Sectoral Heterogeneity and the Inflationary Effects of Productivity Shocks*

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Abstract

This paper argues that the response of aggregate inflation to sectoral productivity crucially depends on the origin of the shock. Contrary to conventional wisdom, expansionary productivity shocks may *raise* aggregate inflation when they originate in sectors with a sufficiently high degree of price rigidity. A quantitative production-network economy implies a positive comovement between the responses of aggregate inflation and aggregate output to sectoral productivity when the shock originates in 11 (out of 57) industries. We empirically validate the relationship between sectoral heterogeneity and the response of aggregate inflation to productivity shocks within a panel of manufacturing industries.

Key Words: Sectoral Heterogeneity, Production Network, Sectoral TFP Shocks.

JEL Classification Codes: E31, E32, E52.

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1 Introduction

Productivity shocks can hit specific industries or groups of industries of the economy. For instance, shortages in semiconductors have led to production interruptions along the supply chain like the automotive sector in 2021.[1] This feature of productivity shocks, however, is disregarded by theoretical studies that focus on one-sector models, and which imply a negative comovement of inflation and output. We argue that sectoral heterogeneity and input-output linkages can affect the propagation of sectoral productivity shocks into aggregate inflation and output such that the aggregate response depends on the sector in which the shock originates.

In this paper, we investigate the effects of sectoral productivity shocks through the lens of a multi-sector New Keynesian model with production networks. We study an economy with 57 sectors and calibrate it based on the summary level Input-Output matrix of the U.S. economy, which corresponds to the three-digit level of the NAICS classification codes. We allow for sectoral heterogeneity in the degrees of nominal price rigidity, factor intensities, contribution to consumption and investment, and input-output linkages. Despite the complexity of the model, the standard one-sector New Keynesian model (Woodford, 2003; Gali, 2015) is a limiting case.

Our first contribution is to show how sectoral heterogeneity and input-output linkages influence the aggregate effects of productivity shocks compared to a one-sector economy. We find that the two-year cumulative output response displays large dispersion and may be larger than the one-sector response depending on the sectoral origin of the productivity shock. The cumulative response is always expansionary but ranges from 0.1 to 3.5 times the relative response in a one-sector model, depending on the sector in which the shock originates. To investigate the mecha-

[1]Other examples include: i) the Covid-19 shock and policies to mitigate its spread have features of sectoral supply shocks as stay-at-home orders and the availability of smart working opportunities differed across industries; or ii) a shortage in shipping containers has lead to a surge in container-shipping costs from November 2020 to mid-2021.

nism underlying this result, we study counterfactual economies in which we consider only one source of heterogeneity at a time. Consistent with theories on granularity (Gabaix, 2011), we find that shocks to relatively larger sectors create relatively larger fluctuations of aggregate output. In the present case, this corresponds to sectors with larger contributions to consumption and investment.

Our second contribution is to document that the substantial dispersion in the effects of sector-specific productivity shocks is not limited to output, but also extends to inflation, and the sign of the response. The two-year cumulative inflation response is positive when the productivity shock originates in 11 out of 57 sectors. This result implies that the response of aggregate variables to a sectoral productivity shock looks like the effects of an aggregate demand shock.

We then aim to identify which factors are responsible for the heterogeneity in the response of aggregate variables and the comovement of inflation and output in some sectors. First, we document that aggregate variables respond stronger to shocks in sectors that are relatively more upstream. This is consistent with the network origins of business cycles (Acemoglu et al., 2012), which argues that expansionary supply shocks propagate downstream by triggering a cascading effect in upstream sectors. Second, we show that variations in the degree of labor intensity do not play a relevant role in the transmission of sectoral productivity shocks. This is in contrast to the literature that has highlighted that labor intensity is an important driver for the sectoral origins of demand shocks (Baqaee 2015; Baqaee and Farhi, 2019b; Bouakez et al. 2021).

In addition to these dimensions, we document that a sector's degree of nominal price rigidity is a key determinant for the sign and size of the aggregate effects of sectoral productivity disturbances. The aggregate output response is always positive and tends to be smaller when the shock originates in sectors with a relatively higher degree of nominal price rigidity. This is in line with the exposition in Pasten et al. (2021), in which a small degree of nominal price rigidity increases the effective size of a sector and, hence, a shock originating in that sector generates larger volatility for prices and inflation. The striking and novel result of our paper is that expansionary productivity shocks may be inflationary when they originate in a sector with a sufficiently high degree of nominal price rigidity. We highlight that what drives this positive response of aggregate inflation is not the average level of price rigidity in the economy but the amount of heterogeneity – in the form of dispersion – in the degree of price rigidity across sectors.

We then provide empirical evidence in support of the relationship between the degree of nominal price rigidity and the response of inflation to sectoral productivity shocks. To do so, we rely on data from the NBER-CES Manufacturing database as well as available estimates of sectoral price rigidity. In a panel regression on sectoral productivity shocks, we find that moving from the 25th percentile of the distribution of sectoral price rigidity to the 75th percentile raises the response of aggregate inflation by the equivalent of 15% of its standard deviation. Moreover, the response turns inflationary when a shock originates in a sector at the 75th percentile of the price rigidity distribution. The results stand for a battery of robustness checks.

In sum, our findings highlight that the size and sign of the aggregate response depend on the sectoral origin of the productivity shock. This result poses a challenge for empirical research on supply and demand shocks, as the identification of supply shocks relies on the negative comovement of inflation and output. In fact, we show that the elasticity of the response of aggregate inflation with respect to the response of aggregate output is either positive or close to zero for half of the sectors, limiting the informativeness of the sign of aggregate responses for the identification of supply shocks. A second important finding is that our model predicts that the relationship between the response of inflation to sectoral productivity crucially depends on the stance of monetary policy. In a counterfactual economy in which the monetary authority reacts more strongly to inflation, inflationary responses to sectoral productivity shocks roughly double.[2]

This paper relates to the literature that studies the effects of productivity shocks (Basu et al., 2006). This strand of the literature has usually focused on aggregate productivity shocks with the notable exception of Acemoglu et al. (2015), who investigate the transmission of sectoral productivity shocks through the Input-Output matrix. We build on and extend their work by showing that productivity shocks can propagate up- and downstream in a multi-sector New Keynesian model. Our paper also differs from theirs in that we document dispersion in the aggregate responses of inflation and output depending on the sectoral origin of the productivity shock.

A recent strand of the literature argues that supply shocks can have aggregate demand spillovers and vice versa. Those spillover effects can either originate from complementarities in consumption (e.g. Guerrieri et al., 2021) or complementarities from the production network (e.g. Baqaee and Farhi, 2021). In this paper, we add a novel channel through which supply shocks can look like demand-driven variations, which is the occurrence of sectoral productivity shocks in industries with a sufficiently high degree of price rigidity.

Our paper also relates to the literature on sectoral heterogeneity, production networks, and nominal price rigidities. First, it is connected to the literature that emphasizes the role of sectoral heterogeneity in nominal price rigidities for the non-neutrality of money (Pasten et al., 2020) or in the propagation of government spending shocks (Bouakez et al., 2021, 2022). Second, there is also a strand of the literature that evaluates how secular changes in the Input-Output matrix alter the slope of the Phillips curve (Galesi and Rachedi, 2019; Höynck, 2020; Rubbo, 2020). In this paper, we study the implications of sectoral productivity shocks on aggregate inflation in an environment in which the structural parameters, including those describing the production network connecting all sectors, are constant.

[2]In this context, we, therefore, plan to study the implications of different types of monetary policy rules, and the implications of a multi-sector model on the paradox of toil at the zero lower bound (Eggertssson, 2010; Eggertson et al., 2014; Wieland, 2019).

The closest paper to ours is Pasten et al. (2021), in which the authors study the conditions under which sectoral shocks matter for aggregate volatility. The authors argue in line with our study that heterogeneity in price rigidity matters for the dispersion in aggregate responses. We extend and deviate from their analysis by showing the importance of different heterogeneities for the sign of the inflation response to sectoral productivity shocks in a more general multi-sector economy.

The rest of this paper is organized as follows. Section 2 outlines the model. Section 3 investigates the propagation of sectoral productivity shocks, first by documenting the dispersion in aggregate responses in size and sign, then by examining the sources of the dispersion, focusing on the role of heterogeneity in price rigidity and the production network. The section begins with a discussion of the calibration. Section 4 outlines our empirical approach to provide evidence for the main mechanism in the paper. Section 5 concludes.

2 Model

We consider a cashless Calvo (1983) staggered price New Keynesian model with physical capital and multiple inter-connected industries. Specifically, the economy features a representative household, a monetary authority, and firms distributed over S sectors. To account for the large heterogeneity across production industries, we allow sectors to differ in terms of their (i) contribution to aggregate consumption, (ii) contribution to aggregate investment, (iii) contribution to the Input-Output matrix, (iv) factor intensities, and (v) the degree of nominal price rigidity. Finally, the only source of exogenous variation is given by the sectoral productivity shocks.

2.1 Households

The economy is populated by a representative household with preferences over consumption, C_t, and labor, N_t, such that its life-time utility equals

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \theta \frac{N_t^{1+\eta}}{1+\eta} \right\}, \tag{1}$$

where β is the time discount parameter, σ is the degree of risk aversion, η is the inverse of the Frisch elasticity of labor supply, and θ is a labor disutility shifter.

The household maximizes its lifetime utility (1) subject to the budget constraint

$$P_{C,t}C_t + P_{I,t}I_t + B_{t+1} = W_tN_t + R_{K,t}K_t + R_tB_t + D_t. \tag{2}$$

In each period the household purchases consumption goods at the price $P_{C,t}$ and investment goods, I_t, at the price $P_{I,t}$. The household also invests in one-period bonds, B_{t+1}, which are in zero net-supply, and yield the nominal interest rate, R_t. In addition, the household earns a nominal labor income, W_tN_t, – where W_t denotes the nominal aggregate wage rate – a nominal capital income, $R_{K,t}K_t$, – where $R_{K,t}$ is the nominal aggregate rental rate of capital, and K_t denotes the stock of physical capital – and receives firms' aggregate profits, D_t.

The accumulation of physical capital is subject to investment adjustment costs as in Christiano et al. (2005). Specifically, the law of motion of capital equals

$$K_{t+1} = (1-\delta) K_t + I_t \left[1 - \Omega \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right], \tag{3}$$

where δ denotes the depreciation rate and Ω captures the magnitude of the adjustment costs.

To account for the imperfect reallocation of labor across sectors at the business cycle frequency (Davis and Haltiwanger, 2001; Lee and Wolpin, 2006), we follow

Horvath (2000) and posit that aggregate labor is a CES aggregator of sectoral labor flows, that is

$$N_t = \left[\sum_{s=1}^{S} \omega_{N,s}^{-\frac{1}{\nu_N}} N_{s,t}^{\frac{1+\nu_N}{\nu_N}} \right]^{\frac{\nu_N}{1+\nu_N}}, \tag{4}$$

where $N_{s,t}$ denotes the labor supplied to sector s firms, $\omega_{N,s}$ are sectoral labor weights, and ν_N is the elasticity of substitution of labor across sectors. The aggregator (4) implies that the household's supply of labor to sector s equals

$$N_{s,t} = \omega_{N,s} \left(\frac{W_{s,t}}{W_t} \right)^{\nu_N} N_t, \qquad s = 1, \ldots, S, \tag{5}$$

where $W_{s,t}$ is the nominal sectoral wage rate. In this setting, the elasticity ν_N captures in a parsimonious way the degree of labor mobility across sectors. As long as $\nu_N < \infty$, then labor cannot move freely across sectors, and the wage rate differs across sectors, consistently with the evidence in Krueger and Summers (1988) and Gibbons and Katz (1992).[3] Equations (4) and (5) imply that the aggregate wage rate depends on the sectoral wage rates as follows:

$$W_t = \left[\sum_{s=1}^{S} \omega_{N,s} W_{s,t}^{1+\nu_N} \right]^{\frac{1}{1+\nu_N}}. \tag{6}$$

Analogously, we capture the sluggish reallocation of physical capital across sectors by positing that aggregate capital is a CES aggregator of sectoral capital services, that is

$$K_t = \left[\sum_{s=1}^{S} \omega_{K,s}^{-\frac{1}{\nu_K}} K_{s,t}^{\frac{1+\nu_K}{\nu_K}} \right]^{\frac{\nu_K}{1+\nu_K}}, \tag{7}$$

where $K_{s,t}$ denotes the capital services supplied to sector s firms, $\omega_{K,s}$ are sectoral capital weights, and ν_K is the elasticity of substitution of capital across sectors. The

[3] Katayama and Kim (2018) show that imperfect labor mobility provides a better accounting of the comovement between hours worked and output than alternative theories based on labor-supply wealth effects.

household's supply of capital services to sector s equals

$$K_{s,t} = \omega_{K,s} \left(\frac{R_{K,s,t}}{R_{K,t}} \right)^{\nu_K} K_t, \qquad s = 1, \ldots, S, \tag{8}$$

where $R_{K,s,t}$ is the nominal sectoral rental rate of capital. Also in this case the elasticity ν_K determines the degree of sectoral capital mobility: when $\nu_K < \infty$ then capital cannot freely move across sectors, and there exist differentials in the rental rate of capital across sectors.[4] In this case, the aggregate rental rate of capital equals

$$R_{K,t} = \left[\sum_{s=1}^{S} \omega_{K,s} R_{K,s,t}^{1+\nu_K} \right]^{\frac{1}{1+\nu_K}}. \tag{9}$$

2.2 Firms

As in any New Keynesian model, the production structure is split into two levels: there is a continuum of monopolistically competitive producers and a representative perfectly competitive wholesaler in each sector. The producers assemble different varieties of the sectoral good using labor, capital, and intermediate-inputs, and set prices subject to a Calvo-type pricing protocol. The producers then sell their different varieties to the wholesaler, who combines them into a final sectoral-good bundle.

In addition, the production sector also consists of a representative consumption-good retailer, a representative investment-good retailer, and – for each sector – a representative intermediate-input retailer. These retailers are devised to map the contribution of each sector to aggregate consumption, aggregate investment, and the intermediate inputs used by all the other industries of the economy.

[4]Miranda-Pinto and Young (2019) document that imperfect capital mobility provides a similar fit of the volatility and comovement of both aggregate and sectoral output to economies featuring sector-specific capital.

2.2.1 Producers

In sector s, there is unit measure of monopolistically competitive producers, indexed by $i \in [0, 1]$, that assemble different varieties of sectoral gross output, $X^i_{s,t}$, using the Cobb-Douglas technology[5]

$$X^i_{s,t} = Z_{s,t} \left({N^i_{s,t}}^{\alpha_{N,s}} {K^i_{s,t}}^{1-\alpha_{N,s}} \right)^{1-\alpha_{H,s}} {H^i_{s,t}}^{\alpha_{H,s}} \tag{10}$$

where $Z_{s,t}$ is the level of the Hicks-neutral productivity of all producers in sector s, and $N^i_{s,t}$, $K^i_{s,t}$, and $H^i_{s,t}$ denote the labor, physical capital, and bundle of intermediate inputs used by producer i in sector s, respectively. The parameters $\alpha_{N,s}$ and $\alpha_{H,s}$ denote the share of labor in value added and the share of intermediate inputs in gross output, respectively. Importantly, factor intensities are constant across producers within a sector, but differ across sectors.

We posit that the logarithm of the sectoral productivity, $Z_{s,t}$, follows a first-order autoregressive process, such that

$$\log Z_{s,t} = \rho \log Z_{s,t-1} + u_{s,t}, \tag{11}$$

where ρ measures the persistence of the process, and the sectoral productivity shock, $u_{s,t}$, is a zero-mean normally distributed innovation.

Producers then set their price, $P^i_{s,t}$, subject to a Calvo-type pricing protocol. Specifically, in each period producers can update their price with a probability $1-\phi_s$, which is constant over time and sector-specific. In this way, we can account for the heterogeneity in nominal price rigidity across sectors. Producers set their optimal reset price, $P^\star_{s,t}$, to maximize their expected discounted stream of real profits, that

[5] The unit elasticity of substitution between value added and intermediate inputs implied by the Cobb-Douglas technology (10) is consistent with the empirical evidence of Atalay (2017).

is

$$P_{s,t}^{\star} = \arg\max_{P_{s,t}^i} \mathbb{E}_t \left[\sum_{j=t}^{\infty} (\beta\phi_s)^{j-t} \left(\frac{C_j}{C_t}\right)^{-\sigma} \frac{D_{s,j}^i \left(P_{s,t}^i\right)}{P_j} \right], \tag{12}$$

where $D_{s,j}^i \left(P_{s,t}^i\right)$ denote producers' nominal profits – conditional on setting their price to $P_{s,t}^i$ – which equal

$$D_{s,t}^i \left(P_{s,t}^i\right) = P_{s,t}^i X_{s,t}^i - W_{s,t} N_{s,t}^i - R_{K,s,t} K_{s,t}^i - P_{H,s,t} H_{s,t}^i \tag{13}$$

where $P_{H,s,t}$ denotes the price of the intermediate-input bundle used in the production by the producers of sector s.

2.2.2 Wholesalers

In each sector, there is a representative wholesaler that purchases the different varieties of the producers, and bundles them into a final sectoral good. Specifically, the wholesaler of sector s assembles the sectoral good with the following technology:

$$X_{s,t} = \left(\int_0^1 {X_{s,t}^i}^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{14}$$

where ϵ denotes the elasticity of substitution across varieties within a sector. As a result, the optimal demand of variety i equals

$$X_{s,t}^i = \left(\frac{P_{s,t}^i}{P_{s,t}}\right)^{-\epsilon} X_{s,t}, \tag{15}$$

which implies that the price of the sector s goods is

$$P_{s,t} = \left(\int_0^1 {P_{s,t}^i}^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}. \tag{16}$$

The wholesaler then sells its gross output to the consumption-good retailers, the investment-good retailers, and the intermediate-input retailers, such that the resource constraint at the sectoral level reads

$$X_{s,t} = C_{s,t} + I_{s,t} + \sum_{x=1}^{S} H_{x,s,t}, \tag{17}$$

where $C_{s,t}$ is the demand of the consumption-good retailers, $I_{s,t}$ is the demand of the investment-good retailers, and $H_{x,s,t}$ is the demand of the intermediate-input retailer of sector x.

2.2.3 Consumption-good Retailers

A representative consumption-good retailer bundles the purchases of consumption goods from each sector, $C_{s,t}$, into the aggregate consumption good using the CES aggregator

$$C_t = \left[\sum_{s=1}^{S} \omega_{C,s}^{\frac{1}{\nu_C}} C_{s,t}^{\frac{\nu_C - 1}{\nu_C}} \right]^{\frac{\nu_C}{\nu_C - 1}}, \tag{18}$$

where $\omega_{C,s}$ is the sectoral consumption weight, and ν_C denotes the elasticity of substitution across sectoral consumption goods. The optimal purchase of consumption goods from sector s then equals

$$C_{s,t} = \omega_{C,s} \left(\frac{P_{s,t}}{P_{C,t}} \right)^{-\nu_C} C_t, \qquad s = 1, \ldots, S. \tag{19}$$

Thus, given prices $P_{s,t}$ and $P_{C,t}$ and the elasticity of substitution ν_C, the parameters $\omega_{C,s}$ determine the contribution of each sector to the aggregate personal consumption expenditures.

Equations (18) and (19) imply that the consumption price index depends on the sectoral prices as follows:

$$P_{C,t} = \left[\sum_{s=1}^{S} \omega_{C,s} P_{s,t}^{1-\nu_C} \right]^{\frac{1}{1-\nu_C}}. \tag{20}$$

2.2.4 Investment-good Retailers

A representative investment-good retailer bundles the purchases of investment goods from each sector, $I_{s,t}$, into the aggregate investment good using the CES aggregator

$$I_t = \left[\sum_{s=1}^{S} \omega_{I,s}^{\frac{1}{\nu_I}} I_{s,t}^{\frac{\nu_I - 1}{\nu_I}} \right]^{\frac{\nu_I}{\nu_I - 1}}, \tag{21}$$

where $\omega_{I,s}$ is the sectoral investment weight, and ν_I denotes the elasticity of substitution across sectoral investment goods. The optimal purchase of investment goods from sector s then equals

$$I_{s,t} = \omega_{I,s} \left(\frac{P_{s,t}}{P_{I,t}} \right)^{-\nu_I} I_t, \qquad s = 1, \ldots, S. \tag{22}$$

In this case, given prices $P_{s,t}$ and $P_{I,t}$ and the elasticity of substitution ν_I, the parameters $\omega_{I,s}$ pin down the contribution of each sector to the aggregate investment expenditures.

Equations (21) and (22) imply that the investment price index depends on the sectoral prices as follows:

$$P_{I,t} = \left[\sum_{s=1}^{S} \omega_{I,s} P_{s,t}^{1-\nu_I} \right]^{\frac{1}{1-\nu_I}}. \tag{23}$$

2.2.5 Intermediate-input Retailers

In each sector, there is a representative intermediate-input retailer that assembles the intermediate inputs used by producers. Specifically, the intermediate-input retailer of sector s produces the bundle of intermediate inputs used exclusively in the production by firms in that sector, $H_{s,t}$ with the following CES aggregator

$$H_{s,t} = \left[\sum_{x=1}^{S} \omega_{H,s,x}^{\frac{1}{\nu_H}} H_{s,x,t}^{\frac{\nu_H - 1}{\nu_H}} \right]^{\frac{\nu_H}{\nu_H - 1}}, \tag{24}$$

where $H_{s,x,t}$ denotes the intermediate inputs supplied by the wholesalers of sector x and used by producers in sector s. The parameter $\omega_{H,s,x}$ is the sectoral weight of intermediate inputs produced by sector x in intermediate inputs used by firms in sector s, and ν_H denotes the elasticity of substitution across sectoral intermediate inputs. The optimal purchase of intermediate inputs supplied by the wholesalers of sector x to the retailer of sector s then equals

$$H_{s,x,t} = \omega_{H,s,x} \left(\frac{P_{x,t}}{P_{H,s,t}} \right)^{-\nu_H} H_{s,t}, \qquad s, x = 1, \dots, S. \tag{25}$$

Given prices $P_{x,t}$ and $P_{H,s,t}$, and the elasticity of substitution ν_H, the parameters $\omega_{H,s,x}$ describe the entire Input-Output matrix of the economy.

Finally, the price of the intermediate-input bundle used by sector s producers is

$$P_{H,s,t} = \left[\sum_{x=1}^{S} \omega_{H,s,x} P_{x,t}^{1-\nu_H} \right]^{\frac{1}{1-\nu_H}}. \tag{26}$$

2.3 Monetary Authority

The economy features a monetary authority that sets the nominal interest rate following a standard Taylor rule that reacts to both the aggregate gross inflation rate computed over the GDP deflator, Π_t, and the aggregate output gap, $\frac{Y_t}{Y_t^{\text{flex}}}$, where Y_t denotes the aggregate value added and Y_t^{flex} is the aggregate value added of a counterfactual economy featuring flexible prices:

$$\frac{R_t}{R^\star} = \left(\frac{R_{t-1}}{R^\star} \right)^{\phi_R} \left(\Pi_t^{\phi_\Pi} \left\{ \frac{Y_t}{Y_t^{\text{flex}}} \right\}^{\phi_Y} \right)^{1-\phi_R}, \tag{27}$$

where $R^\star$ is the value of the interest rate at the steady state, ϕ_R is the degree of interest-rate smoothing, and ϕ_Π and ϕ_Y denote the degrees of accommodation of the nominal interest rate with respect to inflation and the output gap, respectively.

2.4 Aggregation

The nominal value added of producer i of sector s, $\mathcal{Y}^i_{s,t}$, equals the difference between the nominal value of its gross output, and the nominal value of its bundle of intermediate inputs used in production, that is

$$\mathcal{Y}^i_{s,t} = P^i_{s,t} X^i_{s,t} - P_{H,s,t} H^i_{s,t}. \tag{28}$$

Aggregating across producers within each sector yields the formula for the nominal value added at the sectoral level, $\mathcal{Y}_{s,t}$:

$$\mathcal{Y}_{s,t} = \int_0^1 \mathcal{Y}^i_{s,t} di = P_{s,t} X_{s,t} - P_{H,s,t} H_{s,t}. \tag{29}$$

We can then define the nominal aggregate value added, $\mathcal{Y}_t$, by aggregating nominal dividends across producers and sectors, and substitute them out in the households' budget constraint, which gives

$$\mathcal{Y}_t = \sum_{s=1}^{S} \mathcal{Y}_{s,t} = P_{C,t} C_t + P_{I,t} I_t. \tag{30}$$

The real aggregate value added, Y_t, equals the ratio between the nominal aggregate value added and the GDP deflator, P_t,

$$Y_t = \frac{\mathcal{Y}_t}{P_t}. \tag{31}$$

Finally, the labor and capital markets clear, such that

$$N_t = \sum_{s=1}^{S} N_{s,t} = \sum_{s=1}^{S} \int_0^1 N^i_{s,t} di, \tag{32}$$

and

$$K_t = \sum_{s=1}^{S} K_{s,t} = \sum_{s=1}^{S} \int_0^1 K^i_{s,t} di. \tag{33}$$

3 Quantitative Analysis

3.1 Calibration

We discipline the quantitative relevance of the sectoral heterogeneity by disaggregating the economy at a high level of granularity, by assuming that our model consists of $S = 57$ sectors, which correspond to the three-digit level of the North American Industry Classification System (NAICS) classification codes. We report in Appendix A the entire list of sectors, as well as further details on the calibration of the model.

We start by setting the time discount factor to $\beta = 0.995$, to be consistent with a 2% annual real rate. The risk aversion parameter is calibrated to the standard value of $\sigma = 2$, whereas we set $\eta = 1.25$, so that the model features a Frisch elasticity of 0.8, in line with the empirical evidence of Chetty et al. (2013). The labor disutility shifter is set to $\theta = 94.40$ to imply a steady-state value of aggregate labor of $N^\star = 0.33$. To have a 10% annual depreciation rate for physical capital, we set $\delta = 0.025$. We calibrate the adjustment cost parameter to $\Omega = 20$ to match the ratio of the standard deviations of investment and output at the quarterly frequency.

We use information from the Input-Output Tables of the U.S. Bureau of Economic Analysis to calibrate the sectoral factor intensities, the parameters that govern the sectoral heterogeneity in the contribution to consumption and investment, as well as the entries of the Input-Output matrix. As far as the factor intensities are concerned, we set the elasticity of substitution across varieties between sectors to $\epsilon = 4$, to match the 33% average markup that De Loecker et al. (2020) estimate for U.S. firms over the recent decade. Given this markup, we back out the intermediate-input factor intensity, $\alpha_{H,s}$, to match the share of sectoral expenditures in intermediate inputs in gross output, defined as the sum of the sectoral expenditures in intermediate inputs, the compensation of employees, and the gross operating surplus. The labor factor intensity, $\alpha_{H,s}$, is set to match the share of the sectoral compensation of employees in value added, defined as the sum of the sectoral compensation of employees and the gross operating surplus.

We set the elasticity of substitution of consumption across sectors to $\nu_C = 2$, in line with the evidence of Hobijn and Nechio (2019), who estimate the upper-level elasticity of substitution of consumption goods at a business cycle frequency in a similarly high granular level of disaggregation. Analogously, we set the elasticity of substitution of investment across sectors to $\nu_I = 2$. The elasticity of substitution of intermediate inputs across sectors is set to $\nu_H = 0.1$, which is motivated by the empirical evidence of Barrot and Sauvagnat (2016), Atalay (2017), and Boehm et al. (2019) on the very high degree of complementarity across intermediate inputs at the business cycle frequency. Given the elasticities of substitution, we calibrate the sectoral consumption weights, $\omega_{C,s}$, to match the sectoral contributions to personal consumption expenditures, the sectoral investment weights, $\omega_{I,s}$, to match the sectoral contributions to the sum of nonresidential private fixed investment in equipment, intellectual property products, and structures, as well as the sectoral intermediate-input weights, $\omega_{H,s,x}$, to match the Input-Output matrix entries.

With respect to the aggregator of sectoral labor into aggregate labor, we set the elasticity of substitution to $\nu_N = 1$, following the estimate in Horvath (2000). We then calibrate the sectoral labor weights to the ratio between the steady-state value of sectoral labor and the steady-state value of aggregate labor, that is, $\omega_{N,s} = \frac{N_s^\star}{N^\star}$. This choice implies that there is no differential between the sectoral wage rates at the steady state (i.e., labor is fully mobile at the steady state). We calibrate the parameters of the aggregator of sectoral capital services into aggregate capital in an analogous manner: the elasticity of substitution equals $\nu_K = 1$, and the sectoral capital weights are set to $\omega_{K,s} = \frac{K_s^\star}{K^\star}$.

To discipline the extent of the sectoral heterogeneity in the nominal price rigidity, we calibrate the sectoral Calvo probabilities ϕ_s to match the price durations estimated using microdata by Nakamura and Steinsson (2008) and Bouakez et al.

(2014). This approach leads to an average price change frequency of 31.49%, which implies a price duration of around 9 months.

We set the auto-regressive coefficient for the law of motion of sectoral productivity to $\rho = 0.95$, in line with the estimate of an average persistence of the sectoral TFP shocks of around 0.8 at the annual frequency (Horvath, 2000). Finally, we calibrate the Taylor rule parameters following the estimates of Clarida et al. (2000). Specifically, we set the interest-rate smoothing to $\phi_R = 0.8$, and fix the degrees of accommodation of the nominal interest rates with respect to inflation and the output gap to $\phi_\Pi = 1.5$ and $\phi_Y = 0.2$, respectively.

Throughout the paper, we solve the model with a first-order approximation around a zero-inflation steady state.

3.2 Sectoral Heterogeneity and the Aggregate Effects of Sectoral Productivity Shocks

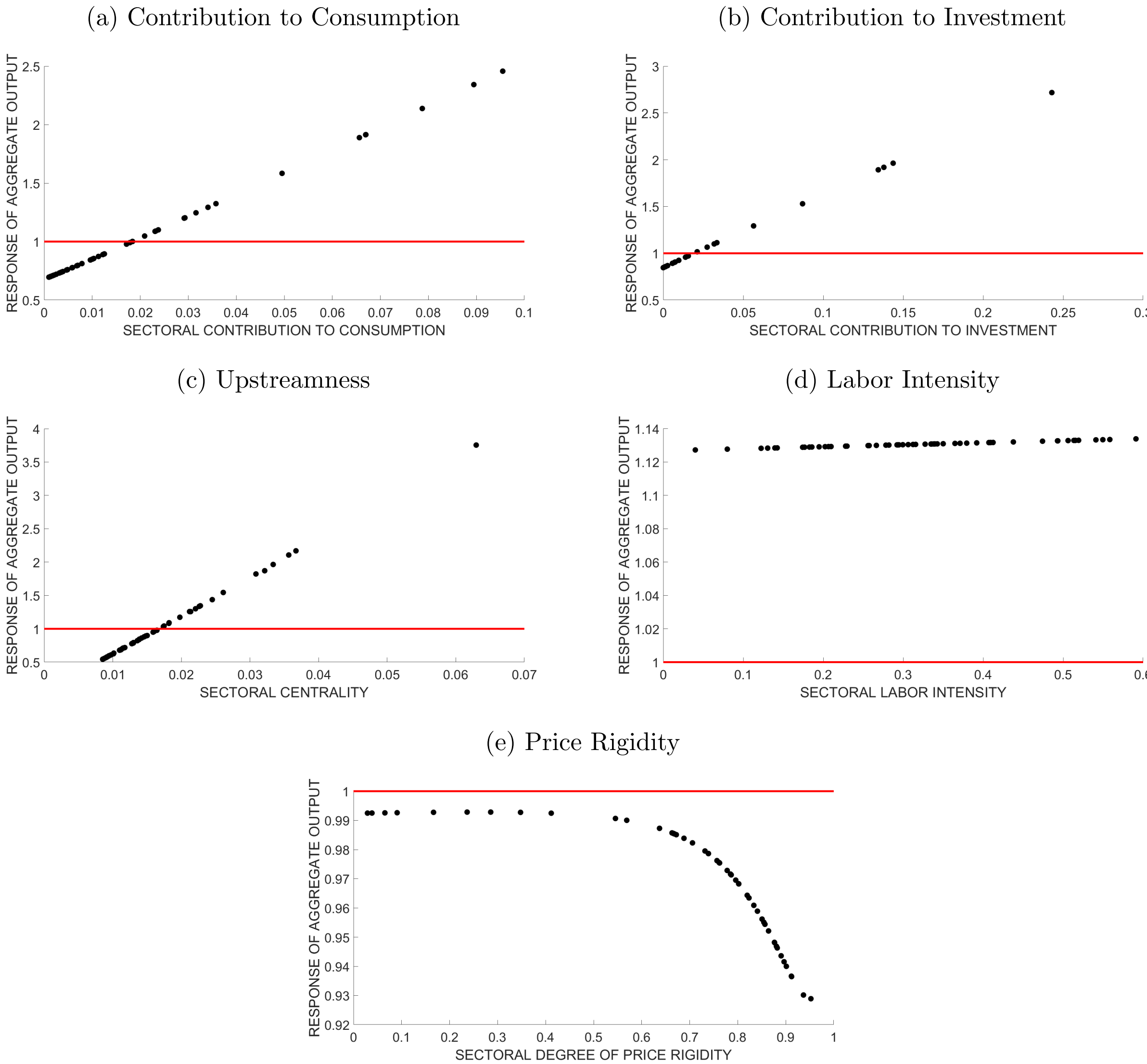
We start by inspecting how the effects of sectoral productivity shocks on aggregate output and aggregate inflation depend on the characteristics of the affected sector. To do so, we run the following exercise: we study the impact response of aggregate output and inflation to each sectoral productivity shock in a sequence of economies, which feature complete symmetry across sectors in all dimensions but one at a time. Specifically, we study five different economies: one with only heterogeneity in the degree of price rigidity (ϕ_s), one with only heterogeneity in the value-added labor intensity ($\alpha_{N,s}$), one with only heterogeneity in the Input-Output matrix ($\omega_{H,s,x}$), one with only heterogeneity in the contribution to consumption ($\omega_{C,s}$), and one with only heterogeneity in the contribution to investment ($\omega_{I,s}$). By comparing the implications of these economies we can isolate the role of each source of sectoral heterogeneity on the aggregate propagation of the sectoral productivity shocks. Table 1 and Table 2 report the results of this exercise for the response of aggregate output and aggregate inflation to each of the 57 sectoral productivity shocks featured by the model, respectively.

Panels (a) and (b) of Figure 1 show that positive sectoral productivity shocks are always expansionary, and the response of aggregate output is relatively larger when the shock originates in sectors with a large contribution to consumption and investment. The same dynamics also apply to the response of aggregate inflation, as depicted in Panels (a) and (b) of Figure 2, with the only difference being that positive sectoral productivity shocks are always deflationary. These results are in line with the granular origin of aggregate fluctuations proposed by Gabaix (2011). Specifically, in an environment with finitely many sectors, then shocks to relatively larger sectors end up triggering relatively larger fluctuations of the aggregate economy. In this case, the size of a sector moves one to one with its contribution to consumption and investment.

However, there is a difference in the implications of the sectoral contributions of consumption and investment to the magnitude of the response of aggregate inflation and output. Figure 3 shows for each sectoral shock the elasticity of the response of aggregate inflation relative to aggregate output, defined as the ratio between the 2-year cumulative response between these two variables. Panel (a) shows that the absolute value of the elasticity decreases with the contribution to consumption, and thus shocks to sectors with larger contributions generate a relatively lower change in aggregate inflation relative to that generated in aggregate output. Instead, the contrary applies for the contribution to investment, as shown in Panel (b), since the absolute value of the elasticity increases with the size of the sector.

Panel (c) of Figure 1 and Figure 2 show that the responses of both aggregate output and inflation are relatively larger in upstream industries, respectively. Although also in this case the positive productivity shocks lead to a surge in aggregate output and a drop in inflation, shocks to sectors that are more central in the Input-Output matrix lead to larger aggregate fluctuations. This result is consistent with

Figure 1: Sectoral Heterogeneity and the Response of Aggregate Output.



Notes: The figure reports the 2-year cumulative response of aggregate output to each of the 57 sectoral productivity shocks featured in the model in five counterfactual economies in which we set one dimension of sectoral heterogeneity at a time, while imposing symmetry in all the other sectoral characteristics. The dimensions we consider are: the consumption weight ($\omega_{C,s}$) in Panel a, the investment weight ($\omega_{I,s}$) in Panel b, the degree of Katz-Bonacich centrality in the Input-Output matrix ($\omega_{H,s,x}$) in Panel c, the labor intensity in the production function ($\alpha_{N,s}$) in Panel d, and the degree of nominal price rigidity (ϕ_s) in Panel e. The continuous red line denotes the response of aggregate inflation in the fully-symmetric model. The productivity shocks are normalized so that the 2-year cumulative response of aggregate output in the fully-symmetric model equals 1%.

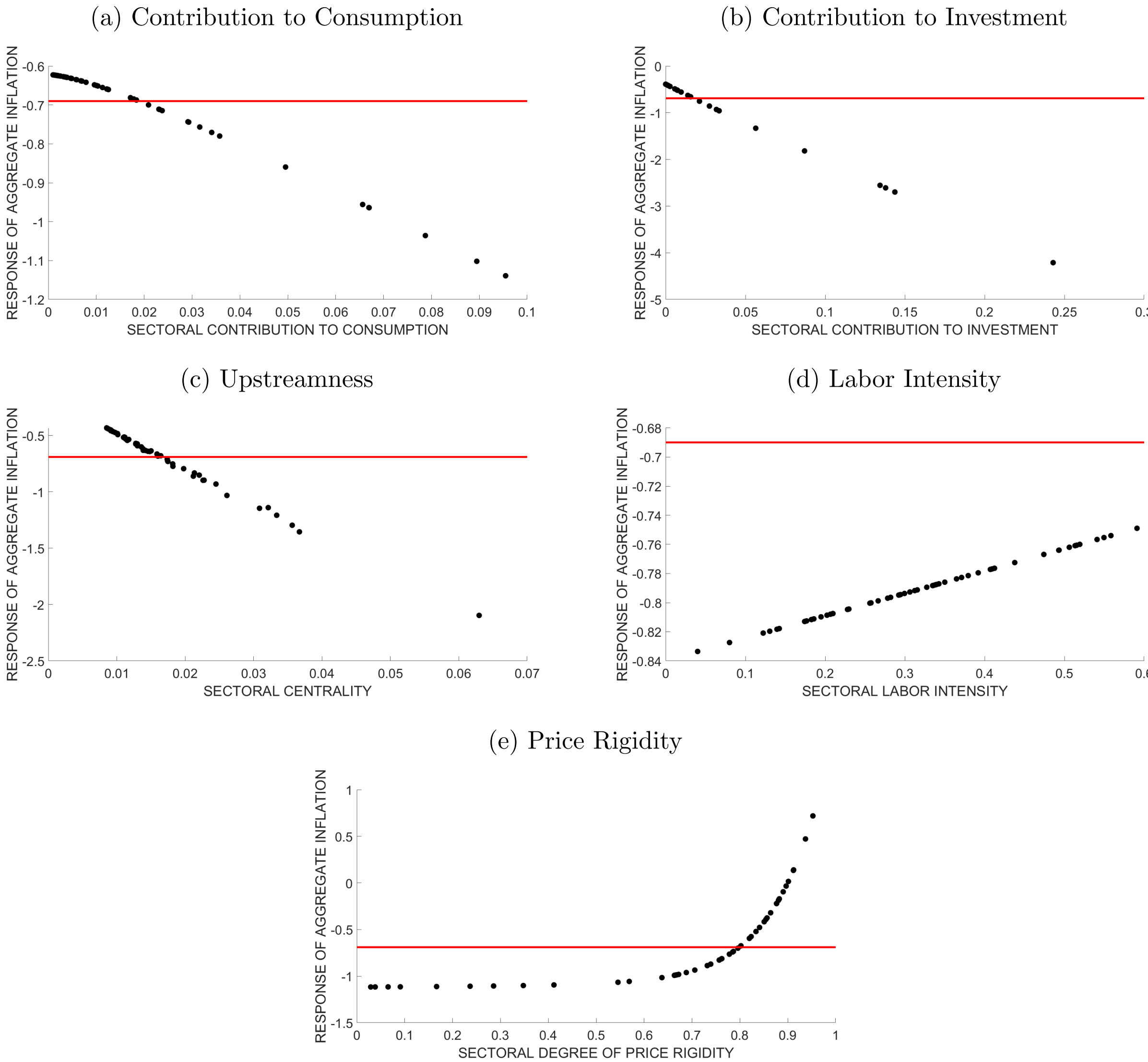
the network origins of business cycles (Acemoglu et al., 2012), which posits that expansionary supply shocks in upstream industries trigger a cascade effect by propagating downstream (Acemoglu et al., 2015) since downstream sectors can upscale exploiting the relatively less expensive intermediate inputs provided by the most central sectors. Interestingly, Panel (c) of Figure 3 shows that the absolute value of the elasticity of the changes in aggregate inflation relative to the changes in aggregate output decreases with the degree of sectors' centrality.

We find that variations in the labor intensity across industries lead to no significant changes in the response of aggregate output and inflation to productivity shocks. This result can be observed by looking at Panel (d) of Figure 1 and Figure 2: neither the response of aggregate output nor that of aggregate inflation displays a strong degree of variation across the different values of the labor intensity. Thus, although the labor intensity has been highlighted as an important determinant for the sectoral origins of demand shocks such as fiscal disturbances (Baqaee 2015; Baqaee and Farhi, 2019b; Bouakez et al., 2021), it does not play a relevant role for the propagation of sectoral productivity shocks.

Finally, Panel (e) of Figure 1 shows that the response of aggregate output is always positive and decreases with the degree of nominal price rigidity. Indeed, Pasten et al. (2021) uncover the key role of the heterogeneity in the nominal price rigidity as a frictional source of business cycle fluctuations: when sectors have the same size, then shocks to relatively more flexible-price industries generate larger volatility for prices and quantities.[6] The striking and novel result of this section is in Panel (e) of Figure 2, which reports how the response of aggregate inflation varies with the degree of price rigidity of the sector hit by the productivity shock. Analogously to the case of output, the response of aggregate inflation is large and

[6] In an environment in which sectors differ in their sizes, then the relevance of the perturbances in one industry for the volatility of the macroeconomy depends on a multiplier which is a function of both the size and the inverse of the degree of price rigidity, such that the effective size of the sector is relatively lower in rigid-price industries.

Figure 2: Sectoral Heterogeneity and the Response of Aggregate Inflation.



Notes: The figure reports the 2-year cumulative response of aggregate inflation to each of the 57 sectoral productivity shocks featured in the model in five counterfactual economies in which we set one dimension of sectoral heterogeneity at a time, while imposing symmetry in all the other sectoral characteristics. The dimensions we consider are: the consumption weight ($\omega_{C,s}$) in Panel a, the investment weight ($\omega_{I,s}$) in Panel b, the degree of Katz-Bonacich centrality in the Input-Output matrix ($\omega_{H,s,x}$) in Panel c, the labor intensity in the production function ($\alpha_{N,s}$) in Panel d, and the degree of nominal price rigidity (ϕ_s) in Panel e. The continuous red line denotes the response of aggregate inflation in the fully-symmetric model. The productivity shocks are normalized so that the 2-year cumulative response of aggregate output in the fully-symmetric model equals 1%.

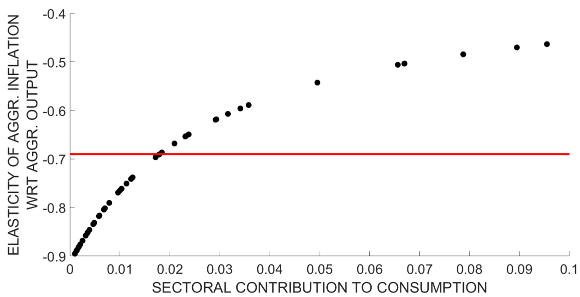
negative when the shock originates in flexible-price industries. As the degree of price rigidity increases, then the response of aggregate inflation becomes relatively less negative. However, the sign of the inflation response turns positive for 5 out of the 57 sectors of the model: in these cases, a positive sectoral productivity shock leads to a surge in both aggregate output and aggregate inflation.

The results on the positive response of inflation to expansionary sectoral productivity shocks – and the implied positive comovement of inflation and output to supply innovations – challenges the conventional wisdom on the effects of demand and supply shifts on quantities and prices. Thus, the sign of the response of aggregate inflation may not be necessarily be a sufficient statistic to disentangle the sources of business cycle fluctuations. This result adds to the narrative of Pasten et al. (2021), by showing that the frictional origins of business cycles hypothesis has also implications on the sign of the comovement of inflation and output. Thus, the frictional hypothesis affects both the magnitude and the sign of aggregate fluctuations.

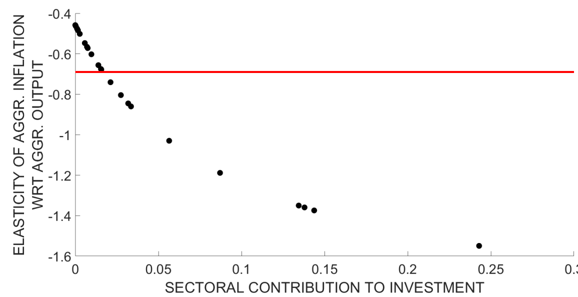
Figure 3 reports the elasticity of the response of aggregate inflation with respect to the response of aggregate output for each of the sectoral productivity shocks of the model, and shows that for half of the sectors the elasticity is either positive or negative but close to zero. Thus, it would be very challenging for an econometrician that attempts to exploits the differences in the sign responses of aggregate output and inflation to disentangle between supply and demand shocks. In our economy, the econometrician would label as demand shocks almost half of the sectoral productivity innovations. From this perspective, the results of our model add to the recent contributions that highlight how supply disturbances can generate demand shortages (Baqaee and Farhi, 2021; Cesa-Bianchi and Ferrero, 2021; Guerrieri et al., 2021). Specifically, we add a novel channel through which supply shocks can look like demand-driven variations, which is the occurrence of sectoral productivity shocks in industries with a sufficiently high degree of price rigidity.

Figure 3: The Elasticity of Aggregate Inflation Relative to Aggregate Output.

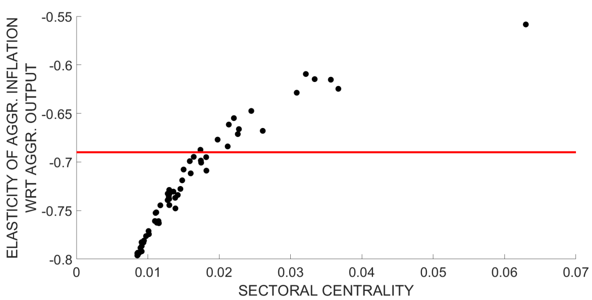
(a) Contribution to Consumption



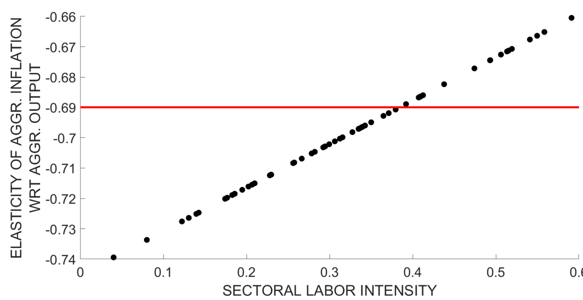
(b) Contribution to Investment



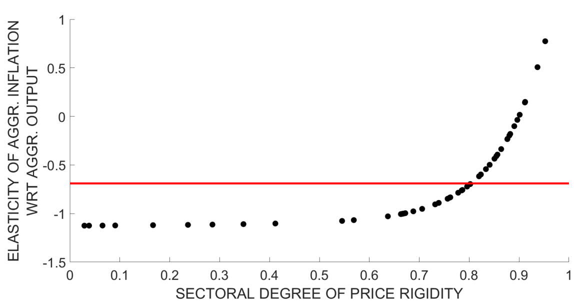
(c) Upstreamness



(d) Labor Intensity



(e) Price Rigidity



Notes: The figure reports the elasticity of aggregate inflation with respect to aggregate output, defined as the ratio between the 2-year cumulative response of aggregate inflation and the 2-year cumulative response of aggregate output to each of the 57 sectoral productivity shocks featured in the model in five counterfactual economies in which we set one dimension of sectoral heterogeneity at a time, while imposing symmetry in all the other sectoral characteristics. The dimensions we consider are: the consumption weight ($\omega_{C,s}$) in Panel a, the investment weight ($\omega_{I,s}$) in Panel b, the degree of Katz-Bonacich centrality in the Input-Output matrix ($\omega_{H,s,x}$) in Panel c, the labor intensity in the production function ($\alpha_{N,s}$) in Panel d, and the degree of nominal price rigidity (ϕ_s) in Panel e. The continuous red line denotes the elasticity in the fully-symmetric model. The productivity shocks are normalized so that the 2-year cumulative response of aggregate output in the fully-symmetric model equals 1%.

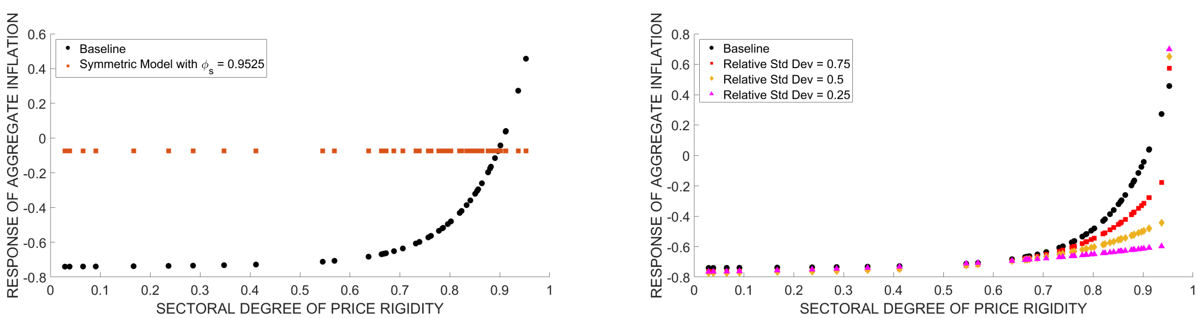
3.3 The Role of the Heterogeneity in the Price Rigidity

In this section, we highlight that what drives the positive response of aggregate inflation to a positive productivity shock to an industry with a very high degree of price rigidity is the amount of heterogeneity in the degree of price rigidity across sectors. That is, only as long as there is substantial heterogeneity in the frequency of price adjustment across industries, then positive shocks to rigid-price sectors lead to inflationary pressures at the aggregate level.

Figure 4: Sectoral Heterogeneity in Price Rigidity and the Response of Aggregate Inflation.

(a) The Magnitude of the Price Rigidity

(b) The Dispersion in the Price Rigidity



Notes: Panel a reports the 2-year cumulative response of aggregate inflation to each of the 57 sectoral productivity shocks in a version of the model with sectoral heterogeneity in nominal price rigidity, while imposing symmetry in all the other sectoral characteristics (black circles), and in a version of the model which is fully symmetric, and the degree of nominal price rigidity is set to the highest value observed in the data across sectors (blue squares). Panel b reports the 2-year cumulative response of aggregate inflation to each of the 57 sectoral productivity shocks in four versions of the model with sectoral heterogeneity in nominal price rigidity, while imposing symmetry in all the other sectoral characteristics. The black squares indicate the responses associated with the degree of nominal price rigidity observed in the data, whereas the red squares, the blue diamonds, and the purple triangles indicate the responses in counterfactual versions of the model in which the highest degree of price rigidity across sectors is set constant, but all the remaining sectoral degrees are normalized such that the standard deviation of the sectoral degrees equals 75%, 50%, and 25% of the standard deviation of the sectoral degrees observed in the data, respectively.

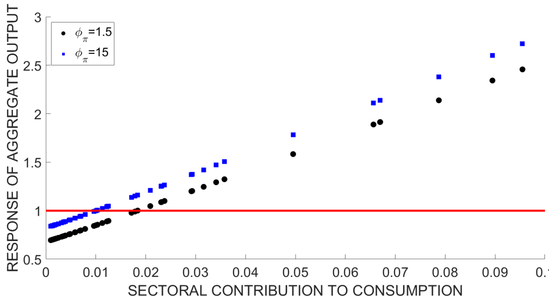
To highlight the key role of heterogeneity in the degree of price rigidity across industries, we devise two exercises. In the first one, we compare the implications of the version of the model with only heterogeneity across sectors in the Calvo parameter, with all other dimensions being symmetric, to a fully-symmetric economy in which the Calvo parameter in all sectors is set to the highest value observed across the 57 sectors, that is, the value of 0.9525. As we show in Panel (a) of Figure 4, this high level of price rigidity in all sectors is not enough to turn the sign of the response of aggregate inflation. To compare the implications of this symmetric economy to that featuring heterogeneity in price rigidity, notice that in the former economy a productivity shock originating in a sector with a Calvo parameter of 0.9525 leads to a drop in aggregate inflation by -0.07%, whereas in the latter the same productivity shock raises inflation by +0.5%. Thus, what matters is not the fact the productivity shocks originate in rigid-price sectors, the key factor is the presence of heterogeneity in the frequency of price changes across industries.

In the second exercise, we change the variation in the degrees of price rigidity across sectors. Namely, we keep the Calvo parameter of the most rigid-price sector constant, and we change the dispersion of all the other Calvo parameters such that their standard deviation equals 100%, 75%, 50%, and 25% of the standard deviation of the price frequencies across the 57 industries. We then plot the implied response of aggregate inflation to the sectoral productivity shocks in each of these four economies in Panel (b) of Figure 4. The panel shows that even if the Calvo parameter of the most rigid-price sector does not change across economies, the response of aggregate inflation to shocks originating in that sector is relatively larger at higher dispersions in the price frequency probabilities across industries.

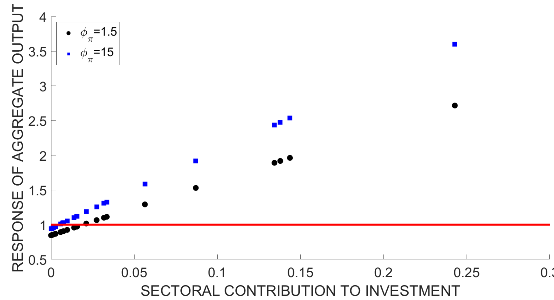
This finding is consistent with Pasten et al. (2021), who uncover the key role of heterogeneity in price rigidity as a novel mechanism that allows sectoral idiosyncratic shocks to generate substantial aggregate fluctuations. Again, our results differ from Pasten et al. (2021) insofar as we show that the response of aggregate inflation to productivity shocks originating in rigid-price industries can switch sign and become positive, and the necessary condition for this to happen is the presence of a substantial amount of heterogeneity in the frequency of price adjustment across sectors.

Figure 5: Sectoral Heterogeneity and the Response of Aggregate Output: Differences in the Monetary Policy Stance.

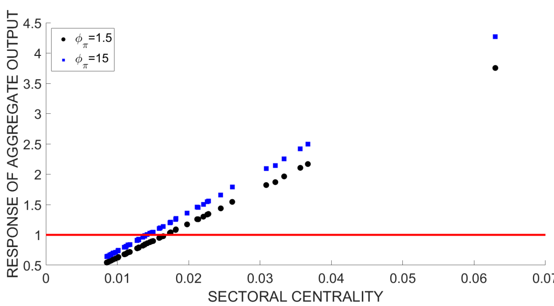
(a) Contribution to Consumption



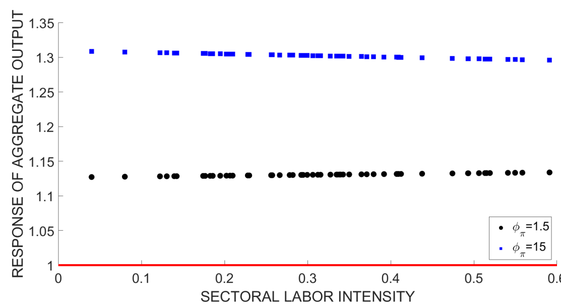
(b) Contribution to Investment



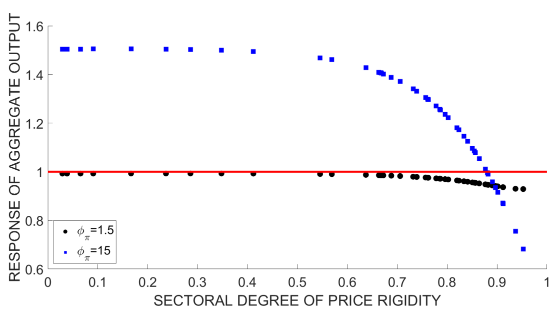
(c) Upstreamness



(d) Labor Intensity



(e) Price Rigidity



Notes: The figure reports the 2-year cumulative response of aggregate output to each of the 57 sectoral productivity shocks featured in the model in five counterfactual economies in which we set one dimension of sectoral heterogeneity at a time, while imposing symmetry in all the other sectoral characteristics. We compare the baseline economy in which the monetary authority sets the nominal interest rate with respect to changes in inflation with a parameter of $\phi_\Pi = 1.5$ (black circles), to an alternative economy in which the monetary authority is less accommodative and the inflation-responsiveness parameter is set to $\phi_\Pi = 15$ (blue squares). The dimensions we consider are: the consumption weight ($\omega_{C,s}$) in Panel a, the investment weight ($\omega_{I,s}$) in Panel b, the degree of Katz-Bonacich centrality in the Input-Output matrix ($\omega_{H,s,x}$) in Panel c, the labor intensity in the production function ($\alpha_{N,s}$) in Panel d, and the degree of nominal price rigidity (ϕ_s) in Panel e. The continuous red line denotes the response of aggregate inflation in the fully-symmetric model. The productivity shocks are normalized so that the 2-year cumulative response of aggregate output in the fully-symmetric model equals 1%.

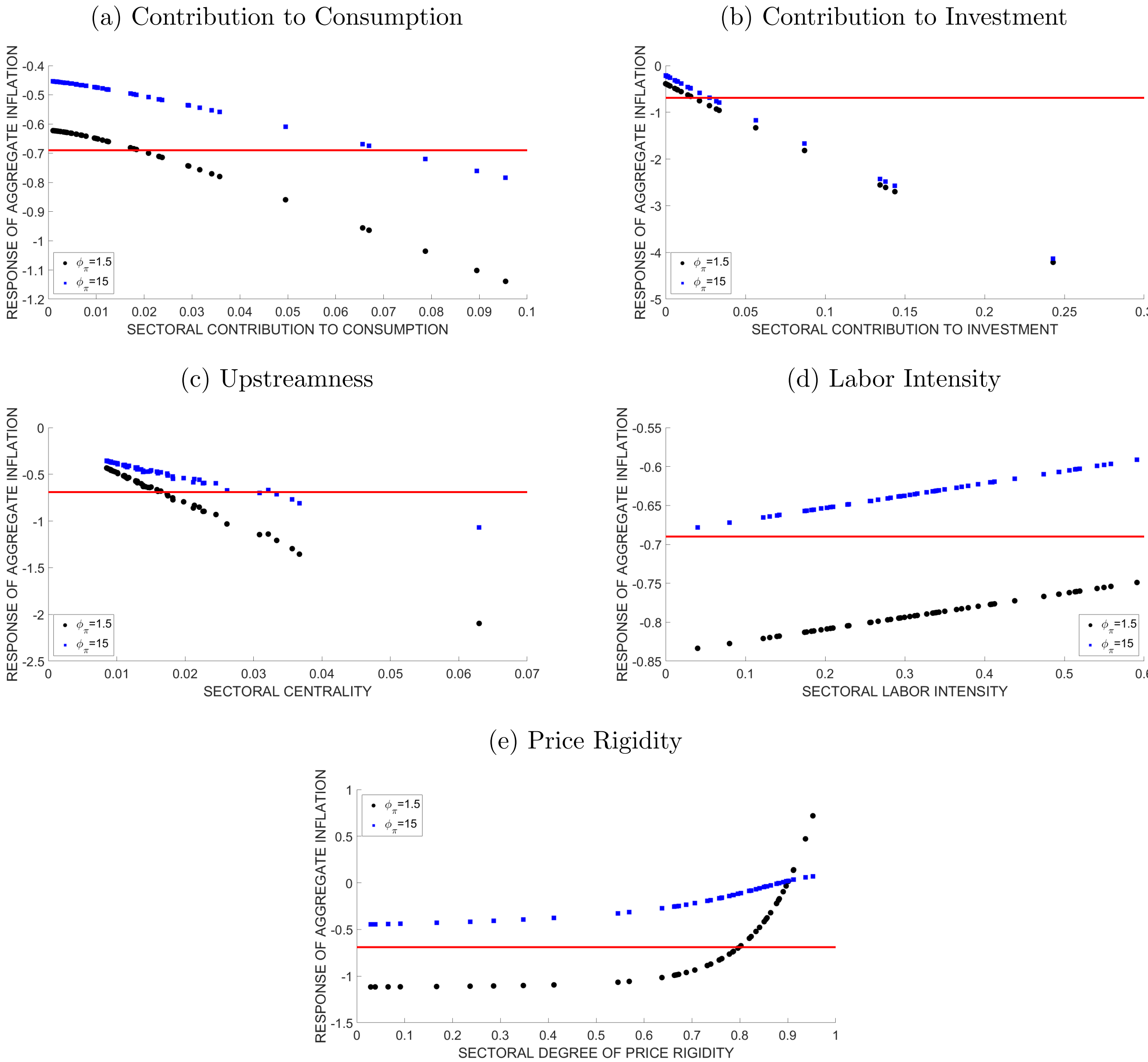
3.4 The Role of the Monetary Policy Stance

We then evaluate how the degree of accommodation of the monetary authority affects the relevance of sectoral heterogeneity in shaping the responses of aggregate output and aggregate inflation to the sectoral productivity shocks. To do so, we compare the baseline economy in which the monetary authority sets nominal interest rates with a degree of responsiveness to changes in aggregate inflation is given by $\phi_\pi = 1.5$, to a counterfactual economy with a much more active monetary policy, in which the degree of responsiveness to changes in inflation is given by $\phi_\pi = 15$.[7] Figure 5 reports the results of this exercise for the response of aggregate output in the five model economies with only one dimension of sectoral heterogeneity at a time, while keeping all the other dimensions symmetric across industries, and Figure 5 shows the results for the case of the response of aggregate inflation.

The key finding is that the degree of accommodation of the monetary authority pins down the frequency with which aggregate inflation responds positively to expansionary sectoral productivity shocks. Indeed Panel (e) of Figure 6 indicates that while aggregate inflation rises when the productivity shocks originate in 5 out of the 57 sectors of the baseline economy, when monetary policy is more active then aggregate inflation rises when the productivity shocks originate in 9 out of the 57 sectors. Panel (e) of Figure 5 shows that the change in the stance of monetary policy substantially dampens also the rise in output associated with shocks to rigid-price industries. As a result, a very active monetary policy implies that 48 sectors out of 57 feature an elasticity in the change of aggregate inflation to changes in aggregate output below 2.5%, while this happens only in 13 industries of the baseline model. However, in this case the response of inflation is very close to zero, whereas with a less responsive monetary policy the response to inflation peaks up to almost 1%.

[7]As we mention in Section 3.6, we plan also to study the implications of different policy rules, by looking into model economies featuring a price-level targeting rule, or an average inflation targeting rule. However, this exercise only looks at the comparison of two model economies featuring a standard inflation targeting rule with different responsiveness to changes in aggregate inflation.

Figure 6: Sectoral Heterogeneity and the Response of Aggregate Inflation: Differences in the Monetary Policy Stance.

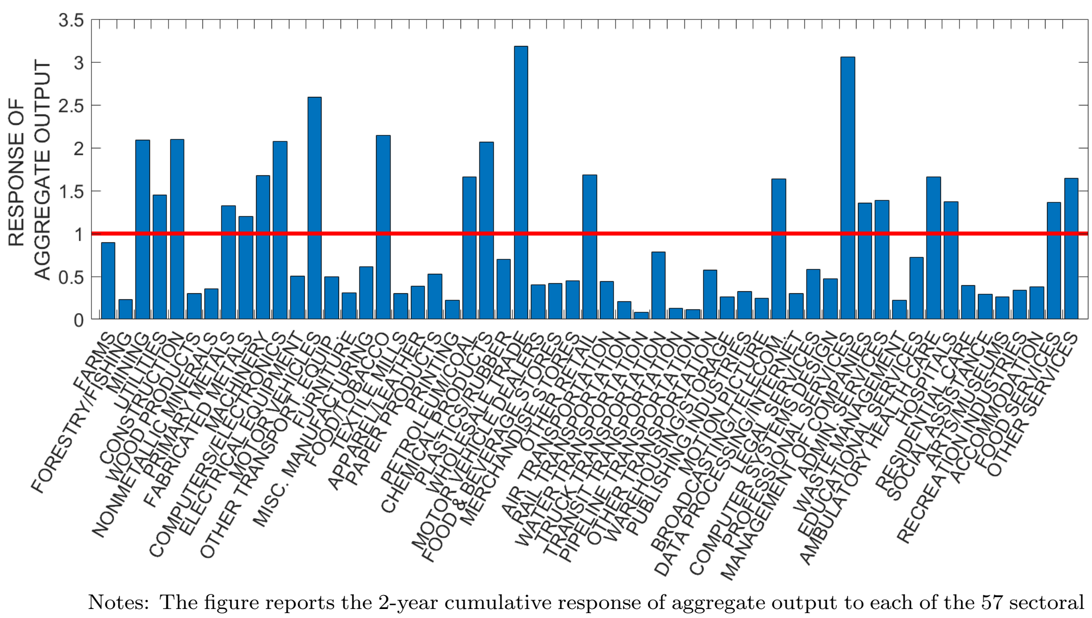


Notes: The figure reports the 2-year cumulative response of aggregate inflation to each of the 57 sectoral productivity shocks featured in the model in five counterfactual economies in which we set one dimension of sectoral heterogeneity at a time, while imposing symmetry in all the other sectoral characteristics. We compare the baseline economy in which the monetary authority sets the nominal interest rate with respect to changes in inflation with a parameter of $\phi_\Pi = 1.5$ (black circles), to an alternative economy in which the monetary authority is less accommodative and the inflation-responsiveness parameter is set to $\phi_\Pi = 15$ (blue squares). The dimensions we consider are: the consumption weight ($\omega_{C,s}$) in Panel a, the investment weight ($\omega_{I,s}$) in Panel b, the degree of Katz-Bonacich centrality in the Input-Output matrix ($\omega_{H,s,x}$) in Panel c, the labor intensity in the production function ($\alpha_{N,s}$) in Panel d, and the degree of nominal price rigidity (ϕ_s) in Panel e. The continuous red line denotes the response of aggregate inflation in the fully-symmetric model. The productivity shocks are normalized so that the 2-year cumulative response of aggregate output in the fully-symmetric model equals 1%.

3.5 Inflation Dynamics in a Quantitative Production Network

In the previous sections, we have evaluated the responses of aggregate output and inflation to sectoral productivity shocks in a sequence of economies that feature only one dimension of sectoral heterogeneity at a time. In this section, we study the implications of a fully-fledged quantitative production network economy, which allows us to study to what extent the heterogeneity across U.S. industries observed in the data implies a comovement of quantities and prices following sectoral productivity shocks which is actually in line with the expected propagation of demand disturbances. To do so, we consider the baseline economy and let heterogeneity in all the sectoral dimensions studied so far, and then compute the 2-year cumulative responses of aggregate output and aggregate inflation to each of the 57 sectoral productivity shocks.

Figure 7: The Response of Aggregate Output.



Notes: The figure reports the 2-year cumulative response of aggregate output to each of the 57 sectoral shocks in the fully-heterogeneous version of the model economy. The continuous red line denotes the response of aggregate inflation in the fully-symmetric model. The productivity shocks are normalized so that the 2-year cumulative response of aggregate output in the fully-symmetric model equals 1%.

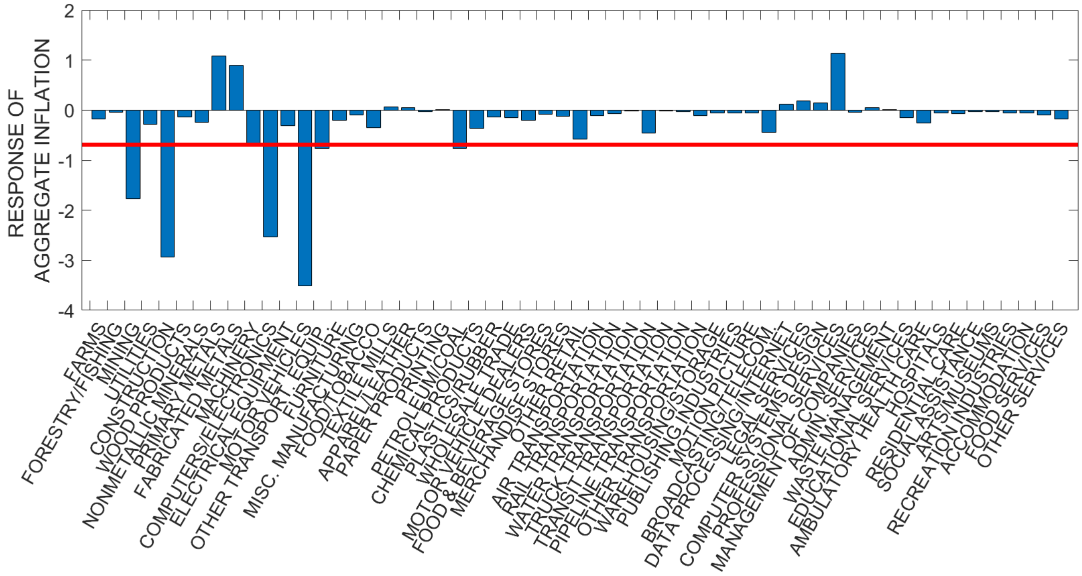
Figure 7 reports the results of this exercise for the response of aggregate output. The shocks are calibrated to imply a 1% rise in output in the fully symmetric model, and so all sectoral shocks are of the same size. Yet these shocks imply a vast heterogeneity in the magnitude of the response of aggregate output. For instance, productivity shocks to the “Water Transportation” industry imply a surge of economic activity by just 0.08%, which is followed by the “Pipeline Transporation” industry, whose productivity shocks raise aggregate output by 0.12%. These two industries are characterized by a very low contribution to consumption, a nil contribution to investment, and are positioned among the most downstream industries in the U.S. Input-Output matrix.

On the other range of the spectrum, shocks to ”Wholesale trade” and ”Professional services” generate a 3.20% and 3.04% increase in aggregate output, respectively. These are the two most upstream sectors of the economy, which explains the large responsiveness of aggregate output to shocks originating in these two industries.

Figure 8 reports the 2-year cumulative response of aggregate annualized inflation. In the fully symmetric model, the response equals -0.69%, whereas in the fully heterogeneous model the average response is -0.27%. Again, we observe a large heterogeneity in the response of inflation. On the one hand, it drops by -3.5% and -2.9% when the TFP shocks originate in the “Motor vehicles manufacturing” and “Construction” industries, respectively. On the other hand, aggregate inflation raises by 1.1% when the shocks originate in either “Prime metals manufacturing” or “Professional services”. Importantly, the figure highlights that the response of aggregate inflation is positive when expansionary productivity shocks originate in 11 of the 57 industries.[8] Thus, not only the model generates variation in the magnitude of the response of aggregate inflation to sectoral shocks, but also heterogeneity in

[8]The industries whose expansionary productivity shocks raise inflation are “Primary metal manufacturing”, “Fabricated metal products manufacturing”, “Textile manufacturing”, “Apparel and leather manufacturing”, “Printing Activities”, “Data processing and other information services”, “Legal services”, “Computer systems design and related services”, “Professional services”, “Administrative services”, and “Waste management services”.

Figure 8: The Response of Aggregate Inflation.

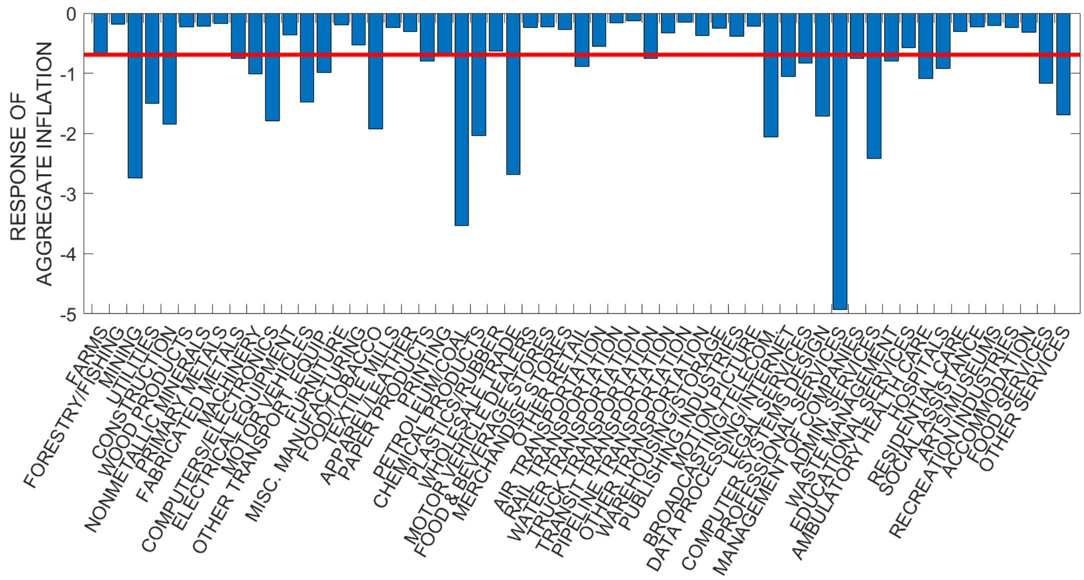


Notes: The figure reports the 2-year cumulative response of aggregate inflation to each of the 57 sectoral shocks in the fully-heterogeneous version of the model economy. The continuous red line denotes the response of aggregate inflation in the fully-symmetric model. The productivity shocks are normalized so that the 2-year cumulative response of aggregate output in the fully-symmetric model equals 1%.

its sign.

The main driver of the variation in the response of aggregate inflation is the heterogeneity in the degree of price rigidity. This finding can be observed by looking at Figures 9, which reports the response of aggregate inflation to sectoral productivity shocks in an economy that is fully heterogeneous except for the degree of price rigidity, which is set symmetrically across industries to the average Calvo parameter of the economy. In this case, inflation always reacts negatively to any productivity shock. Thus, this simple exercise highlights how the heterogeneity in price rigidity is a key factor generating a positive response of aggregate inflation to expansionary sectoral productivity shocks in 11 industries. Interestingly, the high degree of price rigidity of the "Professional services" sector allows productivity shocks originating in this sector to lead to a positive response of aggregate inflation notwithstanding the fact that this is the most upstream sector of the economy. In other words, even if shocks to upstream industries should lead to a relatively large and negative response

Figure 9: The Response of Aggregate Inflation - No Heterogeneity in Nominal Price Rigidity.

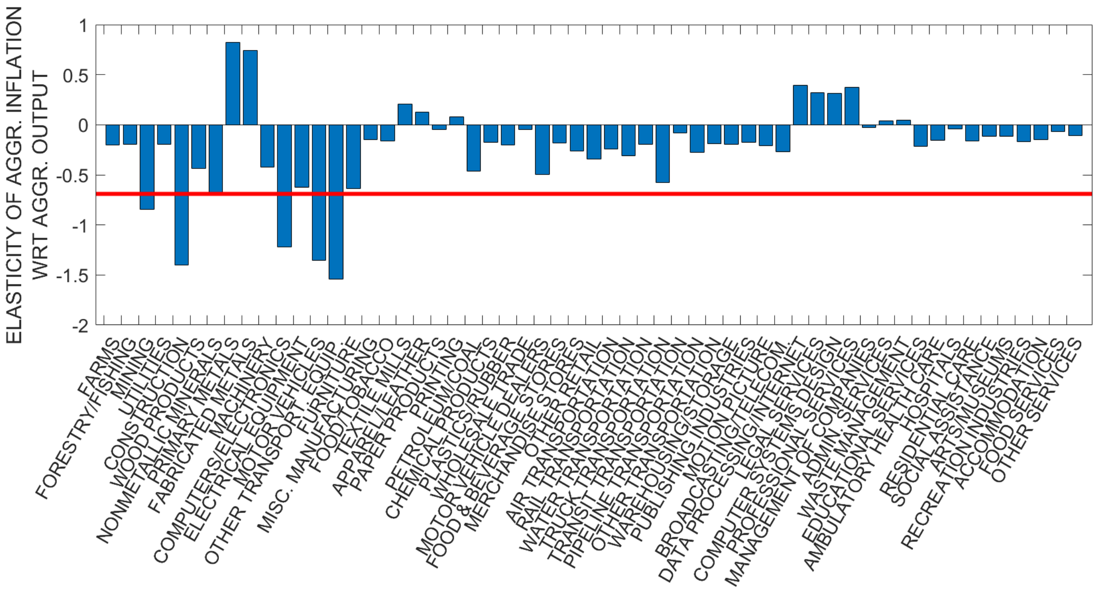


Notes: The figure reports the 2-year cumulative response of aggregate inflation to each of the 57 sectoral shocks in a version of the model economy that is fully heterogeneous except for the degree of nominal price rigidity, which is set symmetrically across sectors. The continuous red line denotes the response of aggregate inflation in the fully-symmetric model. The productivity shocks are normalized so that the 2-year cumulative response of aggregate output in the fully-symmetric model equals 1%.

of aggregate inflation, this implication is completely overturned when the upstream sector's prices are sufficiently rigid. In this perspective, the sign of the response of aggregate inflation hinges relatively more on the frictional origins of business cycles highlighted in Pasten et al. (2021), rather than the network origins hypothesis of Acemoglu et al. (2012).

Figure 10 reports the elasticity of the response of aggregate inflation relative to the response of aggregate output in the fully-heterogeneous model. The figure shows that the elasticity is around -0.6 in the fully symmetric model, a level which is passed by only 5 sectors in the fully heterogeneous economy. In this version, 52 sectors out of the 57 industries have elasticities that are below those implied by the symmetric model, and the vast majority of the industries have elasticities that are either positive or below -0.025. This figure then confirms that identifying demand and supply shocks by looking at the sign of the responses of aggregate quantities and prices could be very challenging, and to the extent that sectoral productivity

Figure 10: The Elasticty of Aggregate Inflation Relative to Aggregate Output.



Notes: The figure reports the elasticity of aggregate inflation with respect to aggregate output, defined as the ratio between the 2-year cumulative response of aggregate inflation and the 2-year cumulative response of aggregate output to each of the 57 sectoral shocks in the fully-heterogeneous version of the model economy. The continuous red line denotes the elasticity in the fully-symmetric model. The productivity shocks are normalized so that the 2-year cumulative response of aggregate output in the fully-symmetric model equals 1%.

shocks are a main determinant of supply-driven business cycles, then it is likely to misinterpret aggregate demand shocks with supply shocks to highly rigid-price industries.

3.6 Inflation Dynamics at the Zero Lower Bound

Our model predicts that the link between the response of aggregate inflation to sectoral productivity and the origin of the shock crucially depends on the stance of monetary policy. In this section – which is work in progress at the current stage of the draft – we plan to thoroughly evaluate the implications on our key finding of different types of monetary policy rules and, most importantly, the fact that the monetary authority may be constrained by the zero lower bound (ZLB).

In terms of different monetary policy rules, we will evaluate how the results of the model change in we consider (*i*) a price-level targeting rule, (*ii*) a nominal GDP targeting rule, (*iii*) a strict inflation targeting rule, and (*iv*) an average inflation targeting rule.

In terms of the role of the ZLB, we will evaluate what is the aggregate response of inflation to the sectoral productivity shocks once the economy hits the zero lower bound. Specifically, we will consider a sequence of liquidity-preference shocks, as in Bouakez et al. (2022), that increase households' desire for safe and liquid assets, leading them to save in bonds and cut on consumption.

Why is the ZLB exercise particularly interesting? The standard one-sector New Keynesian model is characterized by the paradox of toil at the zero lower bound: positive productivity shocks are contractionary as they trigger a further drop in inflation, and thus may prolong further the deflationary spiral (Eggertsson, 2010; Eggertsson et al., 2014; Wieland, 2019). However, this is not necessarily the case in the multi-sector New Keynesian model. To the extent that positive productivity shocks to a substantial number of sectors lead to a rise in inflation, then in all these circumstances, the paradox of toil will not apply. In addition, we have shown that the heterogeneity in the response of aggregate inflation to the sectoral shocks raises when the monetary policy is more accommodative. As such, the ZLB will be the ideal scenario in which the monetary authority cannot react to variations in expected inflation, and thus we should expect even a much more important role for the origins of the shock in the response of aggregate inflation to changes in sectoral productivity.

4 Empirical Evidence

This section provides empirical evidence supporting the main mechanism of the paper. Specifically, we test whether the response of aggregate inflation to a sectoral productivity shock crucially depends on the degree of price rigidity of the affected sector, such that the response of aggregate inflation responds positively when an expansionary productivity shock hits a highly rigid-price sector.

To carry out the analysis, we use as the main data source the NBER-CES Manufacturing. This data provides granular information on sectoral variables for a pool of 462 6-digit manufacturing industries, at the yearly frequency from 1958 to 2018. Importantly, the NBER-CES Manufacturing database provides information on a 5-factor TFP index at the industry level, which is computed as the residual of real gross output once accounting for physical capital, the hours of production workers, the number of non-production workers, energy inputs, and non-energy intermediate inputs. Overall, we can leverage detailed sectoral productivity information on a panel of roughly 27,000 industry-year observations.

We then estimate the following panel regression

$$\pi_t = \beta_1 \Delta \log TFP_{s,t} + \beta_2 \Delta \log TFP_{s,t} \times \text{Calvo}_s + \mathbf{X'_{s,t-1}}\gamma_1 + \mathbf{X'_{t-1}}\gamma_2 + \epsilon_{s,t}, \quad (34)$$

where π_t is the aggregate inflation rate – defined either over the consumption price index, the implicit aggregate GDP deflator, or the implicit manufacturing GDP deflator – $\Delta TFP_{s,t}$ is the sectoral productivity shock, Calvo_s is the sectoral degree of price rigidity, computed at this level of disaggregation by Pasten et al. (2020), and $\mathbf{X'_{s,t-1}}$ and $\mathbf{X'_{s,t-1}}$ are a set of sectoral and aggregate covariates, respectively, including the lags of changes in sectoral real value added, sectoral wage bill, sectoral employment, manufacturing real value added, manufacturing wage bill, and manufacturing employment.

The key term of interest in the regression (34) is the interaction between the sectoral TFP shock and the sectoral degree of price rigidity: the quantitative model predicts that although the coefficient governing the direct effect of the sectoral productivity shocks on aggregate inflation should be negative (i.e., $\beta_1 < 0$), the coefficient of the interaction term should be positive (i.e., $\beta_2 > 0$), so that the response of aggregate inflation increases with the degree of price rigidity of the sector being shocked.

Table 1 reports the results of the regressions in which the dependent variable is the inflation rate defined upon the consumer price index, and the standard errors are double clustered over the two panel dimensions.

Column (1) reports the estimates of a case in which changes in aggregate inflation are regressed only on changes in sectoral productivity, and shows that sectoral TFP changes lead to a drop in aggregate inflation, and this effect is highly statistically significant. Column (2) introduces the interaction of changes in sectoral TFP with the sectoral index of nominal price rigidity, and shows that although the effect of sectoral TFP shocks keeps being negative and statistically significant, the coefficient associated with the interaction term is positive and statistically significant, in line with the predictions of our model. Column (3) introduces sector fixed effects and Column (4) introduces both sectoral and aggregate covariates.[9]

In all cases, the interaction between the sectoral TFP shock and the degree of price rigidity is negative and highly statistically significant. The interaction is also highly economically significant: using the estimates of Column (4), we find that moving from the 25th percentile of the distribution of sectoral price rigidity to the 75th percentile raises the response of aggregate inflation by the equivalent of 15% of its standard deviation. Interestingly, moving between these two percentiles leads also to a change in the sign in the response of aggregate inflation. While a sectoral TFP shock hitting an industry at the 25th percentile of the price rigidity is associated with a negative response of aggregate inflation, the response turns positive if the shock originates in a sector at the 75th percentile of the price rigidity distribution.

We report in Section B an extensive battery of robustness checks. First, Table

[9]Since the dependent variable is the change in aggregate inflation, we cannot saturate the regression with year fixed effects. However, our approach does not require time fixed effects for the identification of the shocks, as in Nakamura and Steinsson (2014, 2018) and Chodorow-Reich (2019), as we exploit the time variation in the Solow residual at the industry level, as computed with the 5-factor approach by the NBER-CES Database. The lack of time fixed effects allows us to interpret the estimated coefficients β_1 and β_2 as the general-equilibrium elasticities of aggregate inflation to changes in sectoral TFP and its interaction with the sectoral index in price rigidity, thus providing the actual counterpart of the results provided by the quantitative model.

Table 1: Sectoral Heterogeneity in Price Rigidity and the Response of Aggregate Inflation to Productivity Shocks in the Data.

Dependent Variable:	$\Delta \log CPI_t$			
	(1)	(2)	(3)	(4)
$\Delta \log TFP_{s,t}$	-0.0173^{***} (0.0026)	-0.0622^{***} (0.0128)	-0.0632^{***} (0.0132)	-0.0377^{***} (0.0100)
$\Delta \log TFP_{s,t} \times \text{Calvo}_s$		0.1634^{***} (0.0450)	0.1652^{***} (0.0463)	0.1231^{***} (0.0348)
Industry Fixed Effects	NO	NO	YES	YES
Sectoral Controls	NO	NO	NO	YES
Aggregate Controls	NO	NO	NO	YES
N. Obs.	26,757	26,757	26,757	26,757

Notes: The table reports the estimates of the response of aggregate inflation to changes in the sectoral 5-factor TFP index, and its interaction with the sectoral degree of nominal price rigidity in a panel of 462 6-digit manufacturing industries, at the yearly frequency from 1958 to 2018. Aggregate inflation is computed over the consumption price index. Column (1) reports the estimate in which the only independent variable is the change in sectoral productivity. Column (2) also adds the interaction with the sectoral degree of price rigidity. Column (3) includes sector fixed effects, and Column (4) adds sectoral controls (i.e., the lags of changes in real sectoral value added, sectoral wage bill, and sectoral employment), as well as aggregate controls (i.e., the lags of changes in real manufacturing value added, manufacturing wage bill, and manufacturing employment). Standard errors double-clustered at the sector-year level are reported in parentheses. $\star\star\star$, $\star\star$, and $\star$ denote statistical significance at the 1%, 5%, and 10% level, respectively.

B.1 shows that the relationship between sectoral heterogeneity in the nominal price rigidity and the response of aggregate inflation to sectoral productivity shocks holds not only in the unweighted regression of Table 1, but also if we weight each observation by either sectoral value added, sectoral gross output, or sectoral employment. Table B.2 includes the interaction of sectoral productivity with the other sectoral characteristics studied in the quantitative model: the sectoral contribution to consumption and investment, the sectoral centrality in the Input-Output matrix,[10] and the sectoral labor intensity. Interestingly – and in line with the predictions of our

[10]The sectoral contribution to consumption and investment, as well as the sectoral centrality in the Input-Output matrix, are derived by merging the NBER-CES Manufacturing Database with the 1997 Input-Output Table of the BEA.

model – the interaction of the productivity shocks with the sectoral degree of price rigidity is the only one being statistically different from zero, that is, the regression confirms the special role of these sectoral characteristics in driving the response of aggregate inflation to changes in sectoral TFP. The table also considers cases in which we add a one-year and two-year lag for both the inflation rate and the sectoral productivity shocks, as well as different data samples, with one that starts only from 1984 on, in the Great Moderation period, and one that also excludes the 2007 financial crisis. Finally, Table B.3 and Table B.4 confirms the findings of the baseline regression by considering as the dependent variable the inflation rate computed over the implicit aggregate GDP deflator and the implicit manufacturing GDP deflator, respectively.

Overall, these results provide compelling empirical evidence validating the main mechanism of our model: the response of aggregate inflation to expansionary sectoral productivity shocks tends to be relatively less negative when the shock originates in industries with a high degree of nominal price rigidity.

5 Conclusion

This paper has analyzed the macroeconomic effects of sectoral productivity shocks in a multi-sector New Keynesian model calibrated to the U.S. economy. In sum, our findings highlight that the size and sign of the aggregate response depend on the sectoral origin of the productivity shock. The results show that the conventional wisdom on the fact that demand shocks generate a positive comovement between aggregate output and inflation, whereas supply shocks generate a negative comovement, may not hold generally.

This result poses a challenge for empirical research on supply shocks, as the identification of supply shocks relies on the negative comovement of inflation and output. On the other hand, policy institutions aiming to mitigate the aggregate effects of shocks, may face a dilemma when a demand stimulus may become warranted in response to a de facto supply shock. In this context, our model predicts that the relationship between the response of inflation to sectoral productivity crucially depends on the stance of monetary policy.

In current work in progress, we therefore plan to study the implications of different types of monetary policy rules and the zero lower bound on our findings. We will evaluate to what extent the paradox of toil at the ZLB, that is, the fact that positive productivity shocks are contractionary when the monetary authority is constrained by the lower bound on its policy rate (Eggertsson, 2010; Eggertsson et al., 2014; Wieland, 2019), holds when we consider sectoral heterogeneity, and importantly the dispersion in the nominal price rigidity. Finally, we will use our framework to evaluate what are the aggregate inflationary dynamics over the short and medium-term triggered by some salient sectoral shocks, such as changes in the productivity of the semiconductor manufacturing industry, and changes in the productivity of all those services industries which have been hit by the COVID pandemics.

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A More on the Calibration

This section provides additional information on the calibration of the model. First, we report in Tables A.1-A.3 the entire list of 57 sectors of the model. As we mention in Section 3.1, this granularity of the economy corresponds to the three-digit level of the NAICS code classification, once excluded the real estate and the financial industries.

We then report in Table A.4 the list of calibrated values and the description of the aggregate parameters of the model, and Table A.5 shows the values and the calibration targets of the set of sector-specific parameters. The information on the calibrated values for the sector-specific parameters (i.e, $\alpha_{N,s}$, $\alpha_{H,s}$, $\omega_{C,s}$, $\omega_{I,s}$, $\omega_{H,s,x}$, $\omega_{N,s}$, $\omega_{K,s}$, and ϕ_s) is available upon request.

Table A.1: Sectors 1-20.

1	Farms
2	Forestry, fishing, and related activities
3	Mining
4	Utilities
5	Construction
6	Wood products
7	Nonmetallic mineral products
8	Primary metals
9	Fabricated metal products
10	Machinery
11	Computer and electronic products
12	Electrical equipment, appliances, and components
13	Motor vehicles, bodies and trailers, and parts
14	Other transportation equipment
15	Furniture and related products
16	Miscellaneous manufacturing
17	Food and beverage and tobacco products
18	Textile mills and textile product mills
19	Apparel and leather and allied products
20	Paper products

Table A.2: Sectors 21-40.

21	Printing and related support activities
22	Petroleum and coal products
23	Chemical products
24	Plastics and rubber products
25	Wholesale trade
26	Motor vehicle and parts dealers
27	Food and beverage stores
28	General merchandise stores
29	Other retail
30	Air transportation
31	Rail transportation
32	Water transportation
33	Truck transportation
34	Transit and ground passenger transportation
35	Pipeline transportation
36	Other transportation and support activities
37	Warehousing and storage
38	Publishing industries, except internet (includes software)
39	Motion picture and sound recording industries
40	Broadcasting and telecommunications

Table A.3: Sectors 41-57.

41	Data processing, internet publishing, and other information services
42	Legal services
43	Computer systems design and related services
44	Miscellaneous professional, scientific, and technical services
45	Management of companies and enterprises
46	Administrative and support services
47	Waste management and remediation services
48	Educational services
49	Ambulatory health care services
50	Hospitals
51	Nursing and residential care facilities
52	Social assistance
53	Performing arts, spectator sports, museums, and related activities
54	Amusements, gambling, and recreation industries
55	Accommodation
56	Food services and drinking places
57	Other services, except government

Table A.4: Calibration of the Aggregate Parameters.

Parameter	Description	Target/Source
$\beta = 0.995$	Time discount factor	2% annual real rate
$\sigma = 2$	Risk aversion	Standard value
$\eta = 1/0.8$	Inverse of the Frisch elasticity	Chetty et al. (2013)
$\theta = 94.40$	Labor disutility shifter	$N^{\star} = 0.33$
$\Delta = 0.0083$	Physical capital depreciation rate	10% annual depreciation
$\Omega = 20$	Investment adjustment cost	Relative volatility of investment
$\nu_C = 2$	Elasticity of substitution b/w sectoral consumption goods	Hobijn and Nechio (2019)
$\nu_I = 2$	Elasticity of substitution b/w sectoral investment goods	$\nu_I = \nu_C$
$\nu_H = 0.1$	Elasticity of substitution b/w sectoral intermediate inputs	Atalay (2017)
$\nu_N = 1$	Elasticity of substitution b/w sectoral labor flows	Horvath (2000)
$\nu_K = 1$	Elasticity of substitution b/w sectoral capital services	$\nu_K = \nu_N$
$\epsilon = 4$	Elasticity of substitution b/w within-sector varieties	De Loecker et al. (2020)
$\rho = 0.95$	Auto-regressive coefficient for	Horvath (2000)
$\phi_R = 0.8$	Taylor-rule interest rate smoothing	Clarida et al. (2000)
$\phi_\Pi = 1.5$	Taylor-rule responsiveness to inflation	Clarida et al. (2000)
$\phi_Y = 0.2$	Taylor-rule responsiveness to output gap	Clarida et al. (2000)

Table A.5: Calibration of the Sector-Specific Parameters.

Parameter	Description	Target/Source
$\alpha_{N,s}$	Value-added labor intensity	Sectoral value-added labor share
$\alpha_{H,s}$	Gross-output intermediate inputs intensity	Sectoral gross-output intermediate input share
$\omega_{C,s}$	Contribution to consumption	Sectoral share in total personal consumption expenditures
$\omega_{I,s}$	Contribution to Investment	Sectoral share in total private fixed investment expenditures
$\omega_{H,s,x}$	Contribution to sectoral intermediate inputs	Sectoral shares in Input-Output matrix
$\omega_{N,s}$	Sectoral labor weight	$\omega_{N,s} = \frac{N_s^\star}{N^\star}$
$\omega_{K,s}$	Sectoral capital weight	$\omega_{K,s} = \frac{K_s^\star}{K^\star}$
ϕ_s	Sectoral degree of price rigidity	Nakamura and Steinsson (2008) and Bouakez et al. (2014)

B More on the Empirical Evidence

This section performs an extensive battery of robustness checks to the regressions of Table 1. First, Table B.1 shows that the relationship between sectoral heterogeneity in the nominal price rigidity and the response of aggregate inflation to sectoral productivity shocks holds not only in the unweighted regression of Table 1, but also if we weight each observation by either sectoral value added, sectoral gross output, or sectoral employment.

Table B.2 includes the interaction of sectoral productivity with the other sectoral characteristics studied in the quantitative model: the sectoral contribution to consumption and investment, the sectoral centrality in the Input-Output matrix, and the sectoral labor intensity. The table also considers cases in which we add a one-year and two-year lag for both the inflation rate and the sectoral productivity shocks, as well as different data samples, with one that starts only from 1984 on, in the Great Moderation period, and one that also excludes the 2007 financial crisis.

Table B.3 and Table B.4 confirms the findings of the baseline regression by considering as the dependent variable the inflation rate computed over the implicit aggregate GDP deflator and the implicit manufacturing GDP deflator, respectively.

Table B.1: Sectoral Heterogeneity in Price Rigidity and the Response of Aggregate Inflation to Productivity Shocks in the Data - Robustness Checks.

Dependent Variable:	$\Delta \log CPI_t$		
	(1)	(2)	(3)
	Weighted by Sectoral Value Added	Weighted by Sectoral Gross Output	Weighted by Sectoral Employment
$\Delta \log TFP_{s,t}$	-0.0606^{***}	-0.0648^{***}	-0.0587^{***}
	(0.0175)	(0.0235)	(0.0192)
$\Delta \log TFP_{s,t} \times \text{Calvo}_s$	0.2425^{***}	0.2560^{***}	0.1903^{***}
	(0.0627)	(0.0842)	(0.0668)
Industry Fixed Effects	YES	YES	YES
Sectoral Controls	YES	YES	YES
Aggregate Controls	YES	YES	YES
N. Obs.	26,273	26,273	26,272

Notes: The table reports the estimates of the response of aggregate inflation to changes in the sectoral 5-factor TFP index, and its interaction with the sectoral degree of nominal price rigidity in a panel of 462 6-digit manufacturing industries, at the yearly frequency from 1958 to 2018. Aggregate inflation is computed over the consumption price index. Column (1) weights each observation by the sectoral value added, Column (2) uses sectoral gross output, and Column (3) uses sectoral employment. All cases include industry fixed effects, sectoral controls (i.e., the lags of changes in real sectoral value added, sectoral wage bill, and sectoral employment), as well as aggregate controls (i.e., the lags of changes in real manufacturing value added, manufacturing wage bill, and manufacturing employment). Standard errors double-clustered at the sector-year level are reported in parentheses. $\star\star\star$, $\star\star$, and $\star$ denote statistical significance at the 1%, 5%, and 10% level, respectively.

Table B.2: Sectoral Heterogeneity in Price Rigidity and the Response of Aggregate Inflation to Productivity Shocks in the Data - Robustness Checks.

Dependent Variable:	$\Delta \log CPI_t$			
	(1)	(2)	(3)	(4)
	Controlling for Inflation Interaction with Other Sectoral Characteristics	Additional Lags of Aggregate Inflation & Sectoral TFP	Great Moderation	Excluding Financial Crisis
$\Delta \log TFP_{s,t}$	-0.0220	$-0.0370^{\star\star\star}$	$-0.0333^{\star\star\star}$	-0.0128
	(0.0192)	(0.0097)	(0.0065)	(0.0086)
$\Delta \log TFP_{s,t} \times \text{Calvo}_s$	$0.0911^{\star\star}$	$0.1161^{\star\star\star}$	$0.1551^{\star\star\star}$	$0.0566^{\star}$
	(0.0440)	(0.0340)	(0.0230)	(0.0298)
Industry Fixed Effects	YES	YES	YES	YES
Sectoral Controls	YES	YES	YES	YES
Aggregate Controls	YES	YES	YES	YES
N. Obs.	26,273	25,351	15,209	10,603

Notes: The table reports the estimates of the response of aggregate inflation to changes in the sectoral 5-factor TFP index, and its interaction with the sectoral degree of nominal price rigidity in a panel of 462 6-digit manufacturing industries, at the yearly frequency from 1958 to 2018. Aggregate inflation is computed over the consumption price index. Column (1) includes the interaction of the sectoral productivity changes with the sectoral contribution to consumption, the sectoral contribution to investment, the sectoral centrality in the Input-Output matrix, and the sectoral labor intensity. Column (2) includes the one-year and two-year lags of both the aggregate inflation and the sectoral productivity change. Column (3) considers a shorter sample, by considering only the observations after 1984, in the Great Moderation period, and Column (4) ends the sample just before the 2007 financial crisis. All cases include industry fixed effects, sectoral controls (i.e., the lags of changes in real sectoral value added, sectoral wage bill, and sectoral employment), as well as aggregate controls (i.e., the lags of changes in real manufacturing value added, manufacturing wage bill, and manufacturing employment). Standard errors double-clustered at the sector-year level are reported in parentheses. $\star\star\star$, $\star\star$, and $\star$ denote statistical significance at the 1%, 5%, and 10% level, respectively.

Table B.3: Sectoral Heterogeneity in Price Rigidity and the Response of Aggregate Inflation to Productivity Shocks in the Data - Aggregate GDP Deflator.

Dependent Variable:	$\Delta \log \text{GDP Deflator}_t$			
	(1)	(2)	(3)	(4)
$\Delta \log TFP_{s,t}$	$-0.0118^{\star\star\star}$ (0.0021)	$-0.0424^{\star\star\star}$ (0.0104)	$-0.0431^{\star\star\star}$ (0.0108)	$-0.0237^{\star\star\star}$ (0.0075)
$\Delta \log TFP_{s,t} \times \text{Calvo}_s$		$0.1115^{\star\star\star}$ (0.0367)	$0.1127^{\star\star\star}$ (0.0378)	$0.0756^{\star\star\star}$ (0.0261)
Industry Fixed Effects	NO	NO	YES	YES
Sectoral Controls	NO	NO	NO	YES
Aggregate Controls	NO	NO	NO	YES
N. Obs.	26,757	26,757	26,757	26,757

Notes: The table reports the estimates of the response of aggregate inflation to changes in the sectoral 5-factor TFP index, and its interaction with the sectoral degree of nominal price rigidity in a panel of 462 6-digit manufacturing industries, at the yearly frequency from 1958 to 2018. Aggregate inflation is computed over the implicit aggregate GDP deflator. Column (1) reports the estimate in which the only independent variable is the change in sectoral productivity. Column (2) also adds the interaction with the sectoral degree of price rigidity. Column (3) includes sector fixed effects, and Column (4) adds sectoral controls (i.e., the lags of changes in real sectoral value added, sectoral wage bill, and sectoral employment), as well as aggregate controls (i.e., the lags of changes in real manufacturing value added, manufacturing wage bill, and manufacturing employment). Standard errors double-clustered at the sector-year level are reported in parentheses. $\star\star\star$, $\star\star$, and $\star$ denote statistical significance at the 1%, 5%, and 10% level, respectively.

Table B.4: Sectoral Heterogeneity in Price Rigidity and the Response of Aggregate Inflation to Productivity Shocks in the Data - Manufacturing GDP Deflator.

Dependent Variable:	$\Delta \log$ Manufacturing Deflator$_t$			
	(1)	(2)	(3)	(4)
$\Delta \log TFP_{s,t}$	$-0.3717^{\star\star\star}$ (0.0210)	$-1.4600^{\star\star\star}$ (0.1110)	$-1.4671^{\star\star\star}$ (0.1140)	$-1.4415^{\star\star\star}$ (0.1171)
$\Delta \log TFP_{s,t} \times \text{Calvo}_s$		$3.9570^{\star\star\star}$ (0.3736)	$4.0640^{\star\star\star}$ (0.3832)	$3.9758^{\star\star\star}$ (0.3920)
Industry Fixed Effects	NO	NO	YES	YES
Sectoral Controls	NO	NO	NO	YES
Aggregate Controls	NO	NO	NO	YES
N. Obs.	26,738	26,738	26,738	26,738

Notes: The table reports the estimates of the response of aggregate inflation to changes in the sectoral 5-factor TFP index, and its interaction with the sectoral degree of nominal price rigidity in a panel of 462 6-digit manufacturing industries, at the yearly frequency from 1958 to 2018. Aggregate inflation is computed over the implicit manufacturing GDP deflator. Column (1) reports the estimate in which the only independent variable is the change in sectoral productivity. Column (2) also adds the interaction with the sectoral degree of price rigidity. Column (3) includes sector fixed effects, and Column (4) adds sectoral controls (i.e., the lags of changes in real sectoral value added, sectoral wage bill, and sectoral employment), as well as aggregate controls (i.e., the lags of changes in real manufacturing value added, manufacturing wage bill, and manufacturing employment). Standard errors double-clustered at the sector-year level are reported in parentheses. $\star\star\star$, $\star\star$, and $\star$ denote statistical significance at the 1%, 5%, and 10% level, respectively.