeneous technology. Finally, in terms of macroeconomic implications, some degree of information imperfection is related to the emergence of resource underutilization (Alchian, 1969).

## 4 The emergence of sellers' inflation

While many works have focused on internal demand pressures to explain inflation, ascribing the surge in prices to loose monetary policy, increasing government spending and labor shortages (Bianchi et al., 2023; Benigno and Eggertsson, 2023; Cevik and Miryugin, 2023), others have focused instead on monopolistic behavior by firms, rent seeking and profits as the main drivers of inflation (see Weber and Wasner, 2023). The final battery of Monte Carlo experiments is devoted to assess the possible multiple sources of inflation, possibly detecting whether large, persistent aggregate demand and supply shocks can trigger fluctuations in firms' market power and income distribution, leading to the emergence of a so-called "sellers' inflation", wherein firms are able to increase their prices to protect or even increase their profit margins (more on that in the ECB Economic Bulletin paper by Hahn 2023; see also the IMF Working Paper by Hansen et al. 2023). Our last exercise thus provides a counterfactual-analysis test to the two competing hypotheses over the determinants of the 2021-2023 inflationary surge. Have inflation been increasing due to excessive spending or because firms were able to pass to price the cost increases?

We consider three separate shock scenarios.[14] The first one is a positive demand shock involving a sharp increase in household consumption $c_{h,t}$ (cf. Equation 22). In the second scenario, we consider a shock decreasing labor productivity (see Equation 5), which captures ubiquitous supply chain disruptions (such as restrictions to production, logistic bottlenecks, and intermediate input shortages). The third shock scenario is designed to represent the global energy crisis due to the Russo-Ukrainian War; it involves the introduction in the model of a new external non-labor cost to production, which proxy the

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[14] In reality, the three shocks may have occurred simultaneously. We here separate them to better understand the transmission mechanisms for each of them.

cost of imported energy (more details in Equations 30, 31 and 32). The different shocks are studied for different market selection scenarios captured by the parameter $\rho^{GM}$.

### Demand shock

We first hit the economy with a $AR(1)$ shock that entails an increase of household's consumption at time $t^\star = 1600$. More specifically, households increase their personal consumption by an amount $\mu_\eta = 15\%$ for a 4-weeks period; starting from the fifth week, the shock starts to decay at a rate $\rho_\eta = 0.95$ (cf. Equation 22).

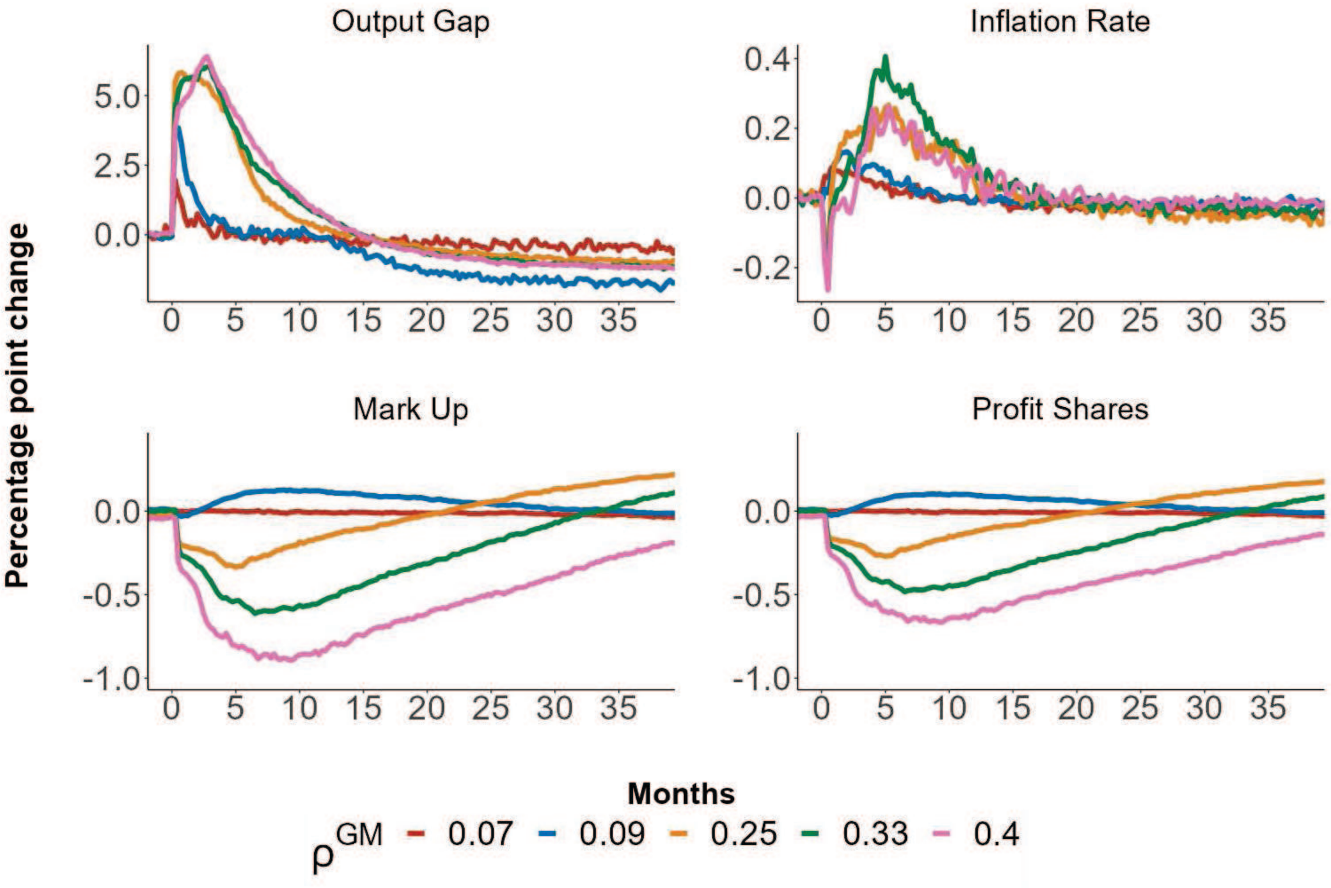

**Figure 9:** Impact of a positive demand shock on aggregate output (top-left), inflation rate (top-right), mark-ups (bottom-left) and profit shares (bottom-right) for different levels of the goods market imperfections. Time is measured in months (i.e., 4 simulation periods). The impact of the shock over time is measured in percentage point deviation from pre-shock level. Higher values of $\rho^{GM}$ imply a more imperfect market selection process.

Figure 9 displays the effect of the demand shock on aggregate output, inflation, mark-up rates and profit shares for five different values of the market imperfection parameter $\rho^{GM}$. The shock exerts a positive impact on output (top-left panel), with the size of the effect being positively associated with market imperfections: scenarios with low values of $\rho^{GM}$ display only a mild increase in mark-ups (bottom-left panel) and remain closer to the pre-shock steady state. The characteristics of market efficiency also determine the response of inflation (top-right panel). The increase is in fact larger for the scenarios where market selection is more imperfect.

Note that for the most inefficient scenarios, the model predicts a very short-lived deflation. This is due to the impact of the shock on the market structure. Indeed, the positive and homogeneous demand shock causes (by construction) an initial redistribution of market shares towards the smallest firms, which are also posting lower prices (see Figure 15 in Appendix C). However, this effect vanishes after the first few months, with the standard positive surge in inflation occurring thereafter for all the market imperfection scenarios.

The effect that the demand shock exert on the market shares, however, also significantly affect the aggregate mark-ups and the profit shares (cf. Figure 9 bottom-left and bottom-right panels respectively), which fall in the scenarios with a high value of the market imperfection parameter.

Finally, it is worth to point out that in the model there is no long-run inflation acceleration due to excess demand, nor occurrence of “wage-price spirals” (in line with the recent empirical evidence documented in Bluedorn et al. 2022), with prices stabilizing between 12-15 months from the shock.

### Productivity shock

We next consider a scenario where the economy is hit by a homogeneous adverse shock to the labor productivity coefficient $a_{f,t}$ (cf. Equation 5), with a magnitude of $-5\%$ on impact. More precisely, the shock has a duration of four weeks during which it operates at full intensity; starting from the fifth week, it starts to decaying at a constant rate $\rho_\eta = 0.95$ (see Equation 32).

The shock generates a decline in aggregate output and a short-living ramp up in inflation for all the market selection regimes (top panels of Figure 10). These are standard results (see Blanchard, 1989, among the others). Furthermore, differently to the demand shock case, the productivity shock does not lead to substantial variation in the mark-up rates or in the profit shares (bottom panels of Figure 10). With a negative productivity shock, mark-ups shift only of about 0.1 percentage points in the 12 months after the shock and ultimately return to the steady-state – notice in the demand shock scenario, the vari-

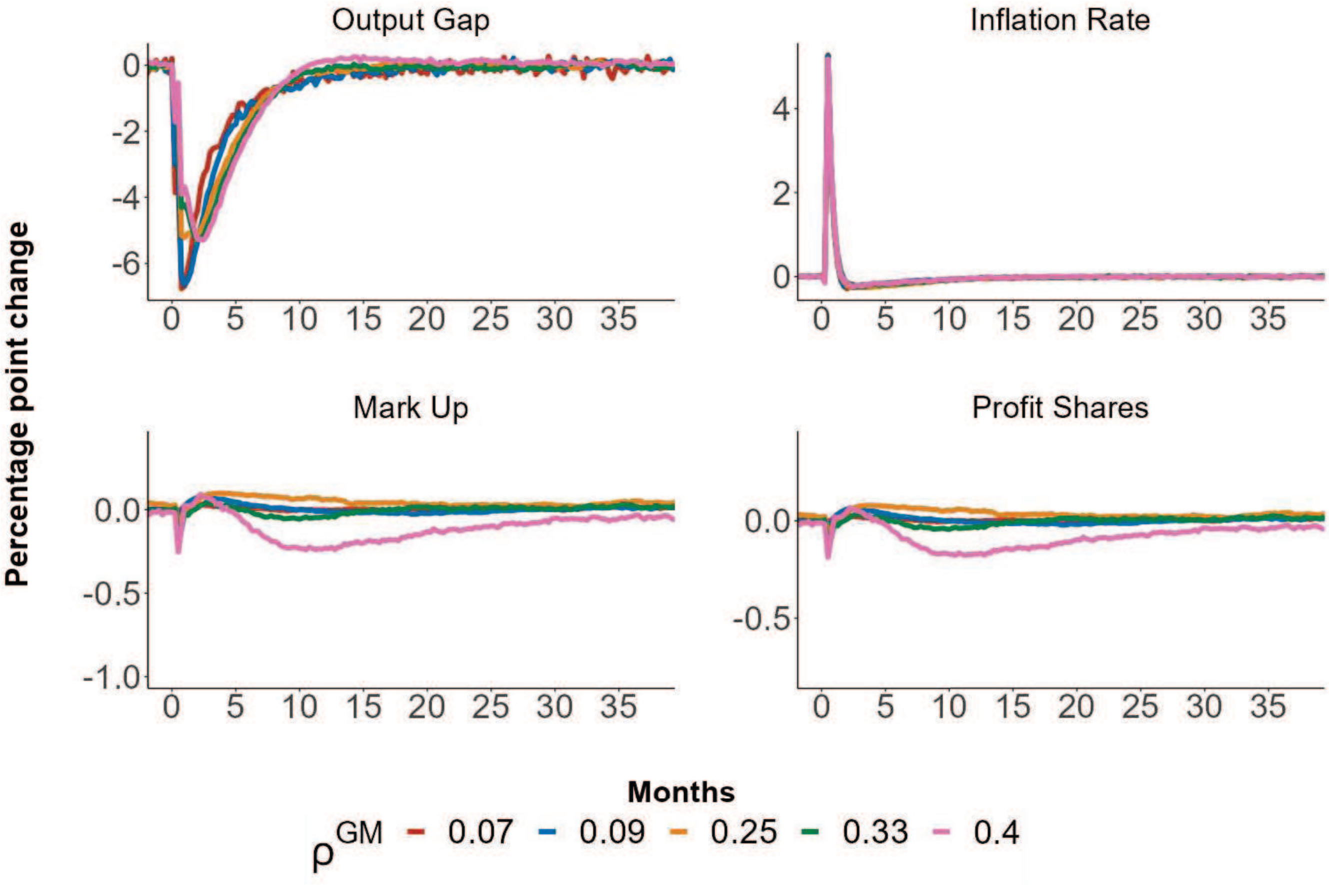

**Figure 10:** Impact of a productivity shock on aggregate output, inflation, mark-up and profit shares in different market selection regimes. Time is measured in months (4 periods). The impact of the shock over time is measured in percentage point deviation from pre-shock level.

Higher values of $\rho^{GM}$ imply a more imperfect market selection process.

ation of mark-ups was five times larger and it did not return to the pre-shock equilibrium. Only in the $\rho^{GM} = 0.4$ scenario the dynamic is partly different, with the productivity shock causing an initial increase in mark-ups (in line with the other parameterizations) which fall in the medium run and come back to the equilibrium level over the long term. This behaviour arises because in this setting the pre-shock equilibrium levels of market concentration and mark-ups are very large (see Section 3.2) and the largest incumbents have exhausted their capabilities to further increase their market shares. This create a temporary windows of opportunity for small firms to satisfy the additional demand in the post-shock recovery. This dynamics explains also the larger persistence of the shock on mark-up. In a disequilibrium model with decentralized matching, adjustments to the pre-shock levels take time, as imperfect selection gradually drives these smaller firms out of the market and restore the *ex-ante status quo*.

### Energy price shock

The last shock scenario requires an extension to the model to account for the energy input required to assess the consequences of an energy price shock akin to the one experienced by most European economies after Russia invaded Ukraine in February 2022. To keep the extension as simple as possible, we assume a fixed proportion production process in which the firm employs $\frac{1}{a_{f,t}}$ units of labor and energy, such that the unitary cost of production becomes:

$$C^*_{f,t} = \frac{W_{f,t} + k_{f,t}}{a_{f,t}} \tag{30}$$

where $k_{f,t}$ denotes the price of the energy input. Thus, the price setting equation for the generic firm now reads:

$$P^*_{f,t} = \frac{W_{f,t} + k_{f,t}}{a_{f,t}}(1 + \mu_{f,t}) \tag{31}$$

In the third experiment, we model a shock in energy price $k_{f,t}$ exhibiting the following dynamics:

$$k_{f,t} = W_{f,t*}(1 + \eta_t) \text{ where } \begin{cases} \eta_t = 5\% \text{ if } t < t^* \\ \eta_t = \mu_\eta * 5\% \text{ if } t \in (t^\star, t^\star + 3) \\ \eta_t = \rho_\eta \eta_{t-1} \text{ if } t > t^\star + 3 \end{cases} \tag{32}$$

where again $\mu_\eta$ represents the intensity of the shock and $\rho_\eta$ its persistence (we set $\mu_\eta = 3$ and $\rho_\eta = 0.95$). In other words, we set the cost of energy $k_{f,t}$ to be 5% of the labor cost before the shock and to increase to 15% of labor costs after with a slow decay. The shock has a duration of four weeks during which it operates at full intensity, and it starts to decay at a constant rate $\rho_\eta = 0.95$ since the fifth week. The calibration of the shock intensity is consistent with the 200% increase of the Global Energy Price Index between 2020 and 2022 (see FRED, 2023). Note that in this version of the model, an increase in the price of the non-labor input can trigger a shift from labor to non-labor costs with possible impacts on income distribution.

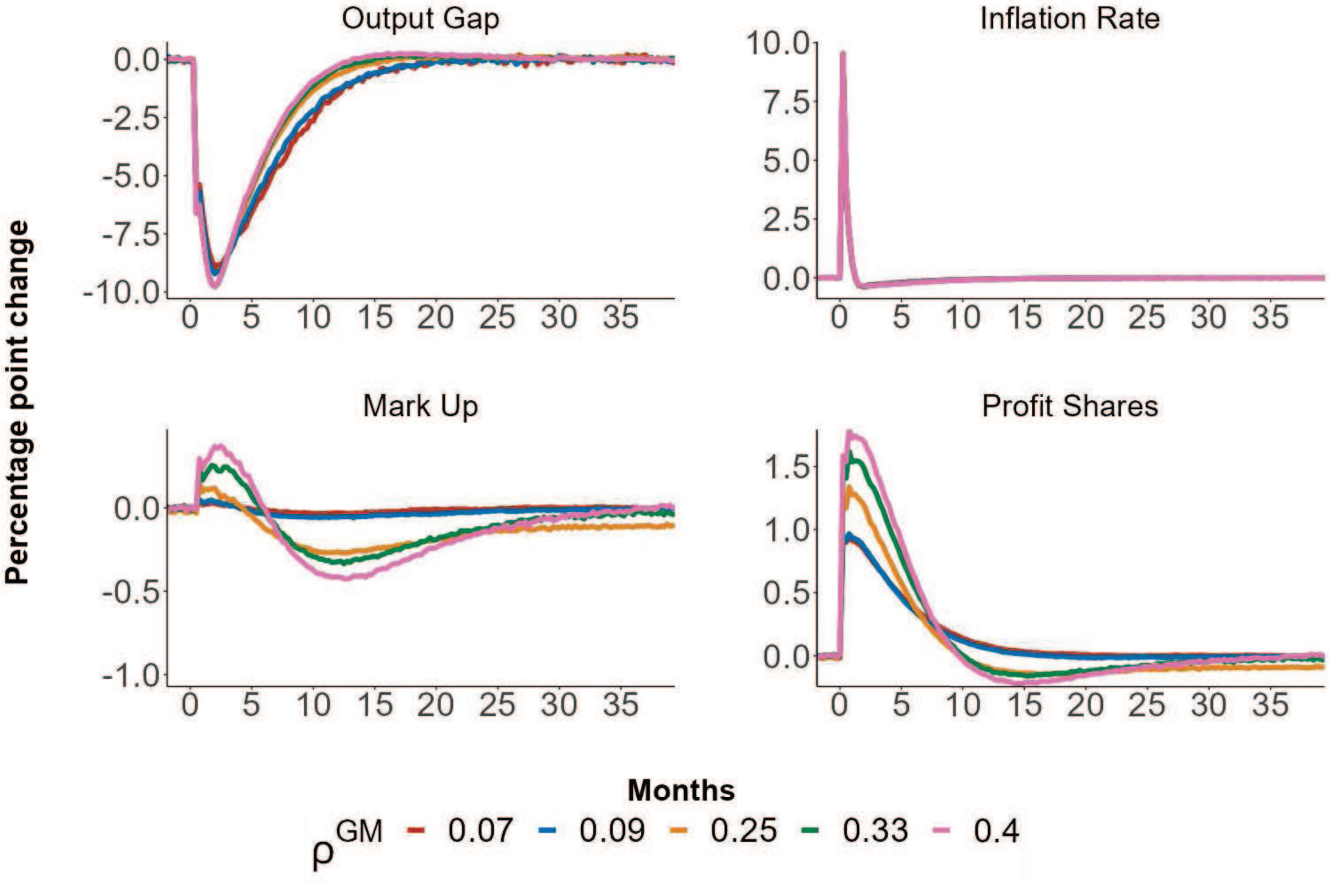

**Figure 11:** Impact of an adverse energy shock on aggregate output, inflation, mark-up and profit shares in different market selection regimes. Time is measured in months (4 periods). The impact of the shock over time is measured in percentage point deviation from pre-shock level.

Higher values of $\rho^{GM}$ imply a more imperfect market selection process.

As expected, simulation results suggest that the energy price shock causes an output decline and a hike in the inflation rate regardless of the market selection regime (cf. Figure 11 top panels). In that respect, it is qualitatively similar to a negative labour productivity shock. However, in sharp contrast with the latter shock, the higher cost of energy significantly affect the mark-up rates and even more the profit shares to a larger extent (see Figure 11 bottom panels). More over , the surge is higher in presence of more pronounced market imperfections. These results are consistent with the empirical evidence provided by Arquié and Thie (2023), who find that a firm's pass-through of energy shock depends upon the industry-specific market power: less competitive industries (in our case represented by the scenarios with high values of $\rho^{GM}$) display higher pass through, even superior to 100%.

The bottom-right panel of Figure 11 also reveal a second remarkable difference with respect to the income-distribution dynamics triggered by other two shocks. For demand and labor productivity shocks, the profit share was exclusively driven by mark-ups, and the two impulse response functions looked alike (see Figures 9 and 10). Here, instead, the sharp increase in energy cost positively affect the profit shares in two ways. On the one hand, mark-up fluctuations increase profit shares through profit margin increases as in the other cases. On the other hand, the shift in the cost structure from the labor component to the non-labor one leads to a relative increase of profits with respect to wages even in presence of invariant mark-ups. In other words, the rise in the profit share results both from higher profit margins and from the pass-through of the energy cost to prices (Blair, 1974; Weber and Wasner, 2023).[15]

### Import prices, profits and wages: bringing the model to the data

After having analyzed the response of the model to different types of shocks, we perform a final exercise by decomposing the price index to single out the relative importance of the various sources of inflation. In order to do so, we exploit the data on aggregate wages, profits and energy costs produced by our model. This decomposition, though not to be interpreted in a causal sense, provides a straightforward method to observe how changes in prices are reflected in labor compensation per unit of real consumption (unit labor costs), profits per unit of real consumption (unit profits), and energy costs (import prices). This decomposition is comparable to similar exercises conducted with real world data (see Hansen et al., 2023; Haskel, 2023; Dhingra and Page, 2023), also allowing us to assess the ability of the three shocks scenarios

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[15] Notice that when a non-wage cost $k$ is introduced in the production process, the share of profits over total output is equal to $r = 1 - \frac{1}{1+\mu \cdot k}$. Therefore, an increase in the non-wage cost $k$ implies a shift in the income distribution in favour of profits, even if the mark-up rate is unaffected.

to match the empirical evidence.

In Figure 12, we compare the cumulative change of three components of inflation - labour costs, profits and import prices - over the first two years triggered by our three shocks with the empirical results provided by Hansen et al. (2023) and Haskel (2023) for the Euro Area and the United States respecitvely.

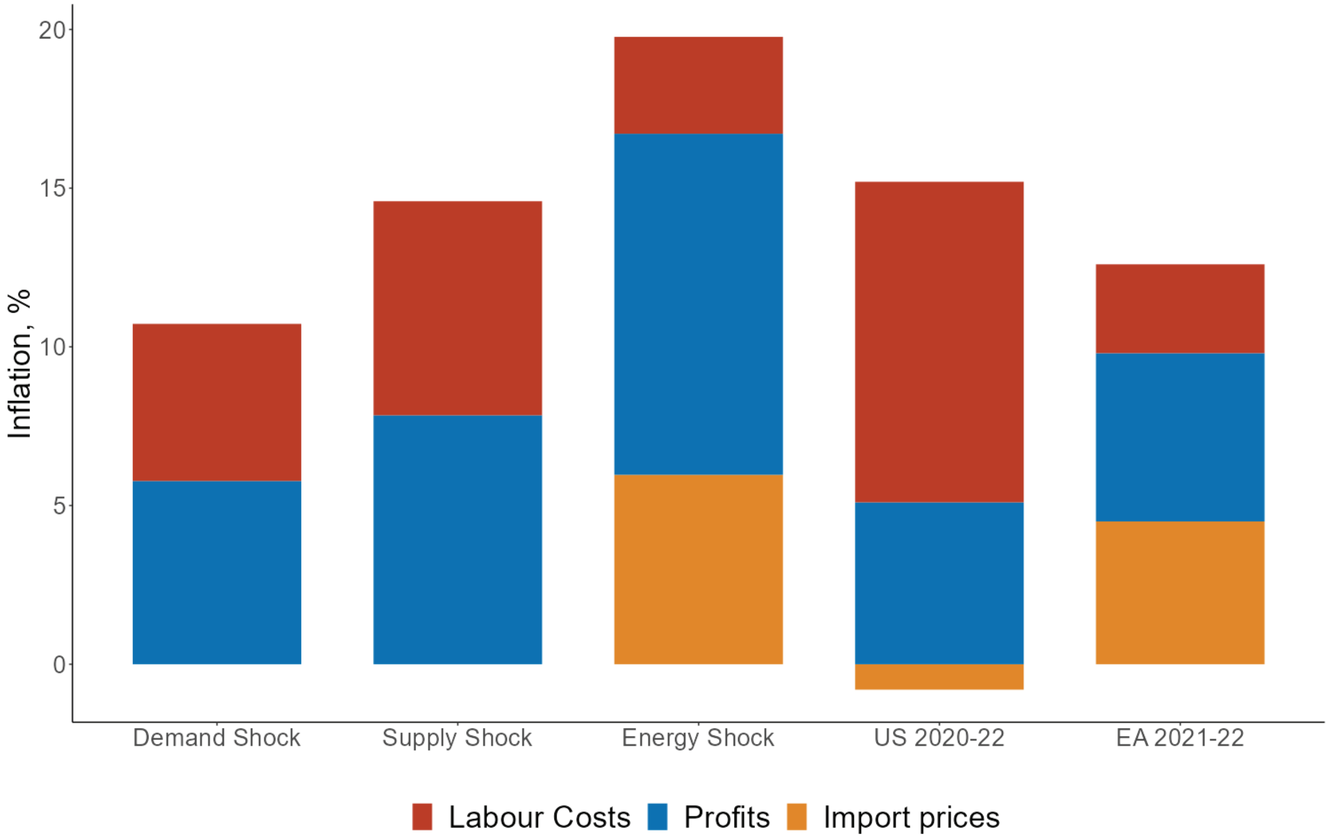

**Figure 12:** Contributions to cumulative change in consumer prices for the three scenarios and as observed in the United States and in the Euro Area. Cumulative change in prices in the model is measured over the two first years after the shocks. Data for the US is found in (Haskel, 2023) and refers to the period 2019Q4-2022Q4. Data for the EA is found in (Hansen et al., 2023) and refers to the period 2020Q4-2022Q4.

In the demand and productivity shock scenarios, the contribution of labour costs and profits on inflation dynamics are almost equivalent.[16] Moving to the energy shock scenario, we highlight three main findings. First, the import prices account for about one fourth of the inflation ramp up. Second, the rise in inflation is mostly due to profit hikes (about 60%) rather than labour costs increase (about 15%). As a mat-

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[16] By construction, these two scenarios cannot compare well with the empirical decomposition since they both lack the imported energy production factor.

ter of fact, profits per consumption unit increase by around 8% per-year, while wages only by 3%. Third, these results are qualitatively comparable to the empirical estimates of the IMF Working Paper by Hansen et al. (2023) for the Euro Area 2021-2022 inflation surge. [17] Also in the United States, profits constitute a non-negligible contributor to inflation although the country experimented a small disinflationary shock from import prices across the 2020-2023 years due to the fact that is is a net oil exporter.

Overall, our counterfactual analysis shows that our model is able to account for the dynamics triggered by an increase in imported energy prices observed for advanced economies over the past few years. In particular, this scenario is able to replicate the increase in unit profits and profit shares observed across most advanced economies since 2021 (Colonna et al., 2023; Hahn, 2023; OECD, 2023), along with the short-lived increase in mark-ups in the aftermath of the shock that mainly depends on the degree of competitiveness in the market (Gerinovics and Metelli, 2023; Arquié and Thie, 2023; Glover et al., 2023). Moreover, the inflation decomposition that we carried out shows how a shock to imported energy prices is able to replicate the qualitative features of inflation in the Euro Area, with unit profits taking the larger role in inflation growth and labour costs acting as a residual part. Finally, this conclusion is consistent with the results of the ECB Occasional Paper by Arce et al. 2024, which imputes the price surge in the Euro Area mostly to energy prices shocks.

## 5 Conclusions

In this work we extended the agent-based business cycle model developed by Guerini et al. (2018) to study i) the relationship between market selection efficiency and inflation dynamics; ii) the possible multiple sources of inflation; iii) the transmission mechanisms after a series of shocks to demand, productivity and non-labour costs. Overall, we show that the model is capable of generating realistic dynamics concerning prices, wages and other macroeconomic variables, and to match several features of the recent Euro Area inflation surge.

Our model is rooted in the seminal contribution by Greenwald and Stiglitz (1987) which shows that imperfect information slows down the capability of the market to channel price information to consumers.

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[17] Hansen et al. (2023) claim that the Euro Area suffered the most from the worsening in the terms of trade due to the rise in the prices of imported energy input, as well as from profits rising faster than wages.

Hence, relatively larger firms might enjoy an advantage in the goods market. In such a setting, the emergent ”spontaneous order” (Hayek, 1975) is incapable of rewarding the most price-competitive firm and leads to sub-optimal outcomes. Furthermore, Keynesian coordination failures might further amplify the economic fluctuations (Howitt, 1986).

We first show that our model is able of generate realistic inflation dynamics, as well as a non-linear Phillips curve in line with the empirical evidence recently put forward by (Gagnon and Collins, 2019; Benigno and Eggertsson, 2023). We then study the possible heterogeneous sources of inflation. In particular, we show that the traditional explanation of inflation as an excess-demand phenomenon stemming from a tight labor market, only holds when markets are competitive and efficient, i.e. when price signals are able to trigger a fast reallocation of firm market shares. On the contrary, in presence of imperfect market selection, inflation mostly arises from changes in mark-up rates happening within the largest firms, which can benefit from a higher monopolistic power.

We then employ the model to study the response of inflation, output and other economic variables to different shocks hitting consumption, labor productivity and energy costs. This allows us to shed light on the multiple sources of inflation possibly discriminating among alternative theories. We show that our framework allows for the possibility of both demand-led and profit-led inflation. In particular, exogenous demand shocks trigger an increase in prices. In such a scenario, the increase in demand and the associated labour scarcity push-up the aggregate wage. In turn, this leads to a temporarily persistently higher inflation rate. A supply-side labour productivity shock spurs inflation as firms are able to fully pass-through the shock to their customers. However, the shock does not significantly impact either on marks-ups or profit shares. Profit-led inflation (see Weber and Wasner, 2023) emerges after a energy shock via two complementary channels. The first one induces an increase in the profit share through changes in the relative cost structure of the firms, as wages do not change in response to the higher cost of the intermediate energy input (consistent with evidence provided by Manuel et al., 2024; Colonna et al., 2023). The second channel involves an increase in firms' profit margins (in line with results by Konczal, 2022; Gerinovics and Metelli, 2023). Finally, in accordance with the recent empirical evidence for the Euro Area (Hansen et al., 2023), our decomposition shows that in the energy shock scenario inflation is largely profit-led.

Our work can be extended along several lines of research. First, the policy implications of our analysis are not fully explored. In particular, new policy interventions beyond interest rates may be necessary to curb inflation at a lower social cost. Relatedly, credible policy exercises would requires a more thoroughly calibrated version of the model (see Guerini and Moneta, 2017; Fagiolo and Roventini, 2017). Third, the model could be extended to account for the relevance of sticky prices and wages, which may play a role in determining short-run economic fluctuations and the inflation rate, as well as in influencing ability of the agent to coordinate effectively through the decentralized matching procedure. Finally, more sophisticated expectations rules could be considered in the model, possibly introducing some form of learning (see e.g. Hommes, 2006; Dosi et al., 2020).

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# A Monte Carlo distribution for key variables in the model

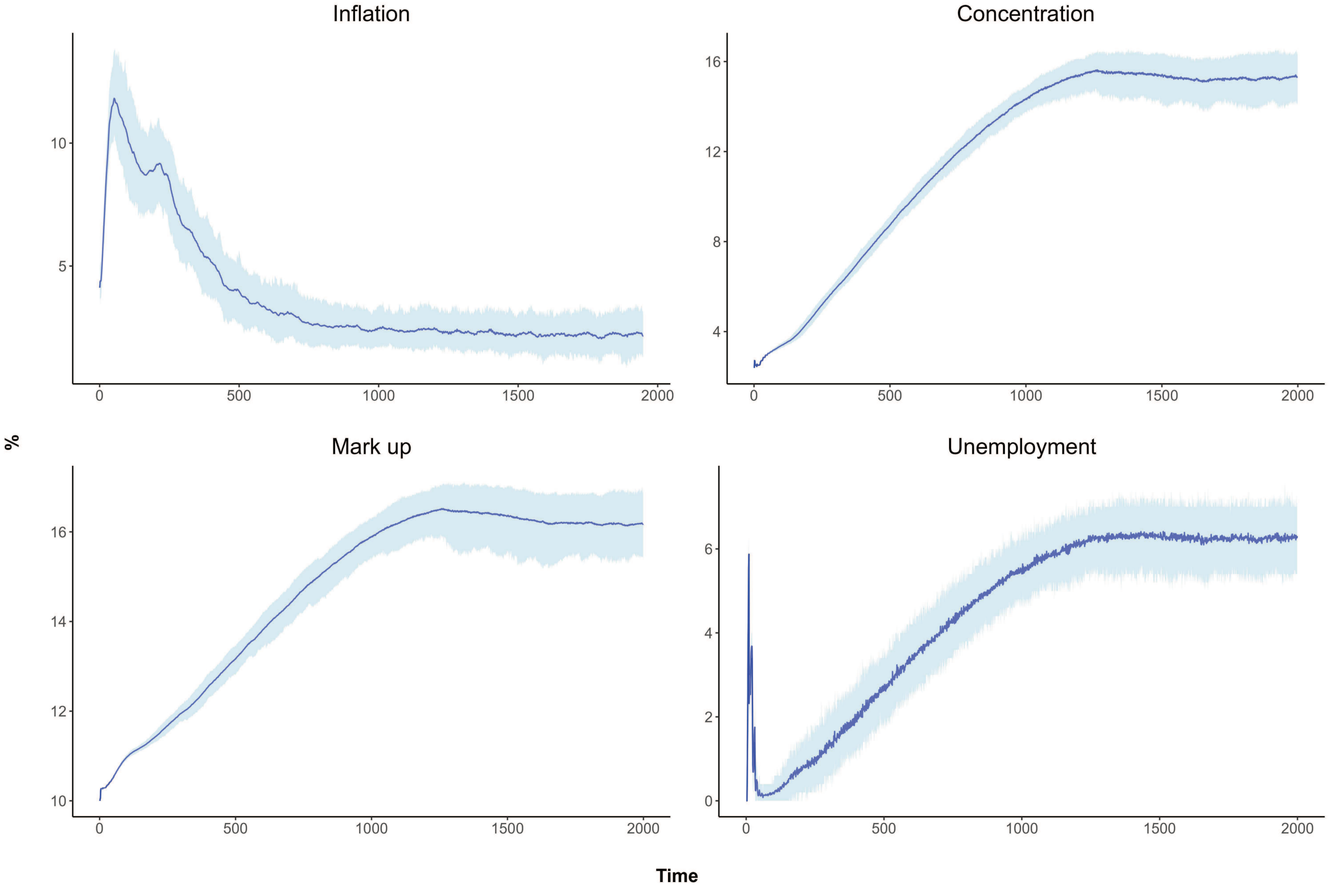

**Figure 13:** Median value (blue line) of the Monte Carlo distribution for inflation rate (top-left), market concentration (top-right), mark-up rate (bottom-left) and unemployment rate (bottom-right) as a function of simulation time. The shaded area is defined by the 10th and 90th percentile values values out of 100 Monte Carlo simulations.

# B Split-sample estimate of the non-linear Phillips Curve

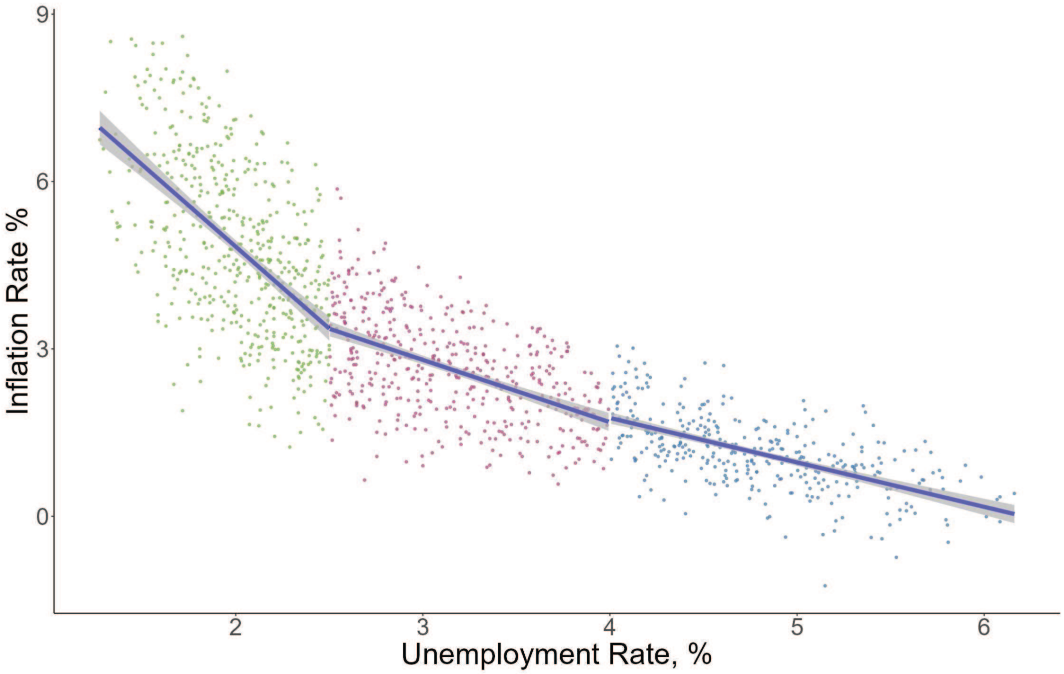

**Figure 14:** Split-sample estimate of the Phillips Curve generated by the model. The slope of the Phillips Curve in the model is conditional on the region of the $(u, \pi)$ plane in which the model operates.

| | $\mathbf{u < 2.5\%}$ | $\mathbf{2,5\% < u < 4\%}$ | $\mathbf{u > 4\%}$ |
|---|---|---|---|
| $Intercept$ | $10.67^{***}$ | $5.59^{***}$ | $4.80^{***}$ |
| | (0.4) | (0.35) | (0.21) |
| $Slope$ | $-2.92^{***}$ | $-1.04^{***}$ | $-0.76^{***}$ |
| | (0.2) | (0.11) | (0.04) |
| $Nobs.$ | 489 | 396 | 415 |
| $R^2$ | 0.84 | 0.43 | 0.27 |
| $* \ p < 0.1$, $** \ p < 0.05$, $*** \ p < 0.01$ | | | |

**Table 6:** Coefficients of the Split-sample estimate of the non linear Phillips Curve. Standard errors are reported in parentheses.

# C Impact of aggregate shocks on market structure

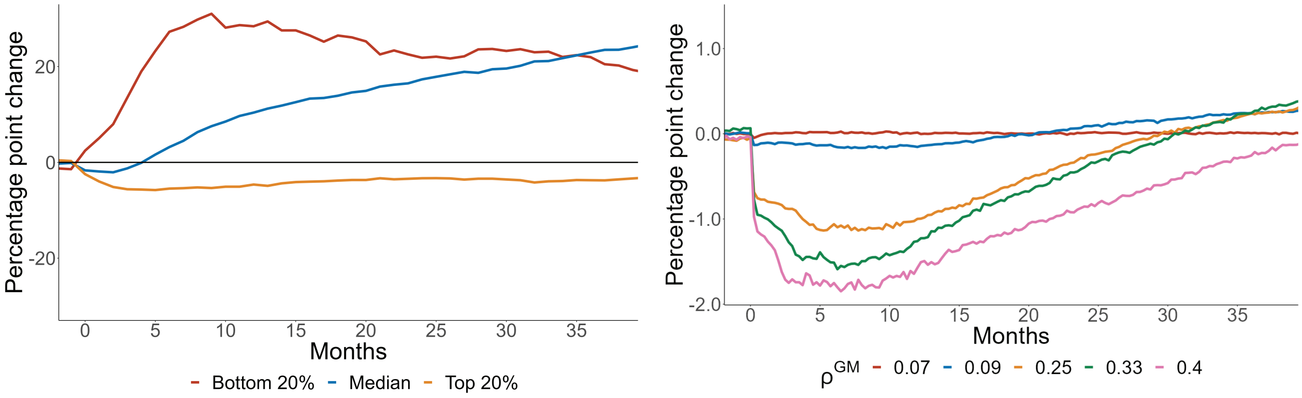

**Figure 15:** Left panel: Firm market share fluctuations after the positive demand shock in the baseline scenario ($\rho^{GM} = 0.4$). Right panel: Impact of the positive demand shock to Herfindahl-Hirschmann Index (HHI) for different scenarios. Time is measured in months (4 periods). The impact of the shock over time is measured in percentage point deviation from pre-shock level.

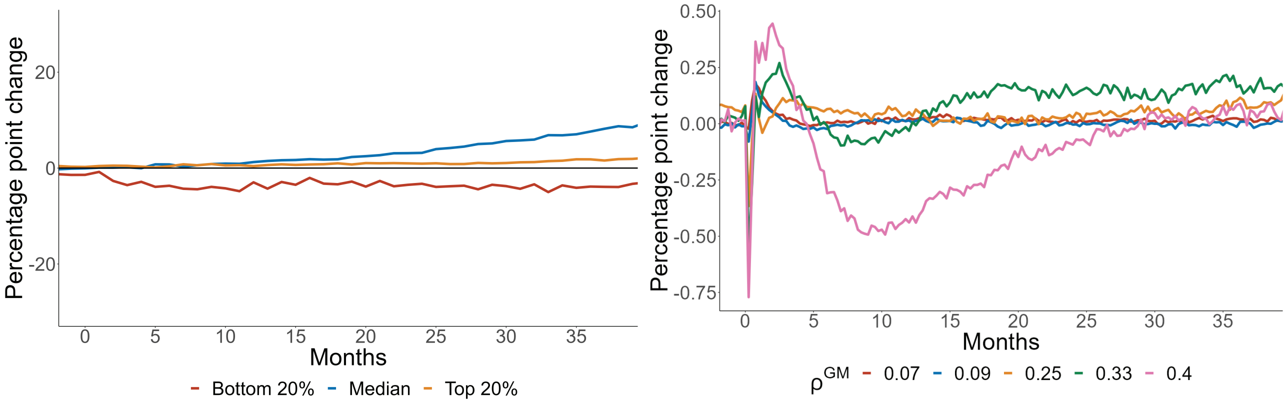

**Figure 16:** Left panel: Firm market share fluctuations after the negative productivity shock in the baseline scenario ($\rho^{GM} = 0.4$). Right panel: Impact of the negative productivity shock to Herfindahl-Hirschmann Index (HHI) for different scenarios. Time is measured in months (4 periods). The impact of the shock over time is measured in percentage point deviation from pre-shock level.

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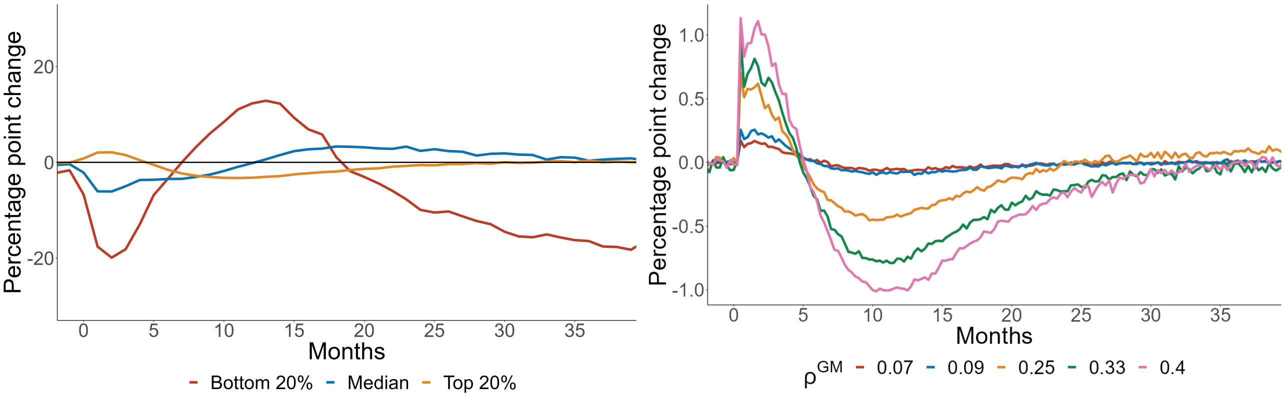

**Figure 17:** Left panel: Firm market share fluctuations after the negative energy shock in the baseline scenario ($\rho^{GM} = 0.4$). Right panel: Impact of the negative energy shock to Herfindahl-Hirschmann Index (HHI) for different scenarios. Time is measured in months (4 periods). The impact of the shock over time is measured in percentage point deviation from pre-shock level.