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Rethinking Inflation in an Agent-Based Macroeconomic Model

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We develop an Agent-Based model to study the role of demand vs. supply in determining inflation dynamics. Heterogeneous firms and households, downward money wage rigidity, and imperfect selection in the goods markets characterize the model. We show that the importance of demand vs. supply factors in determining inflation is related to the degree of imperfect selection in the market for goods. In particular, when the matching between firms and customers depends on firm size as well as on firm price, aggregate demand loses relevance in determining inflation, which is then driven by an increase in mark up rates caused by changes in the structure of the market of goods. Finally, we investigate the impact of different kinds of aggregate demand and supply shocks on output-inflation dynamics in the model. We show that aggregate shocks induce "profit-push" price increases, to the extent that they are able to impact market structure.
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This paper investigates the role of demand vs. supply drivers of inflation in an agent-based model characterized by local search and matching in the labor and goods market and by imperfect selection in the market for goods. We show that when selection in the market for goods is more imperfect, i.e. when the matching between consumers and households is driven by variables other than firm price (firm size) then demand dynamics lose relevance in explaining inflation, which emerges as a supply-driven phenomenon driven by changes in market structure

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and mark up rates.

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. One side of the debate (see e.g. Landau, 2021; Summers, 2021), follows the traditional approach to analyze the recent inflation surge, by considering it as an excess-demand phenomenon. This view is in line with the inflation experience of the 70s and it is theoretically supported by the New Keynesian Dynamic Stochastic General Equilibrium class of models (NK-DSGE). In this view, inflation arises as the result of a negative discrepancy between the market and the natural rate of interest, generating excess demand and an acceleration of wage growth and inflation. (Woodford, 2003; Galı, Gertler, 1999). At the other extreme of the debate, there are scholars who have cast doubts on the demand-driven origins of the current inflation. For instance, the work of Stiglitz, Regmi (2023) argues that the main determinant of current inflation must not be searched in the usual argument of labor markets being "too tight", but in "industry-specific problems [...] possibly exacerbated by market power and market manipulation". Similarly, Weber, Wasner (2023) argue that price pressures due to supply shocks can be propagated and amplified by the attempt of firms to protect and expand their profit margins.

The latter alternative view of inflation is also supported by recent trends in market concentration, and in wage and mark up growth. For instance, several empirical works have documented the decoupling between productivity and wage growth for the US, UK and Canada starting from the eighties (Stansbury, Summers 2018; Greenspon et al. 2021; Baker 2019). At the same time, other works indicate that markups have been rising in the last twenty years (De Loecker et al. 2020; Autor et al. 2020). The above trends seem at odds with the idea that increases in the money wage are the main factor behind price hikes. In addition, some recent contributions focusing on the last inflation dynamics highlight how both corporate profits and markups have been increasing with prices, leaving wages at the post (see e.g. Andler et al., 2022; Konczal, 2022). Likewise, the work of Hansen et al. (2023) documents how firms in the Euro Area have been able to pass on to consumers more than the nominal cost shocks experienced in 2022, therefore increasing the share of gross value added imputed to profits.

We contribute to the above debate about the origins of inflation by developing an agent-based model (ABM) that studies the conditions on the structure of interaction in the labor and goods market under which inflation is either a demand-driven or supply-driven phenomenon. The model builds on the framework developed in Guerini et al. (2018) and it is populated by heterogeneous firms, heterogeneous workers/consumers interacting in the imperfectly competitive labor and goods markets, a banking sector providing credit to firms, and a central bank setting interest rates by using a pure inflation-targeting Taylor rule. Firms employ simple heuristics to set wages in the labor market and prices in the market for goods. In particular, the wage set by a firm in the labor market depends critically on the gap between filled and open vacancies in the previous period (a measure of the excess demand for labor at the firm level). Moreover, firms employ a variable mark up pricing rule to set prices in the market for goods, with mark up rates being an increasing function of the growth of the firm market shares (a measure of changes in the degree of market power of the firm). Furthermore, as in Guerini et al. (2018) agents' interactions in the labor and goods markets are governed by local search and matching protocols. However, while the probability of a worker matching with a firm in the labor market is an increasing function of the wage posted by the latter, in the goods market 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 its size. The dependence of the latter matching probability on firm size mimics the search and matching algorithm introduced in Fontanelli et al. (2023) and it captures imperfect selection in markets for goods, i.e. the idea that selection in those markets imperfectly rewards more competitive firms (i.e. those with lower prices). In particular, the assumption that the probability of matching increases with firm size generates - ceteris paribus - an advantage for larger firms as it implies that they will be able to attract more consumers regardless of the price they set.

By employing the above model we show 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 addition, higher aggregate demand and widespread labor shortages push money wages upwards and put pressure on prices, consistently with the traditional "demand-led" explanation of inflation. In contrast, when selection is more imperfect, i.e. the allocation of market shares is strongly influenced by firm size, the goods market becomes more concentrated, and the demand-led component becomes less and less significant. In this scenario, mark up fluctuations gain prominence as a source of inflation and a "profit-price spiral" dynamic emerges.

Finally, we also analyze the impact of various types of aggregate shocks on output, inflation, and market structure dynamics. We show that large, persistent negative demand shocks such as those experienced in the first half of 2020 can impact market concentration and, as a consequence, induce "profit-push" price increases. In contrast, homogeneous supply shocks, do not impact significantly the market structure. In this case, however, firms are able to pass the increasing costs integrally onto their customers and avoid the compression of profit margins.

Our work is also related to the recent literature on agent-based models studying the inflation process and/or focusing on the effects of inflation-targeting policies. Ashraf et al. (2016) build a model with decentralized markets and staggered contracts, keeping the emphasis on trend inflation and the role of nominal rigidities, with predictions substantially in line with those arising from NK-DSGE models. Bouchaud et al. (2017) build a model with an aggregated household sector and focus on the depressing effects of imposing a too low inflation rate. Knicker et al. (2023) use the same model with minor extensions to assess the impact of Covid-19 related shocks conditional to different policy settings. Yet, many of the salient features related to price growth are left unexplained by the existing literature: in particular the role of market structure and market power and the link between competition, profit margins and inflation have not been thoroughly explored by theoretical contributions. The model in this paper is different from those used so far in the macro ABM inflation literature in two ways. First, contrary to the Mark-0 used in Bouchaud et al. (2017); Knicker et al. (2023), it is intrinsically a disequilibrium model: market clearing is not a datum, coordination is carried through decentralized interactions among individual households and firms, and it is precisely this never-ending process of adjustment within markets that allows inflation to arise and propagate. When an individual firm adjusts its posted price, it contributes to increase the price index and therefore shapes the market environment, as all the other firms will coordinate around a higher level of prices. Therefore it is through the continuous waxing and waning of disequilibria within markets that the system drifts towards higher and higher price levels. Second, while the existing theoretical literature focuses exclusively on demand-supply imbalances as the only source of inflation, our model emphasizes also the role of imperfect market selection dynamics and market power, and considers their role in price determination.

The rest of the paper is structured as follows: Section I introduces the model, while Section II presents the results of Monte-Carlo simulations conditional to different degrees of market selection intensity. Furthermore, Section III explores the simulated impact of three different aggregate shocks on inflation and output in the model. Finally, Section IV concludes.

I. The Model

We consider a closed economy populated by F firms, H households, a central bank and a commercial bank. Time is discrete, indexed by "weeks" t = 1, ..., T. There are 52 weeks per "year". Firms produce a homogeneous consumption good by 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. The Central Bank adopts a single-mandate Taylor Rule in order to steer the economy towards an inflation target, while a representative commercial bank collects deposits from households, provides loans to firms, and charges the relative interests. In the good and labor markets, firms and households are matched according to decentralized protocols.

A. 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 updates 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. The wealth of defaulted firms is reset to a constant value.

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) Demand of loans by each firm is computed, the Bank decides whether or not to grant credit to each firm.

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 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.

B. 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. Every 6 weeks the Central Bank of this model computes the average inflation rate of the past year and plugs this value ($\tilde{\pi}_t = \frac{\sum_{k=1}^{52} \pi_{t-k}}{52}$) into a single mandate Taylor Rule, with the aim of steering the economy towards a target inflation level π^* by conveniently setting a reference rate of interest ρ_t^0.

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

Where ρ^* is a "target" interest rate and ϕ represents the intensity of the policy.

C. The expectations formation process

We assume that inflation expectations by firms and households for the following period are a linear combination between realized inflation during the last week and an inflation "anchor" which is exogenously set, along the lines of Salle et al. (2013).

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

Formally, each agent forms her inflation expectation as a weighted average between the inflation anchor π^{*} and past inflation π_{t-1}. The weight parameter $\chi\,(\chi \in [0,1])$ is assumed to be common across all agents, and may be interpreted as the degree of anchoring private expectations to some long-term inflation rate.

D. Consumption, production, prices, and wages

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.

PRODUCTION, WAGES AND PRICES. — The production of the consumption good takes place by means of a linear production function employing only labor $(n_{f,t})$ as in 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.

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

$$\widehat{q}_{f,t} = \tilde{q}_{f,t} + \alpha^{g} z^{good}_{f,t-1},\ \alpha^{g} > 0 \tag{5}$$

The term $\tilde{q}_{f,t}$ captures a 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 et al., 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, as firms set at each time step , as a new reference:

$$\tilde{q}_{f,t} = \tilde{q}_{f,t-1} + \alpha^g (q_{f,t-1} - \tilde{q}_{f,t-1}) \tag{6}$$

Furthermore, a firm f sets the money wage as follows:

$$W_{f,t} = W_{f,t-1}(1 + \hat{\pi}_{f,t})^{\beta^l}(1 + z^{lab}_{f,t-1})^{\alpha^l},\ \beta^l > 0,\ \alpha^l > 0 \tag{7}$$

More precisely, we assume that the firm uses the money wage posted last week as a benchmark, and adjusts it according to the expected current inflation level (if positive), to account for formal and informal indexation mechanisms operating in the wage formation process. On top of that, wage is influenced by demand through the term $z^{lab}_{f,t-1}$, which represents the share of vacancies left unfilled in the previous period over total vacancies opened. This implies that a gap between open and filled vacancies will lead to an increase in the wage offered by the firm, in an effort to be more competitive in the labor market (see e.g. Mortensen, Pissarides, 1999; Diamond, 1982)).

Notice that by construction our wage setting assumptions imply downward rigidity in money wages. Firms react to labor shortages by increasing the money wage and to excess employment by “firing” employees. Analogously, they allow money wages to adjust to higher price levels but refrain from cutting wages when experiencing deflation. This feature of the model finds justification on the overwhelming individual-level evidence supporting downward money wage rigidity.[1]

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

[1]For the U.S., see Akerlof et al. (1996), Kahn (1997) and Daly, 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, Wulfsberg (2008) provide multi-country evidence from industry-level data.

(8)
$$C_{f,t} = \frac{W_{f,t}}{a_{f,t}}$$

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

(9)
$$P_{f,t} = (\frac{W_{f,t}}{a_{f,t}})(1 + \mu_{f,t})$$

mark up rates are not fixed but change over time as a function of the variation in firm's market share $s_{f,t} = \frac{q_{f,t}}{\sum_g^F q_{g,t}}$

(10)
$$\mu_{f,t} = \mu_{f,t-1} + \nu(s_{f,t-1} - s_{f,t-2}),\ \nu > 0$$

The above rule for setting the mark up mimics the one employed in other ABM macro models (e.g. Dosi et al., 2013), wherein the variation in market shares is taken as a measure of the variation in the degree of market power of the firm. In addition, the above rule is in accordance with the recent empirical evidence indicating that industries with larger firms and more concentrated market structures are associated to higher higher mark up rates (see e.g. Autor et al., 2020; De Loecker et al., 2020)).

Consumption. — We assume that households set their desired consumption $\hat{c}_{h,t}$ evolves according to a buffer-stock consumption rule, analogous with the one implied by Carroll et al. (1992) and Carroll (1997): households make their consumption decisions by targeting a given level of wealth as a proportion of "normal" income $\bar{Y}_{h,t}$, or "cash on hand ratio" as labeled in Carroll (2001).

(11)
$$\begin{cases} \widehat{c}_{h,t} = \bar{Y}_{h,t}[1 + \delta_0(\delta_1 \frac{A_{h,t}}{\bar{Y}_{h,t}} - 1)] & \text{if } \bar{Y}_{h,t}[1 + \delta_0(\delta_1 \frac{A_{h,t}}{\bar{Y}_{h,t}} - 1)] < \frac{A_{h,t}}{\hat{P}_t} \\ \hat{c}_{h,t} = \frac{A_{h,t}}{\hat{P}_t} & \text{if } \bar{Y}_{h,t}[1 + \delta_0(\delta_1 \frac{A_{h,t}}{\bar{Y}_{h,t}} - 1)] \geq \frac{A_{h,t}}{\hat{P}_t} \end{cases}$$

with $\delta_0 > 0$, $\delta_1 > 0$.

Normal income $\bar{Y}_{h,t}$ evolves adaptively according to past realized income:

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

If actual cash-on-hand is greater than the target, the agent is being "over cautious" and will correct by dissaving, while if cash-on-hand is below the target, the precautionary saving motive will induce the household to save in order to build wealth back up toward the target.

The main difference between Carroll's implied buffer-stock saving rule and ours is that our household employs adaptive expectations about normal income instead of facing a given income distribution centered around a fixed "permanent" income mean. This implies that following an income shock, it will take a number of weeks for the household 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 $\rho_t^d A_{h,t}$:

$$S_{h,t} = W_{h,t} + D_{h,t} + \rho_t^d A_{h,t} - \sum_{f=1}^{F} P_{f,t} c_{h,t} \tag{13}$$

E. The banking sector and the credit market

The banking sector is constituted by a single "representative" commercial bank that sets the interest rates in deposits and loans (ρ_t^d and ρ_t^l) uniformly. The bank always sets $\rho_t^d = \rho_t^0$ and $\rho_t^l = \rho_t^0 + \varsigma$, with ς being a fixed positive spread. The bank has a positive initial net worth NW^b and as the firms in the goods sector, redistributes a fixed share of the profits to households at each period, whenever they are positive.

Each firm computes its demand for credit as the difference between the costs it expects to sustain in the next period for production and its own finance: $L_{f,t}^d = n_{f,t} W_{f,t} - NW_{f,t}$. If this amount is positive, the firm applies to the bank for a loan, to be repayed at the beginning of the next period. Otherwise, $\Delta L_{f,t}^d = 0$.

As a firm applies for credit, the bank checks her loan-to-value ratio ($\frac{L^d_{f,t}}{NW_{f,t}}$) and grants credit in full if $\frac{L^d_{f,t}}{NW_{f,t}} \leq \mathscr{E}_t$. Otherwise, the bank provides credit just up to $\mathscr{E}_t NW_{f,t}$. When the latter constraint is binding, the firm scales down its desired production accordingly. The threshold $\mathscr{E}_t$ 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, others, 2007; Disyatat, 2011):

$$\mathscr{E}_t = \mathscr{E}(1 - \theta(\rho^0_t - \pi^*)) \tag{14}$$

The intuition behind this relation is that the perceived strength of the bank balance sheets affects the willingness of the bank to supply loans. Whenever an indebted firm is unable to repay the loan and goes bankrupt, the bank absorbs the corresponding “bad debt”. Financial intermediaries react to a rise in interest rates (which may affect the bank’s asset quality, the bank’s cash flows, or the bank’s risk perception) by enacting stricter controls on the financial stability of borrowers, in order to hedge against increased default probability. Although this mechanism is not modeled explicitly here, there is ample evidence that banks react to monetary tightening by decreasing lending(Altunbaş et al., 2002; Gambacorta, 2005; Gambacorta, Marques-Ibanez, 2011), conditional to their capitalization, risk profile ad liquidity.

F. 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 the work by Guerini et al. (2018). However, while in the labor market, the allocation of the labor force across firms is only determined by wage differences across firms, in the goods market households sort firms on the basis of their prices as well as on their size. We first describe the search and matching process in the labor market and, next, the one in the market for goods.

The labor market. — Firms in the labor market demand labor to fulfill their production plans. Labor demand is determined as in (15):

$$n^d_{f,t} = (\frac{\widehat{q}_{f,t}}{a_{f,t-1}}) \tag{15}$$

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 decide to queue up or not for the job opened by a firm with a probability increasing in the offered wage. More formally, a worker can queue up for one job only and she search for open vacancies and queue up or not for a job according to a binomial draw with probability $p^{LM}_{f,t}$.

$$\Phi^{LM}_{h,t} = \begin{cases} 0 \text{ with probability } p^{LM}_{f,t} & \text{not queue up} \\ 1 \text{ with probability } 1 - p^{LM}_{f,t} & \text{queue up} \end{cases} \tag{16}$$

The probability of queuing $1 - p^{LM}_{f,t}$ is proportional to the wage offered by the firm relative to the market-average one:

$$1 - p^{LM}_{f,t} = 1 - \frac{1}{\varrho^{LM}}[1 - (\frac{W_{f,t} - \bar{W}_t}{\bar{W}_t})] \tag{17}$$

where $\bar{W}_t$ is the market average wage and $\varrho^{LM}, \gamma^{LM} \in (1, \infty)$ are parameters determining the degree of search frictions and imperfect information in the labor market. Note that the probability of queuing is a decreasing function ϱ^{LM}. Therefore, the higher the value of ϱ^{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 are determined by the short side of the market, according to:

$$n_{f,t} = min(n^d_{f,t}, n^s_{f,t}) \tag{18}$$

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.

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 according to a local search and matching process similar to the one described above for the labor market, with the important difference that consumers in the product market do not sort firms randomly but according to their current size on the market and start looking for sellers *giving priority to the largest*. Once firms are sorted according to their size, consumers decide whether to queue up or not for the goods sold by the firms in the list with a binomial trial with probability $p_{f,t}^{GM}$.

$$\Phi_{h,t}^{LM} = \begin{cases} 0 \text{ with probability } 1 - p_{f,t}^{GM} & \text{not queue up} \\ 1 \text{ with probability } p_{f,t}^{GM} & \text{queue up} \end{cases} \tag{19}$$

A household queues up at one firm only, demanding $\hat{c}_{h,t}$ units of the good.[2] The probability of queuing is proportional to the price posted by the firm relative to the market average one:

$$p_{f,t}^{GM} = \frac{1}{\varrho^{GM}}[1 - \gamma^{GM}(\frac{P_{f,t} - \bar{P}_t}{\bar{P}_t}) \tag{20}$$

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.

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. 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

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

to match with more customers for any given price posted (see Fontanelli et al., 2023, for an application of the same idea in the context of international trade dynamics)).

Note also that by varying the values of the parameters ϱ^{GM} and γ^{GM} in Equation 20 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 characterizing the market for goods. In particular, lower values of ϱ^{GM} imply a higher probability of matching for any given price, capturing a higher advantage for larger firms. In addition, higher values of γ^{GM} in turn imply a higher probability of matching for lower prices, capturing the degree of "price selection" in the model. In the simulation analyses in sections II and III we exploit the above properties intensively and we present results for different combinations of $(\varrho^{GM}, \gamma^{GM})$, which capture scenarios where market selection is more or less imperfect.

G. *Financial conditions, exit and entry*

After the matching process in the goods market is concluded, households determine their effective real consumption $c_{h,t} \leq \hat{c}_{h,t}$ 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 store at each time step all of their savings in the form of deposits. Households update their wealth $(A_{h,t+1})$ according to:

$$A_{h,t+1} = A_{h,t} + S_{h,t} \tag{21}$$

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

$$\Pi_{f,t} = q_{f,t} P_{f,t} - n_{f,t} W_{f,t} - \rho^l L_{f,t} \tag{22}$$

Whenever profits are positive, firms pay a fraction $(1 - \omega_1)$ as dividends to households. We assume that firm ownership is symmetric across households. Therefore, each household receives a fraction $1/H$ of the dividends paid by each firm. If profits are negative, firm's net worth is reduced accordingly. The law of motion of the firm's net worth is therefore:

$$NW_{f,t} = \begin{cases} NW_{f,t-1} + \omega_1 \Pi_{f,t} & \Pi_{f,t} \geq 0 \\ NW_{f,t-1} + \Pi_{f,t} & \Pi_{f,t} < 0 \end{cases} \tag{23}$$

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 the initial one, (indexed by price level), while bad debt is absorbed by the bank. Households own an equal share of the new firm, receiving its future dividends (if any). The bailout fund is financed through a contribution by incumbent firms, that put a share of profits ω_2 into the fund every week they realize a positive profit. 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 average ones of the incumbents.

Table 1—: Baseline parametrisation

	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
α^l	Wage adjustment	0.1
α^g	Supply adjustment	0.1
ν	Mark up sensitivity to market shares	0.5
β^l	indexation parameter	1
δ_0	Consumption adjustment	0.5
δ_1	Consumption - Cash-on-hand ratio	0.2
α_y	Consumption - Permanent income adjustment	0.5
$\mathscr{E}$	Debt to Equity threshold	10
θ	Real interest rate effect on credit	300
π^*	Inflation target	0
ρ^*	Baseline weekly deposit rate	0 %
ρ^1	Baseline weekly loan rate	0.05 %
ϕ	Monetary policy intensity	0.5
γ^{LM}	Matching friction labor	3
ϱ^{GM}	Incumbent advantage effect	7
γ^{GM}	Price selection effect	7
ω_1	Firm profit retained	0.5
ω_2	Firm "bailout contribution" share	0.5
ω_3	Unemployment benefit parameter	0.6

II. Simulation Results

Following the standard practice in the agent-based literature we analyze the model described in the previous section through extensive Monte Carlo simulations. More precisely, we perform $MC = 100$ Monte Carlo iterations for each parametrization of the model (see also below). Each Monte Carlo iteration is composed by 2000 periods (or "weeks") which are enough for the model to converge to a stochastic equilibrium for the macroeconomic variables of interest[3].

We perform several Monte Carlo experiments where we vary the values of the

[3]The first 1500 simulated periods are discarded in order to allow the model to transition from initial condition to its steady state.

parameters ϱ^{GM} and γ^{GM} in Equation 20 while keeping all the other parameters at their baseline values (Table 1 shows the baseline parametrization of the model). In particular we experiment with both high and low values of the above parameters (with respect to the baseline) in order to capture scenarios where selection in the goods markets is, respectively, less or more imperfect. More precisely, high values of both ϱ^{GM} and γ^{GM} capture a scenario where market selection is less imperfect, as firm size plays a small role in the matching process between firms and customers, and where competition among firms is mostly driven price differences. On the contrary, scenarios where ϱ^{GM} and γ^{GM} are both small imply a large size advantage in the matching process and therefore characterize a more imperfect market selection process.

A. Macro and microeconomic properties of the model

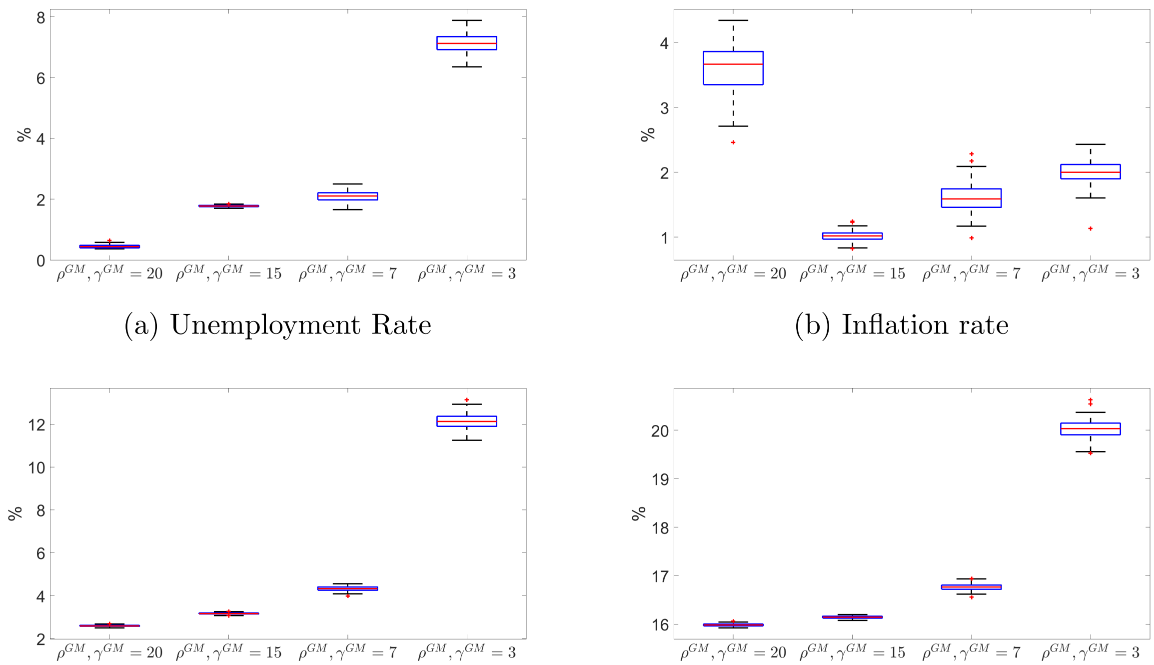
Figure 1 show the box plots of the model-generated Monte Carlo distributions of inflation and unemployment for different market selection scenarios (top panels). In addition, the same figure shows the box plots also for the market concentration (measured by the Hirschman-Herfindahl index) and the firm mark up rates generated by our model.

The analysis of the box plot reveals that all market selection scenarios are characterized by positive trend inflation, although no systematic relation is observed between the degree of market selection and the level of inflation. In contrast, the degree of imperfections in the market selection process has a significant impact of market structure, with less selective markets giving rise to a more concentrated market. This is due to the presence of dynamic increasing returns in demand allocation which is a feature of our matching protocol.

Higher concentration leads to a larger aggregate markups (i.e., lower labor shares) and higher unemployment rates, due to the impact that income distribution has on aggregate demand due to our assumptions on accumulation. Since only a fraction of profits is distributed back to households in the form of dividends, while the remainder is stored within firms, higher markups imply lower aggregate consumption and lower activity levels in the model and, accordingly, higher unemployment.

Since only a fraction of profits is distributed back to households in the form of dividends, while the remainder is stored within firms, higher markups imply lower aggregate consumption and lower activity levels within the model.

To sum up, at the macro level, changes in the 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, Summers, 2020; De Loecker et al., 2020), as well as declining employment trends (e.g. Abraham, Kearney, 2020).



(a) Unemployment Rate

(b) Inflation rate

(c) Market Concentration (HHI)

(d) Mark up rate

Figure 1. : Box-plots of the Monte Carlo distributions of unemployment, inflation, market concentration and the mark up rate as a function of the degree of imperfection in the market selection process in the goods market. Higher values of ρ^{GM} and γ^{GM} imply a less imperfect market selection process.

B. A closer look at the origins of inflation

Our assumptions about firm wage setting and price setting (see Section I.D) allow us to decompose price changes along different dimensions that shed light on the inflation drivers in our model in different market selection regimes.

In the first decomposition analysis, we decompose aggregate price changes in a "within-firm" component, driven price adjustments operated by firms, and a "between-firm" component, that is, aggregate price changes due to the continuous reallocation of sales between firms. In the second decomposition exercise, we focus on price changes at the firm level and on its drivers as implied by the combined wage and price setting behaviour of the firm.

Decomposing price changes at the aggregate level. — The aggregate price index in our model is defined as a weighted (by market share) average of individual firm log-prices: $log(P_t) = \sum_{f \in F} s_{f,t} log(P_{f,t})$. Exploiting this definition, we can decompose changes in the aggregate price index as follows (in the spirit of Baily et al., 1992):

$$log(P_t) - log(P_{t-1}) = \sum_{f \in F} \Delta s_{f,t} log(P_{f,t}) + \sum_{f \in F} s_{f,t-1} \Delta log(P_{f,t}) \quad (24)$$

The first term on the right hand side measures the *between Firm* component of price changes, i.e. the contribution to overall inflation from the reallocation of market shares across firms. The second term tracks instead the *within firm* component, i.e. the contribution to inflation from changes in prices at the firm level. We perform the aforementioned decomposition for different degrees of imperfection in market selection and report the Monte Carlo averages in Figure 2.

Unsurprisingly, the "between-firm" component of aggregate price changes is negative in all market selection regimes we consider, as consumers continuously tend reallocate themselves towards the firms that are located in lower end of the price distribution, even while prices are rising on the aggregate. Nevertheless, the importance of this component fades away as the selection process becomes more imperfect. In markets with relatively efficient selection customers are quicker to turn to firms that charge lower prices. The opposite occurs when selection is imperfect as customers are less sensitive to price differences across firms, and big firms are allowed to increase 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, Roma, 2005;

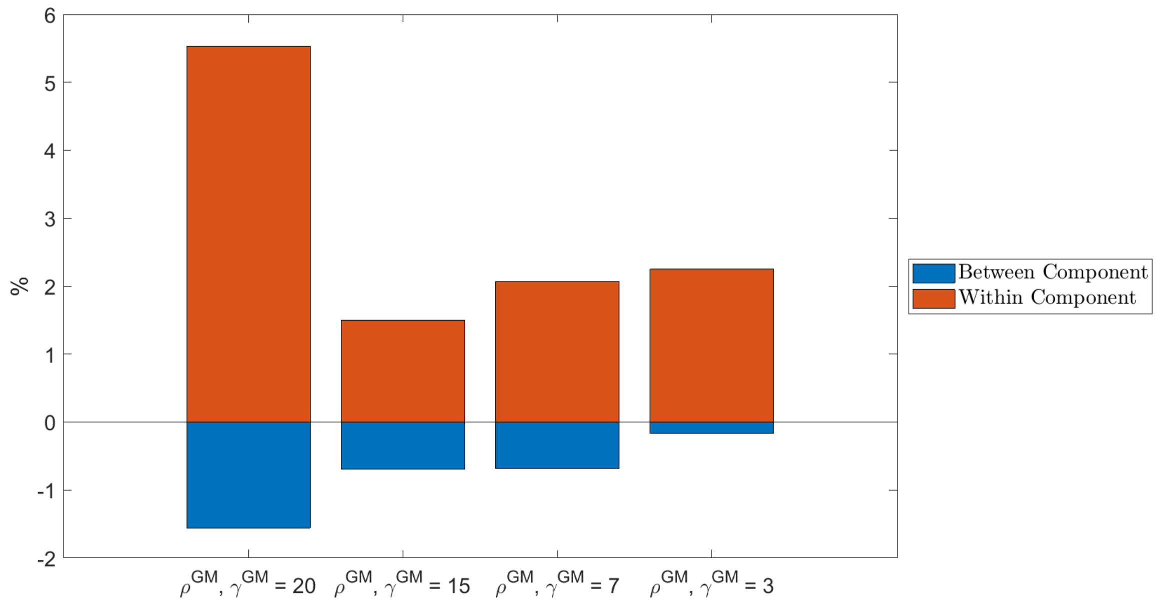


Figure 2. : Monte Carlo averages of within and between firm components of aggregate price changes as a function of the degree of imperfection in the market selection process in the goods market. Higher values of ϱ^{GM} and γ^{GM} imply a less imperfect market selection process.

Torun, Yassa, 2023).

Firm level drivers of inflation. — In the second decomposition exercise we break down price changes at the firm level according to their source. Starting from our assumptions about price and wage setting (cf. Equations 7, 9 and 10) we can obtain a "reduced form" equation for firm-specific price growth. More precisely, by log-differencing eq. 9 we have:

$$\pi_{f,t} = log(W_{f,t}) - log(W_{f,t-1}) - (log(a_{f,t}) - log(a_{f,t-1}) + (\mu_{f,t} - \mu_{f,t-1}) \tag{25}$$

which, after substituting for wages from eq. 7 becomes:

$$\pi_{f,t} = \beta^l \hat{\pi_{f,t}} + \alpha^l z^{lab}_{t-1} - \Delta log(a_{f,t}) + \Delta \mu_{f,t} \tag{26}$$

This decomposition helps us understand what are the fundamental channels through which prices increase at the firm level. The first driver of inflation is excess demand in the labor market, captured by $\alpha^l z_{t-1}^{lab}$. Whenever firms struggle to fill in their posted vacancies - in other words, when the labor market is "too tight" - they increase nominal wages proportionally and this leads to price growth in the following period. This first driver of inflation is akin to the standard interpretation of the relationship between the rate of growth of money wages and excess demand pressures on the labor market as put forth, for example, by Lipsey (1960), and which go by the name of "demand-pull" inflation. A second factor determining price growth is fluctuations in the labor productivity level $\Delta log(a_{f,t})$ which have an immediate impact on the unit cost of output $\frac{W_{f,t}}{a_{f,t}}$ and, therefore on prices. This second source of price growth can be broadly interpreted as a "cost-push" source of inflation in the model. A third driver of inflation is fluctuations in the market shares $\Delta\mu_{f,t}$ which, just as the fluctuations in unit costs, immediately impact the level of prices.[4] Finally, the component $\beta^l \hat{\pi_{f,t}}$ captures wage indexation mechanisms, which act as a propagation channel of inflation by linking today's firm-level price adjustments to past realized inflation at the aggregate level.

Note that the cost-push, indexation and mark up components can take positive or negative values while the excess demand component can take only non-negative values in the model. However, to assess the importance of the above four different factors, Figure 3 shows the absolute value of each of the four components for different degrees of imperfection in market selection.

The analysis of Figure 3 reveals that excess labor demand plays a prominent role in determining firm-level price growth in the scenarios where selection is less imperfect (high values of ϱ^{GM} and γ^{GM}), i.e. the scenarios with more intense price competition and a smaller firm size advantage. We have already remarked (cf. Section II.A that higher selection is associated in our simulations with a lower concentration, higher aggregate demand and lower unemployment. This, in turn, makes the labor market tighter and leads to the occurrence of frequent labor shortages, consistent with the traditional interpretation of inflation as an

[4]Regarding this third source of inflation, it is worth noting that is not necessary to have a time-increasing aggregate mark up rate to have positive trend inflation in the model, as long as we assume asymmetries in the money-wage adjustment process. Even if firms' markups oscillate symmetrically around a fixed average due 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.

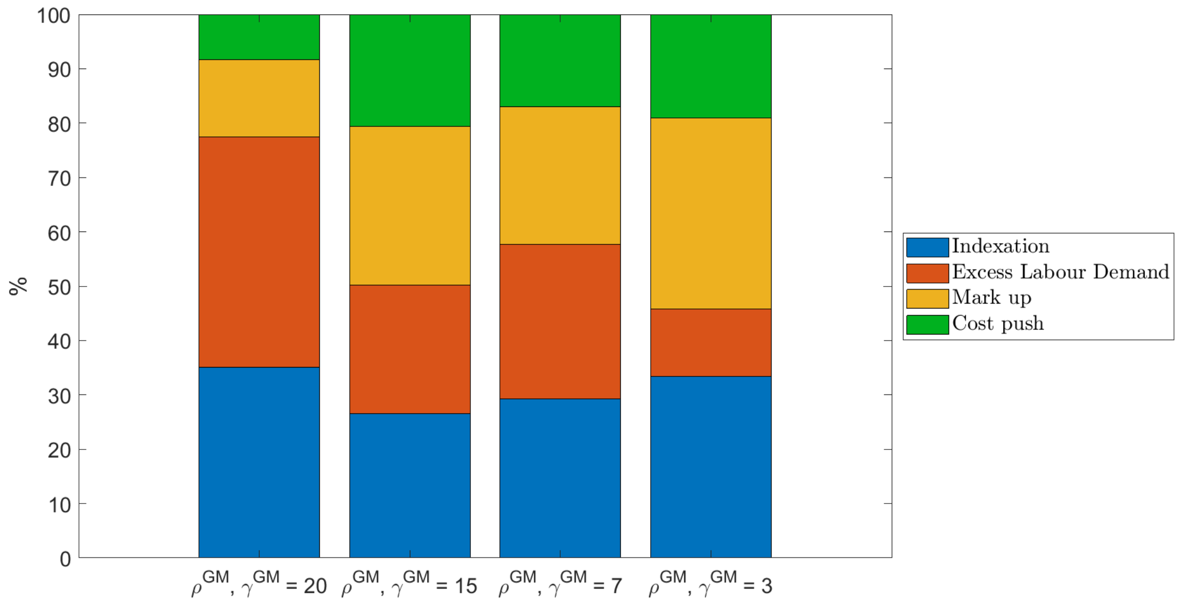


Figure 3. : Absolute value of the Monte Carlo averages of the components of firm-level price growth s a function of the degree of imperfection in the market selection process in the goods market. Higher values of ϱ^{GM} and γ^{GM} imply a less imperfect market selection process.

excess demand phenomenon.

The picture changes sharply as we move towards a setting with less intense price competition and a larger firm advantage (low values of ϱ^{GM} and γ^{GM}) as the excess labor demand component becomes less relevant, and fluctuations in mark up rates become the dominant driver of price changes at the firm level.

Summing up, the plots in Figures 2 and 3 deliver the first important result of our model. Namely, the nature of inflation depends on the characteristics of market selection in the market for goods. In particular, the traditional explanation of inflation as a phenomenon generated by an excessive level of demand and by a tight labor market holds only in a scenario where price competition among firms induces an intense reallocation of market shares across firms. In this scenario, market reallocation plays a significant role in driving aggregate price changes, and price changes at the firm level are mostly driven by excess demand in the labor market. In contrast, when price selection becomes less important and competition among firms is largely influenced by firm size, then inflation becomes a phenomenon largely driven by changes in price at the firm level, which are mostly driven by increases in mark up rates. This latter effect is in particular determined by the fact that - in a scenario where selection is strongly biased by a firm size advantage - large firms are able to increase market shares even if they practice prices that are not lower than their competitors.

III. Impulse response analysis

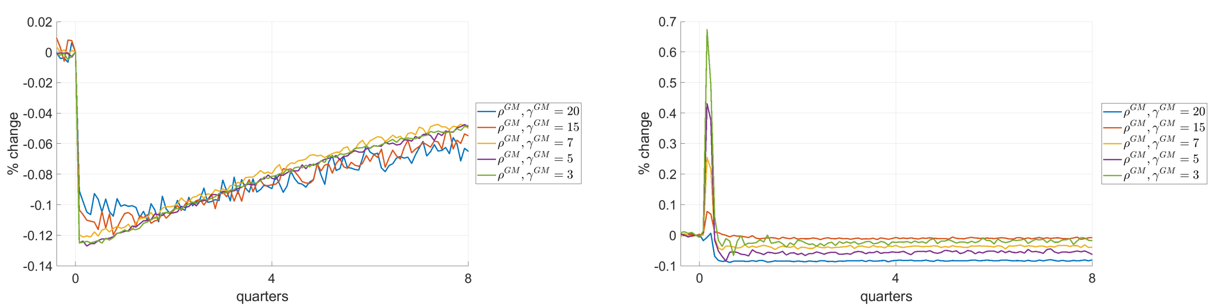
The final battery of our Monte Carlo experiments is devoted to assessing whether large, persistent aggregate shocks can, within our framework, induce fluctuations in firms' market power, and give way to what has been called "sellers' inflation" (see Weber, Wasner, 2023): price increases arising from firms trying to protect or even increase their profit margins. We consider three shock scenarios. The first one is a negative demand shock involving a sharp reduction in household consumption $\widehat{c}_{h,t}$, which is meant to "mimic" the reduction in personal consumption expenditure followed by the implementation of stay-at-home orders following the outbreak of the Covid-19 pandemics. In the second scenario, we consider a shock decreasing labor productivity, which represents ubiquitous supply chain disruptions (such as pandemic restrictions to production, logistic bottlenecks, and intermediate input shortages). The third shock scenario is designed to represent the global energy crisis occurring since February 2022, following the Russo-Ukrainian War. It involves the introduction of a new external non-labor cost to production in the model, which is meant to represent the cost of energy. We repeat the aforementioned shock experiments for different market selection scenarios characterized, as in the previous sections, by different values of the parameters ϱ^{GM} and γ^{GM}.

A Demand Shock. — In this scenario we hit the economy - for each Monte Carlo iteration - with a 15% reduction of household's consumption $\widehat{c}_{h,t}$ at $t = 1600$. The shock is modeled as an $AR(1)$ process with parameter $\phi = 0.95$.

Figures 4a and 4a show the impact of the above-mentioned negative demand shock on aggregate output and inflation for different market selection regimes. The shock has always a negative impact on output in all scenarios. The impact on inflation instead depends on the characteristics of market selection. In particular, the traditional impulse response shape, which involves a decrease in inflation following a fall in demand, is observed only in the scenario where market selection is the least imperfect and competition among firms is largely driven by price differences. In contrast, when market selection is more imperfect, we observe that a negative demand shock increases inflation.

This apparently paradoxical result can be understood by looking at the shock-induced dynamics of market concentration. Figure 5 shows that a reduction in aggregate demand generates an increase in market concentration, which is larger and more persistent when market selection is more imperfect. In its turn, the observed increase in market concentration is explained by the fact that smaller firms are the ones to take most of the fall when aggregate demand sharply decreases, as it is shown in Figure 6.

It follows that, due to increasing concentration, larger firms are able to revise their mark up upwards and this generates a "profit-push" inflation which amounts cumulatively to 1 percentage point, accompanied by a follow-up of smaller price increases due to the wage indexation mechanism. See Figure 7), which shows the dynamics of the components of firm-level price adjustments in the aftermath of the shock for the scenario where market selection is the most imperfect. Therefore in this scenario money wage growth does not constitute the cause of price hikes, but rather its consequence, in line with the empirical evidence documented in Bluedorn et al. (2022).



(a) Output

(b) Inflation rate

Figure 4. : Impact of a negative demand shock on aggregate output (left panel) and inflation (right panel) in different market selection regimes. Time is measured in quarters (12 periods). Higher values of ϱ^{GM} and γ^{GM} imply a less imperfect market selection process.

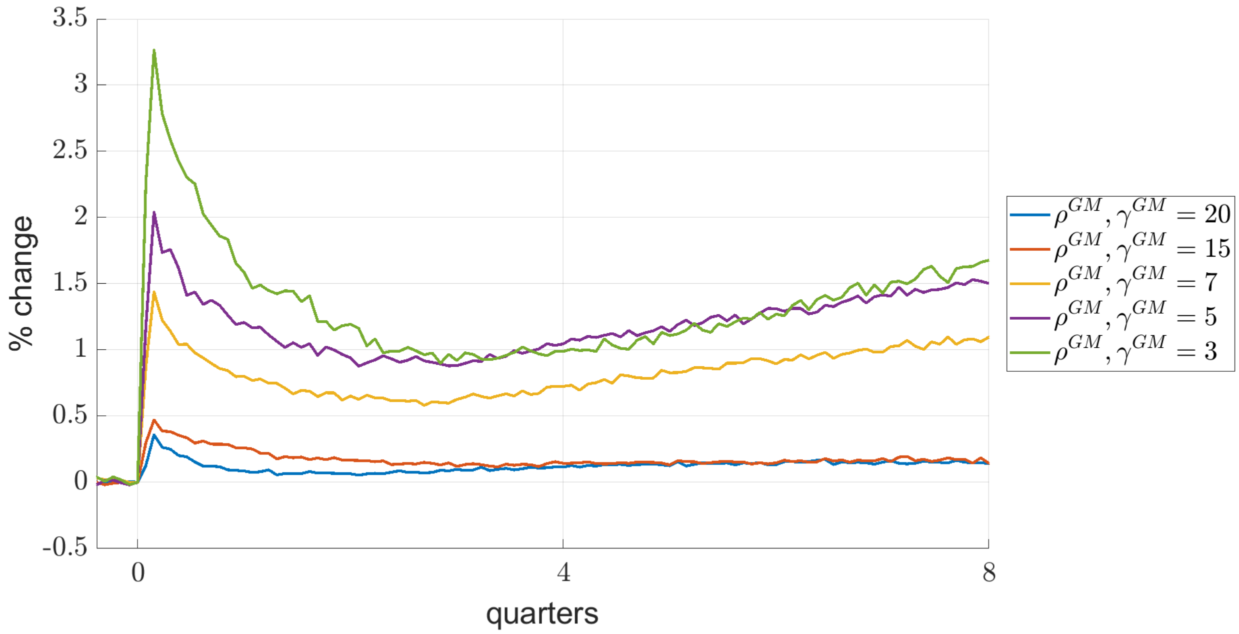


Figure 5. : Impact of the demand shock on market structure under different selection regimes. Time is measured in quarters (12 periods). Higher values of ϱ^{GM} and γ^{GM} imply a less imperfect market selection process.

A Productivity Shock. — We next consider a scenario where the economy is hit by a homogeneous adverse shock to firm productivity ($a_{f,t}$) of an initial magnitude of 2%. The shock is again modeled as an $AR(1)$ process with parameter $\phi = 0.95$. Figures 4a and 8b show the impact on aggregate and output inflation. The shock generates a fall in aggregate output and an increase in inflation in all market selection regimes we consider. Moreover, contrary to the demand shock, the productivity shock doesn't seem to lead to increases in concentration or any important changes in market structure (Figure 9) or to clear shifts in the distribution of income between wages and profits (see Figure 10). Finally, when we look at the composition of the inflationary response (Figure 11), we observe that the totality of the increase in unit costs (2%) is passed over immediately to the customers. This means that following the productivity shock, firms are able to safeguard integrally their profit margins but not expand them, since the market structure is unaffected by the shock. As in the demand-shock scenario, price

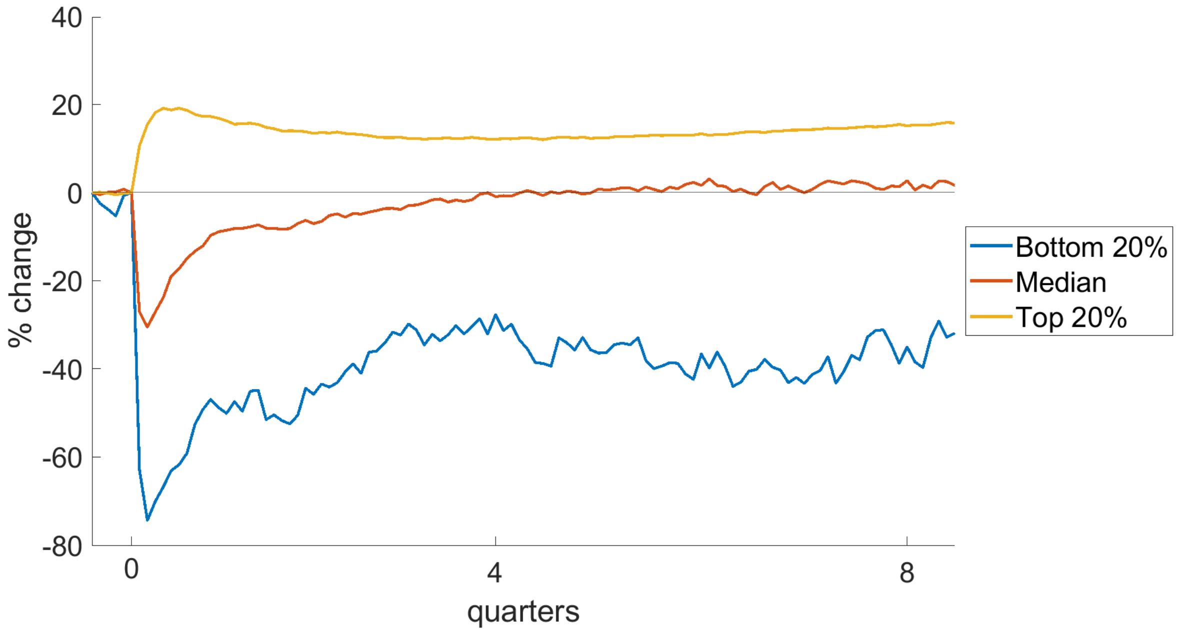


Figure 6. : Firm market share fluctuations after the negative demand shock in the scenario where market selection is the most imperfect ($\varrho^{GM} = \gamma^{GM} = 3$). Time is measured in quarters (12 periods).

hikes trigger the reaction of money wages which contribute to further propagating inflation.

An Energy Price Shock. — For our third shock scenario, we aim to model the sharp increase in energy costs experienced worldwide in 2022. By August of the same year, the Global Energy Price Index had increased by 200 % with respect to 2020 levels (FRED 2023). In order to represent this shock effectively, we extend the model to include, alongside labor, a second production factor (energy). More precisely, we assume a fixed proportion production process in which the firm has to employ $\frac{1}{a_{f,t}}$ units of labor and "energy", such that the unit production cost for the firm is now:

$$C^{*}_{f,t} = \frac{W_{f,t} + k_{f,t}}{a_{f,t}} \tag{27}$$

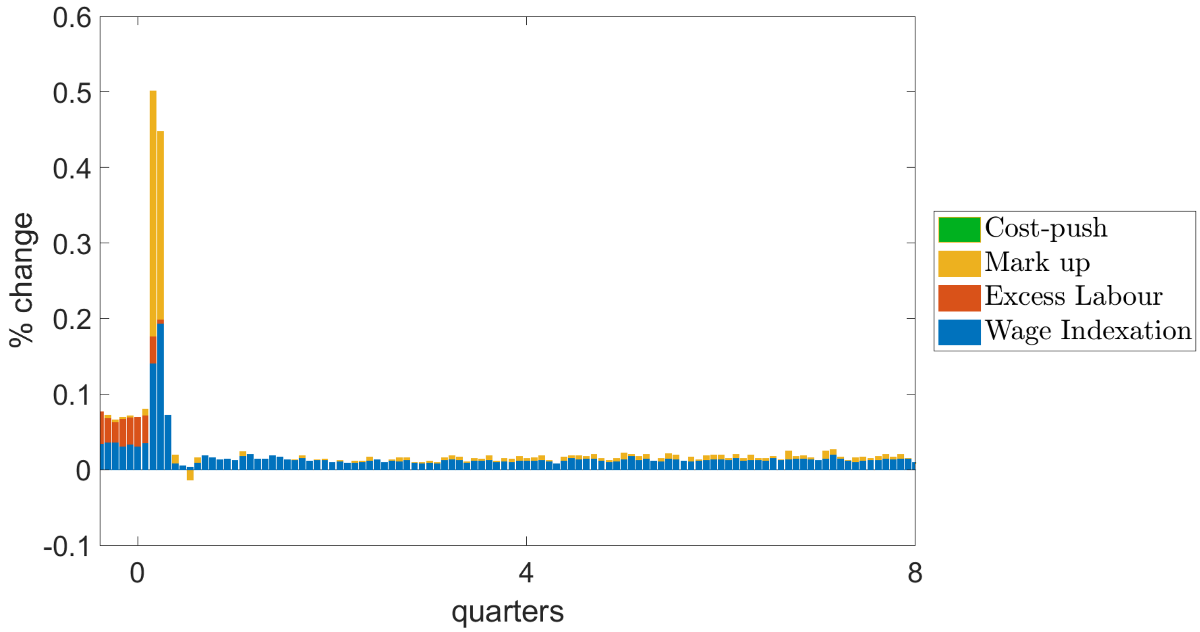


Figure 7. : The components of firm-level price growth after a negative demand shock in the scenario where market selection is the most imperfect ($\varrho^{GM} = \gamma^{GM} = 3$). Time is measured in quarters (12 periods)

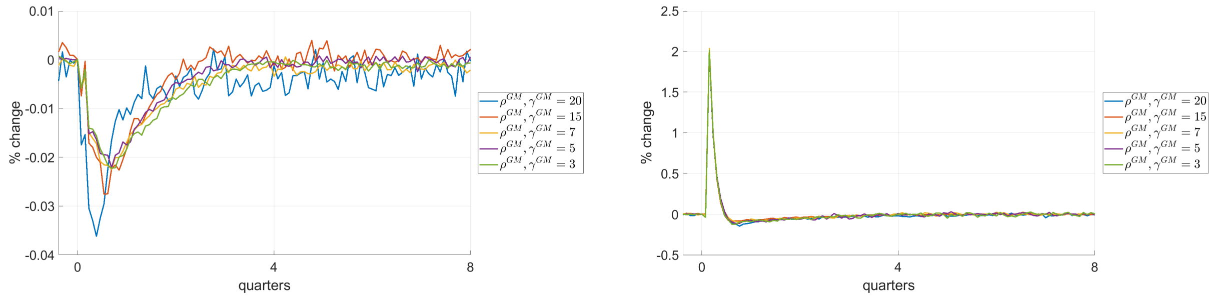
Where $k_{f,t}$ denotes the price of the energy input. The new price equation becomes:

$$P^*_{f,t} = \frac{W_{f,t} + k_{f,t}}{a_{f,t}}(1 + \mu_{f,t}) \tag{28}$$

We set the cost of energy $k_{f,t}$ to be 5 % of the labor cost before the shock, and to reach 15 % of labor costs after. The shock is again modeled as an $AR(1)$ process with parameter $\phi = 0.95$.

Just like the labor productivity shock, an increase in the price of energy generates a fall in output and an inflation hike, regardless of the market selection regime we consider. In addition, no large changes in market concentration (Figure 13) and in mark up rates (Figure 14) are observed in this shock scenario.

However, differently from the labor productivity shock, the sharp increase in



(a) Output

(b) Inflation rate

Figure 8. : Impact of a productivity shock on aggregate output (left panel) and inflation (right panel) in different market selection regimes. Time is measured in quarters (12 periods). Higher values of ϱ^{GM} and γ^{GM} imply a less imperfect market selection process.

energy costs significantly affects the income distribution by driving the wage share down (Figure 15) and the profit share up. Notice that the above fall in the wage share is not driven by profit margin increases but by the larger role of the energy cost which is passed on prices and thus results in a lower real income for workers.

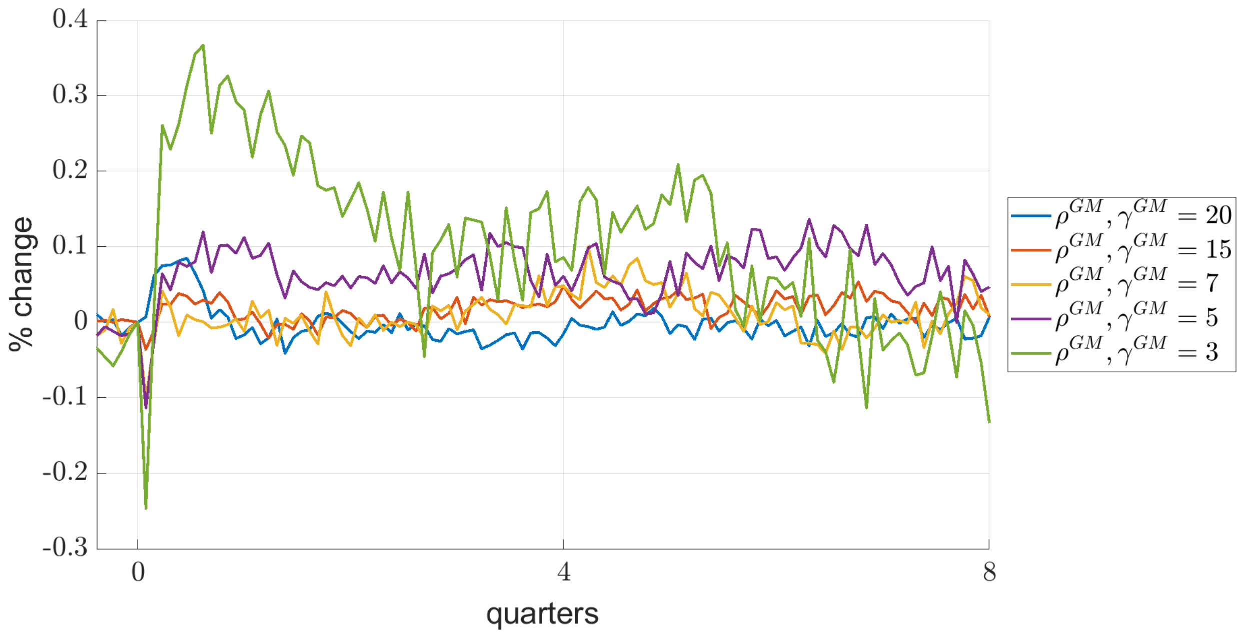


Figure 9. : Impact of a productivity shock on market structure under different market selection regimes. Time is measured in quarters (12 periods). Higher values of ϱ^{GM} and γ^{GM} imply a less imperfect market selection process.

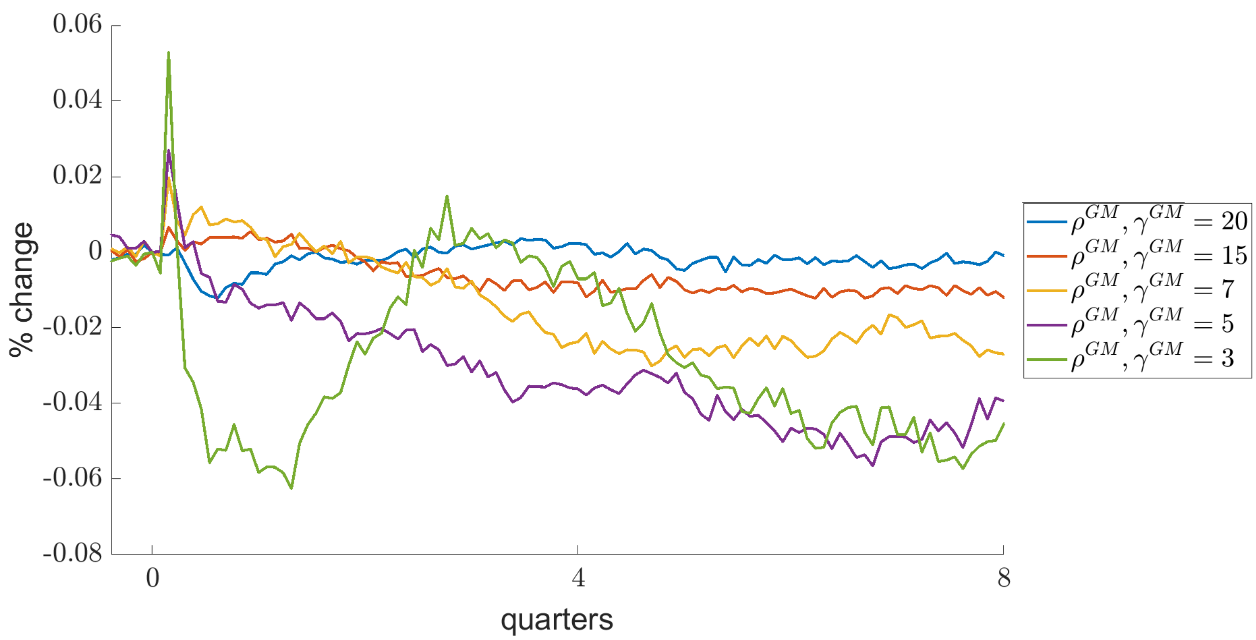


Figure 10. : Impact of the labor productivity shock on the wage share under different selection regimes. Time is measured in quarters (12 periods). Higher values of ϱ^{GM} and γ^{GM} imply a less imperfect market selection process.

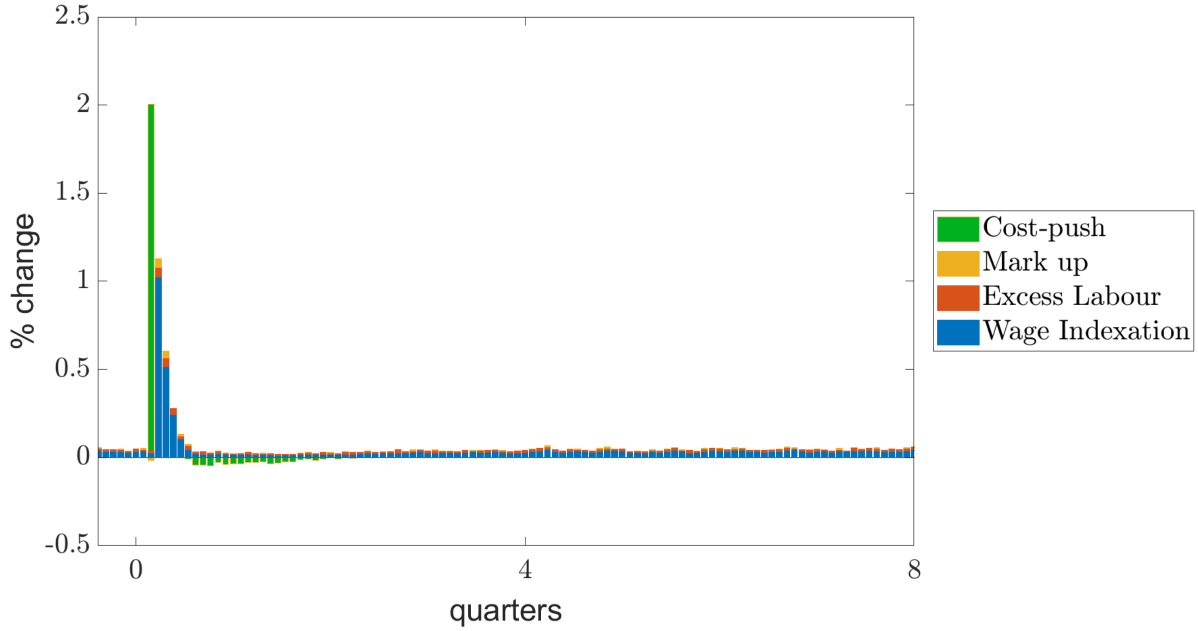
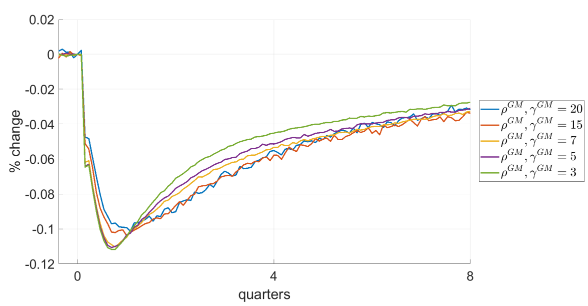
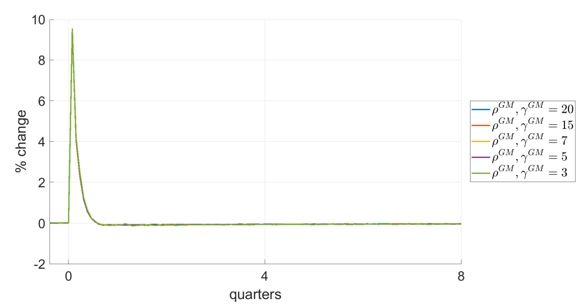


Figure 11. : The components of firm-level price growth after a negative supply shock in the scenario where market selection is the most imperfect ($\varrho^{GM} = \gamma^{GM} = 3$). Time is measured in quarters (12 periods).



(a) Output



(b) Inflation rate

Figure 12. : Impact of an adverse energy shock on aggregate output (left panel) and inflation (right panel) in different market selection regimes. Time is measured in quarters (12 periods). Higher values of ϱ^{GM} and γ^{GM} imply a less imperfect market selection process.

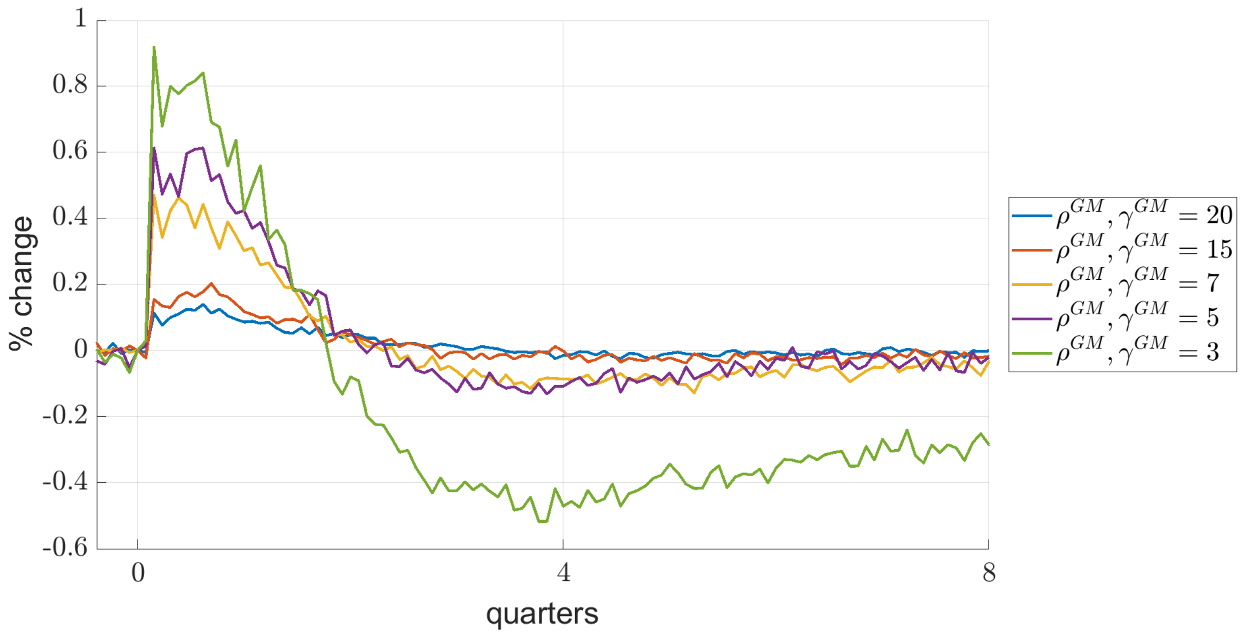


Figure 13. : Impact of the energy shock on market structure in different market selection regimes. Time is measured in quarters (12 periods). Higher ρ, γ mean stronger selection.

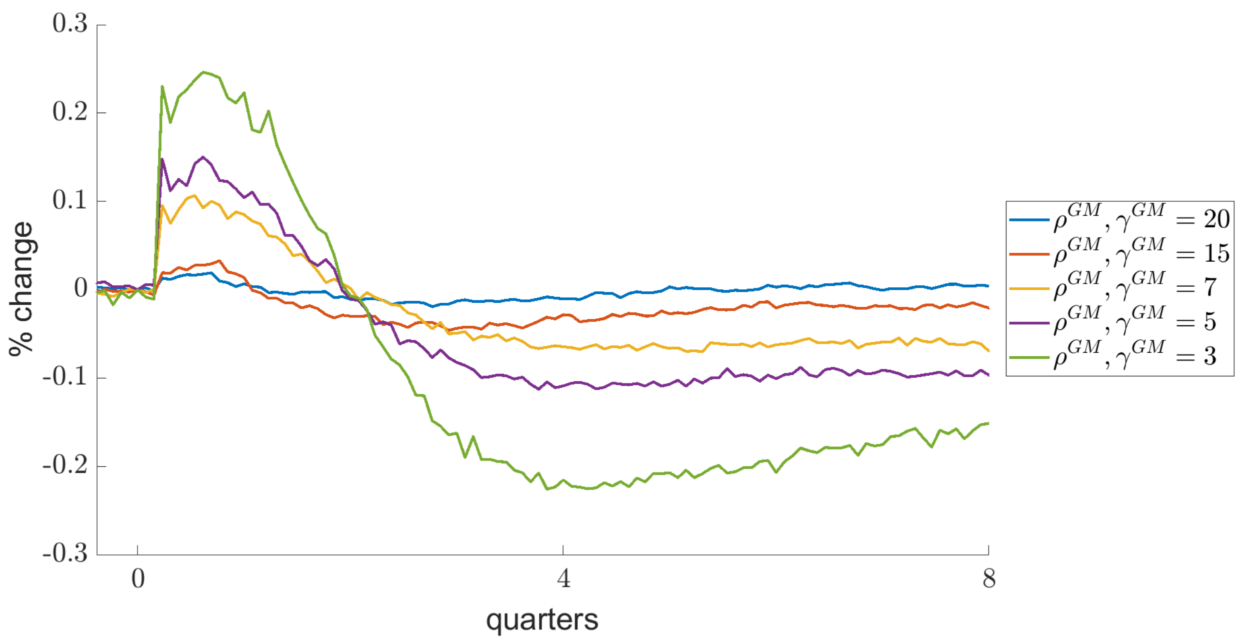


Figure 14. : Impact of the energy shock on average markup under different selection regimes. Time is measured in quarters (12 periods). Higher values of ϱ^{GM} and γ^{GM} imply a less imperfect market selection process.

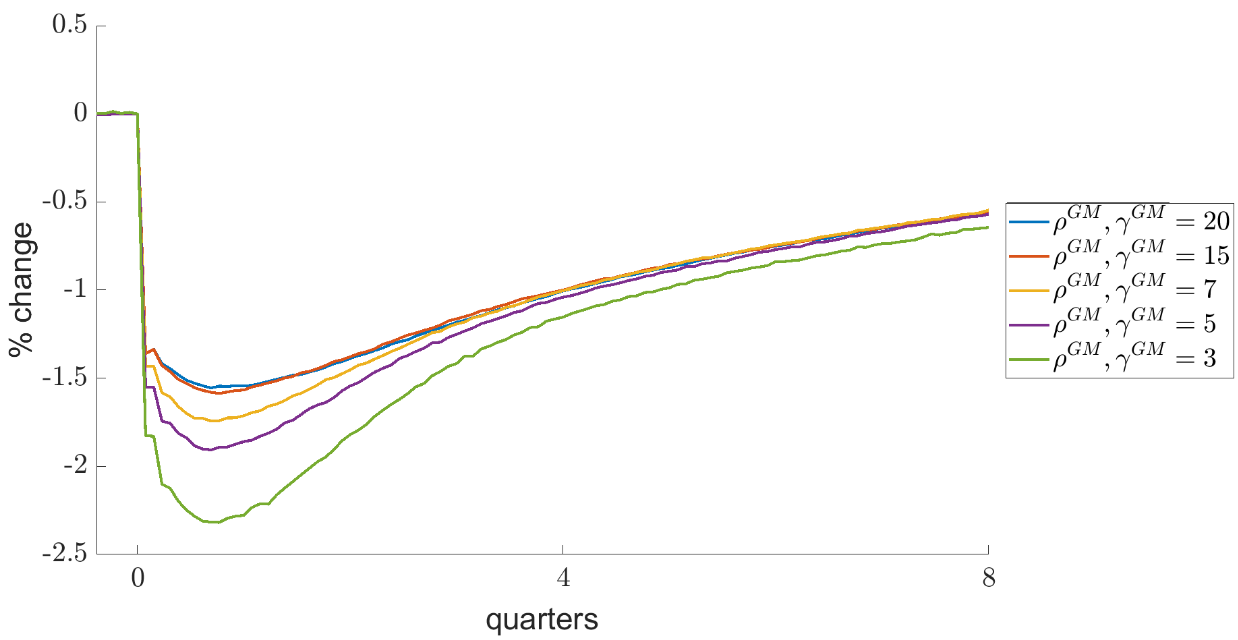


Figure 15. : Impact of the energy shock on the wage share in different market selection regimes. Time is measured in quarters (12 periods). Higher ρ, γ mean stronger selection.

IV. Conclusions

We have developed an Agent-Based Model to explain how the characteristics of market selection in the market for goods can determine the nature of price inflation. In particular, we have introduced the possibility that the probability of matching between firms and customers in the market for goods is influenced by price differences across firms *and* by their size. The dependence of the above probability on firm size introduces success-breeds-success dynamics in the market share allocation process in favor of large firms. Moreover, it implies imperfect selection in the market for goods, as the competition among firms does not just depend on prices and, in particular, firms with lower prices do not necessarily get higher rewards in terms of higher market share.

By using Monte Carlo simulations we have shown that the model generates inflation as an excess demand phenomenon only in the scenarios where selection is the least imperfect and competition among firms is entirely driven by price differences among firms. In contrast, when firm size matters for market share allocation, inflation arises independently from excess demand, and it is driven by changes in mark up rates by dominant firms in a heavily concentrated market.

Furthermore, we have employed the model to analyze the dynamics of the economy hit by different types of adverse shocks, like an adverse shock to demand, an adverse supply shock to labor productivity, and a rise in the price of energy. Our results show that aggregate shocks have the capacity to induce "profit-push" inflation, particularly when they exert an influence on market structure.

We have intentionally left out from the analysis some potentially relevant aspects. In particular, we don't consider explicitly sticky prices and infrequent price and wage adjustments, which may play a role in determining short-run economic fluctuations as well as in determining the inflation rate. These limitations can be addressed in future work. A second avenue for further research is a structured discussion on the policy implications of these findings. Reacting to sellers' inflation by inducing a recession, using tools meant for tackling excess demand, can worsen the underlying conditions that led to the inflation in the first place. Therefore, addressing inflation requires additional policy tools that tackle the problem by understanding its multifaceted origins, and not solely relying on measures like raising interest rates or implementing fiscal austerity to reduce aggregate demand.

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