State-dependent pricing and cost-push inflation in a production network economy*

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Abstract

Post-Covid inflation pressures call for quantifying the cost-push effect of large sectoral shocks within observed inflation. This paper examines how state-dependent pricing shapes cost-push inflation in a New-Keynesian Production Network model, extended with tractable state-dependent price rigidity varying with shock size. I find that state dependence is particularly strong in sectors with inherently higher price rigidity, affecting both the magnitude and direction of the cost-push effect, especially during crises. Overall, state dependence more than doubles the contribution of cost-push factors to observed inflation.

Keywords: production networks, state-dependent pricing, cost-push inflation

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1 Introduction

The recent inflation surge, fueled by Covid and the energy crisis, highlights the challenge that sectoral shocks create for monetary policy in balancing demand and inflation stabilization. This challenge calls for accurately quantifying the cost-push effect of sectoral shocks within observed inflation. The standard New-Keynesian framework attributes cost-push inflation to the imperfect relative price adjustments across sectors, influenced by sectoral price rigidities and the input-output structure (Aoki, 2001; Rubbo, 2023). A key limitation of this framework is its assumption of constant price rigidity over time, which becomes especially pertinent during large shocks like Covid, when affected sectors engage in faster price adjustments. In this regard, state-dependent pricing models–where price rigidity varies with the shock size–provide a more accurate representation of pricing behavior and relative price dynamics.

Against this background, I study the role of state-dependent pricing in shaping cost-push inflation in a multi-sectoral economy. For this, I extend a state-of-the-art New-Keynesian Input-Output Network model of La'O and Tahbaz-Salehi (2022); Rubbo (2023) with tractable state-dependent price rigidity. This rigidity results from firms' heterogeneous inattention to fluctuations in a network-based sectoral state variable. My contribution is two-fold. First, I derive a model-based empirical specification enabling me to estimate sector-specific state dependence across highly disaggregated sectors using detailed sectoral price and quantity data. Second, I provide a theoretical and quantitative analysis of the role of state-dependent pricing in shaping the cost-push effect, showing that it can alter both the size and sign of cost-push inflation. Intuitively, state dependence shapes inflation by inducing strong price adjustments in sectors most impacted by the shock, and not those with unconditionally more flexible prices.

My main result is that state dependence varies strongly across sectors and is generally larger in sectors with inherently more rigid prices, which substantially influences the U.S. cost-push effect, especially during crises. In the post-Covid episode, the state-dependent model attributes nearly the entire inflation increase to the cost-push effect, compared to only half in the non-state-dependent model. Following the Ukraine war, the state-dependent model shows a positive, gradually increasing cost-push inflation, contrasting with a consistently negative effect in the non-state-dependent model. Overall, the state-dependent model attributes 45% of overall inflation fluctuations to the cost-push effect versus 20% in the non-state-dependent model, and significantly outperforms the non-state-dependent model in predicting observed inflation.

The defining feature of my state-dependent New-Keynesian Network model is its analytical tractability, allowing me to isolate the effects of state-dependent pricing by directly comparing the model to its non-state-dependent counterpart. I introduce state-dependent pricing as information friction, combining the sticky information model of Mankiw and Reis (2002) with a heterogeneous inattention framework. As a result of inattention, firms react to large changes in the economic environment while ignoring small changes. In my setup, firms' inattention in each sector is tied to a sector-specific state variable that combines the impact of sectoral shocks on marginal cost occurring either directly or through the production network. This approach reduces a complex multidimensional state to a single sector-specific factor and ensures model tractability. My tractable setup enables a three-step analysis of state-dependent pricing in this paper: 1) empirical estimation of the extent of state-dependent pricing across sectors in the U.S. economy, 2) theoretical examination of the role of state dependence in shaping the cost-push effect, and 3) quantitative assessment of the impact of state-dependent pricing on the cost-push effect in the U.S.

To examine the importance of state-dependent pricing across sectors, I estimate sector-specific price flexibility and its sensitivity to economic conditions by fitting my model to sector-level price and quantity data for the U.S. economy. The model defines price flexibility in each sector through two parameters: average price flexibility reflecting each sector's inherent, time-invariant flexibility, and state-dependence parameter indicating how price flexibility responds to fluctuations in the sector-specific state variable. To estimate these parameters, I derive the model's response of sectoral prices to innovations in the sector-specific state variable, as price response to marginal cost shocks naturally informs about price flexibility—where a stronger response implies greater flexibility and a non-linear response indicates state-dependent adjustment. I construct monthly observations of sector-specific state variables from the observed sectoral data and obtain estimates of the average price flexibility and state-dependence parameters for 370 sectors of the U.S. economy from model-based sector-specific IV regressions.

The key empirical contribution of this paper is a set of highly disaggregated sector-specific estimates of state dependence of pricing friction. I find statistically significant evidence of state dependence in 70% of U.S. sectors, with substantial heterogeneity in both state dependence and average price flexibility across sectors, only the latter of which has been previously documented in the literature. Notably, while average price flexibility tends to increase with sector-specific state volatility, the degree of state dependence exhibits the opposite relationship, indicating that sectors with more stable economic conditions tend to have a higher degree of state-dependent pricing.

To theoretically analyze how state-dependent pricing impacts cost-push inflation I derive an aggregate Phillips curve for consumer price index inflation, where the residual captures the cost-push effect. This residual depends on sectoral price flexibilities, the structure of the production network, and sectoral price gaps – differences between the observed sector-specific prices and their natural counterparts, which reflect the adjustments in a counterfactual flexible-price economy. To address the complex interaction between price rigidity and the production network, I use a decomposition that separates the direct effect, which accounts for the propagation of shocks through the network but abstracts from rigidity propagation, from the additional effect arising due to rigidity propagation. This allows me to establish my main theoretical result: state-dependent pricing can significantly alter the magnitude and even the direction of the cost-push effect, particularly when large shocks hit sectors with low average price flexibility and high state dependence. This result intuitively relies on the direction of relative price adjustment following a sectoral shock, influenced by the differences in price flexibility across sectors. State dependence allows prices to adjust in line with the needs of the most affected sector, as its relative price rigidity drops in response to the shock.

Building on the empirical evidence of state-dependent pricing and its theoretical importance, I assess its quantitative impact on the cost-push effect in the U.S. over time. Using the model-based Phillips curve residual, I compute the monthly cost-push effect, calibrating sector-specific pricing parameters to the estimates of price flexibility and state dependence from the empirical analysis. I also construct a counterfactual cost-push effect by setting the state-dependent component of price flexibility to zero across sectors. I find that state-dependent pricing produces a more volatile cost-push effect over time compared to a non-state-dependent model, with its role varying significantly across historical periods. For example, following the Great Recession, state dependence amplifies a positive cost-push effect driven by an increase in oil prices. By contrast, in the post-Covid period, state dependence often reverses the sign of the cost-push effect. Additionally, I show that the cost-push effect from the state-dependent model offers significant explanatory power for aggregate inflation in a Phillips curve regression, surpassing common proxies like oil price inflation as well as the cost-push effect from a non-state-dependent model. Notably, a subset of service-related sectors, representing less than 25% of the consumption basket, accounts for the bulk of the difference between state-dependent and non-state-dependent cost-push effects.

The paper proceeds as follows. Section 2 reviews the relevant literature. Section 3 develops the New-Keynesian input-output model with state-dependent price rigidity. Section 4 presents a log-linearized version of this model, which serves as the foundation for subsequent analysis. Using the log-linear model alongside disaggregated sectoral data, Section 5 examines sector-specific degrees of price flexibility and state dependence within the U.S. economy. Section 6 then investigates the theoretical role of state-dependent pricing in influencing cost-push inflation. Building on the empirical findings from Section 5 and the theoretical implications for cost-push effects in Section 6, Section 7 provides a quantitative analysis of how state dependence impacts U.S. cost-push inflation over time. Finally, Section 8 concludes the paper.

2 Related literature

This paper relates to the literature on the cost-push effect and the monetary policy trade-offs in multi-sector economies. Aoki (2001) study a two-sector horizontal economy and show that with one sticky and one flexible sector, cost-push inflation arises in response to sector shocks. Erceg et al. (2000) show that upstream rigidity (sticky wages) results in a monetary policy trade-off in a two-sector vertical economy. More recently, La'O and Tahbaz-Salehi (2022) and Rubbo (2023) showed that monetary policy trade-off arises in a more general production network economy under information-related price rigidity and Calvo-type price rigidity respectively. The common feature of this literature is the time-constant degree of price rigidity in each sector. However, Ball and Mankiw (1995) argue that cost-push inflation arises due to a combination of state-dependent price rigidity with asymmetric distribution of desired relative price changes. Building on Ball and Mankiw (1995) conceptual insight, I extend the New-Keynesian production network model to include analytically tractable state-dependent pricing, which allows me to analyze the importance of state dependence for cost-push inflation in a production network economy.

The paper relates the macroeconomic literature on production networks. Seminal contributions include Long Jr and Plosser (1983) and Acemoglu et al. (2012) who develop the framework for efficient production network economies and Baqaee and Farhi (2020), Bigio and La'o (2020) who contribute to the analysis of inefficient network economies with exogenous markups. Similarly to monetary models of La'O and Tahbaz-Salehi (2022) and Rubbo (2023), I endogenize markups by introducing a price rigidity framework. However, in contrast to these papers, I use a price rigidity mechanism based on the combination of the sticky information model and ad-hoc heterogeneous inattention, which allows modeling state-dependent price rigidity at a sectoral level.

The empirical evidence of state-dependent pricing is extensive. Nakamura and Steinsson (2008) show that the frequency of price increases positively depends on inflation in the micro-data underlying the U.S. CPI index. Eichenbaum et al. (2011) and Campbell and Eden (2014) report evidence of the state-dependent frequency of price changes in the U.S. scanner data. Cavallo and Rigobon (2016) report a bi-modal distribution of price changes in online price data, consistent with state-dependent models. Carvalho and Kryvtsov (2021) find evidence of strong selection effect into price adjustment in the micro-data underlying CPI of the U.K., Canada, and the U.S. I contribute to the existing evidence of state-dependent price adjustment by providing sector-specific measures of state-dependence. While existing evidence largely relies on micro-level data, my estimation method relies on a production network model combined with sectoral price and quantity data.

In terms of the approach towards modeling state-dependent price rigidity, my paper belongs to sticky information literature by Mankiw and Reis (2002) as well as behavioral inattention literature, see Gabaix (2019) as my state-dependent price rigidity combines these two approaches. Compared to the two conventional rationality-based frameworks – the menu-cost approach of Dotsey et al. (1999), Caballero and Engel (2007) and rational inattention approach of Sims (2003), Reis (2006) – my model remains analytically tractable due to simplifying behavioral assumptions.

This paper broadly relates to the literature on money non-neutrality. Nakamura and Steinsson (2010) show that intermediate inputs can fix the weak money non-neutrality feature of menu-cost models brought up by Caplin and Spulber (1987), Golosov and Lucas Jr (2007). The ability of intermediate inputs to increase money non-neutrality by affecting the slope of the Phillips curve has also been documented for production network models with a heterogeneous but time-invariant degree of price rigidity by Shamloo (2010), Bouakez et al. (2014) and Pasten et al. (2020). In contrast to this literature, the main focus of this paper is on the role of state-dependent pricing for cost-push inflation rather than aggregate demand. However, I briefly investigate the quantitative importance of state dependence in shaping the slope of the Phillips curve.

Finally, this paper relates to the literature on the propagation of shocks in multi-sector monetary economies. The importance of the production network for shock propagation in such economies has been investigated by Ozdagli and Weber (2017); Ghassibe (2021) for monetary shocks, and Pasten et al. (2021); Ruge-Murcia and

Wolman (2022); Ferrante et al. (2023) for sectoral shock. In contrast to this literature, I focus on the role of state-dependent pricing in the propagation of sectoral shocks.

3 Model description

In this section, I present the framework employed throughout the paper – a New-Keynesian input-output network model in the spirit of La'O and Tahbaz-Salehi (2022) and Rubbo (2023). My version of the model has two distinguishing features compared to previous literature: 1) sector-specific labor, allowing sector-specific wages, and 2) state-dependent price rigidity framework. My pricing framework combines the sticky information model of Mankiw and Reis (2002) with behavioral inattention, enabling an analytically tractable approach to state-dependent price rigidity and facilitating comparison with a corresponding non-state-dependent pricing model. Next, I describe the model setup.

3.1 Firms

The production side of the economy consists of N sectors. In each sector, there is a continuum of monopolistically competitive firms indexed by $k \in [0,\ 1]$. Sectoral output and price indices are the CES sums across all firms within a sector given by $Y_{t,i} = \left(\int_0^1 Y_{t,i,k}^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}}$ and $P_{t,i} = \left(\int_0^1 P_{t,i,k}^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}$ respectively where $Y_{t,i,k}$ and $P_{t,i,k}$ are k-th firm output and price respectively and ϵ is the elasticity of substitution between firm-specific goods within a sector. The firm-specific demand is given by

$$Y_{t,i,k} = \left(\frac{P_{t,i,k}}{P_{t,i}}\right)^{-\epsilon} Y_{t,i} \tag{1}$$

Production technology is sector-specific, has constant returns-to-scale, and is given by

$$Y_{t,i,k} = A_{t,i} L_{t,i,k}^{\alpha_i} \prod_j X_{t,ij,k}^{\omega_{ij}(1-\alpha_i)}$$

where $A_{t,i}$ is sector-specific productivity, $L_{t,i,k}$ is the amount of labor used by firm k of sector i, $X_{t,ij,k}$ is the amount of input from sector j used by firm k in sector i; α_i corresponds to the labor share in the total production costs; ω_{ij} corresponds to the share of input j in the intermediate input costs.

The optimal combination of inputs in each sector is chosen to minimize the unit cost of production, given input prices. Let $MC_{t,i}$ be the marginal cost in sector i, which is the same for all firms within a sector. Cost-minimizing resource allocation yields sectoral labor demand and intermediate input demand given by

$$W_{t,i}L_{t,i} = \alpha_i \cdot MC_{t,i}Y_{t,i} \tag{2}$$

$$P_{t,j}X_{t,ij} = (1-\alpha_i)\omega_{ij} \cdot MC_{t,i}Y_{t,i} \tag{3}$$

where $W_{t,i}$ is the sector-specific wage. Then, the marginal cost of production in sector i is given by

$$MC_{t,i} = \frac{\bar{A}_i}{A_{t,i}} \cdot W_{t,i}^{\alpha_i} \prod_j P_{t,j}^{\omega_{ij}(1-\alpha_i)} \tag{4}$$

where $\bar{A}_i = \frac{1}{\alpha_i^{\alpha_i} \prod\limits_j (\omega_{ij}(1-\alpha_i))^{\omega_{ij}(1-\alpha_i)}}$.

Firms have imperfect information about their true marginal costs. Let me denote the marginal cost belief of firm k in sector i as $\widetilde{MC}_{t,i,k}$. The description of the information structure shaping this belief is postponed until the next subsection. Given this belief, firm sets its price $P_{t,i,k}$ to maximize its perceived profits

$$P_{t,i,k}Y_{t,i,k} - (1-\bar{\tau})\widetilde{MC}_{t,i,k}Y_{t,i,k}$$

subject to the demand constraint (1). Here $\bar{\tau} = \frac{1}{\epsilon}$ is a standard subsidy correcting the inefficiency stemming from monopoly power and ensuring that information-induced price rigidity is the only source of inefficiency in this economy. The price set by the firm k equals the perceived marginal cost

$$P_{t,i,k} = \widetilde{MC}_{t,i,k}$$

This price can be expressed as as a function of true marginal cost as $P_{t,i,k} = \frac{\widetilde{MC}_{t,i,k}}{MC_{t,i}} MC_{t,i}$ where undesired firm-specific markup $\frac{\widetilde{MC}_{t,i,k}}{MC_{t,i}}$ results from the information friction. Let me denote by $\mathcal{M}_{t,i}$ the average sector-specific markup in sector i such that

$$P_{t,i} = \mathcal{M}_{t,i} \cdot MC_{t,i} \tag{5}$$

Sector-specific markups capture the sectoral inefficiencies present in this model.

3.2 Information structure

Information updating by firms relies on a sticky information framework of Mankiw and Reis (2002) extended with ad-hoc heterogeneous inattention across firms. This extension allows for state-dependent intensity in information updating, which in turn results in state-dependent price flexibility.

3.2.1 Sticky information

Let $F_{t,i}$ be the share of firms in sector i that update their information in period t. Accordingly, the share of firms that last updated their information one period ago is $F_{t-1,i} \cdot (1 - F_{t,i})$. The share of firms that last updated h periods ago is $F_{t-h,i} \cdot \prod_{s=0}^{h-1}(1 - F_{t-s,i})$. Firms that update their information in period t observe the true sectoral marginal costs $MC_{t,i}$ and set their prices to $P_{t,i|t} = MC_{t,i}$. Those who last updated their information h periods ago set their prices based on the perceived marginal costs according to information that is h periods outdated: $P_{t,i|t-h} = E_{t-h}MC_{t,i}$. The average price in sector i is a composite of the individual prices set by firms, each reflecting the information available at the time of their last update

$$P_{t,i}^{1-\epsilon} = F_{t,i} \cdot (MC_{t,i})^{1-\epsilon} + \sum_{h=1}^{\infty} \left\{ \left[\prod_{s=0}^{h-1}(1 - F_{t-s,i}) \right] \cdot F_{t-h,i} \cdot (E_{t-h}MC_{t,i})^{1-\epsilon} \right\} \tag{6}$$

3.2.2 Inattention

In a conventional sticky information model, the share of firms updating their information remains constant over time. In contrast, my model assumes that this share varies with fluctuations in the underlying *sector-relevant state* variable $s_{i,t}$. Changes in this sector-relevant state variable lead to time-varying intensity in information acquisition. I select an appropriate state variable for each sector based on the log-linear characterization of the model equilibrium. Therefore, I postpone the precise definition of $s_{t,i}$ until the next section. Now I describe the inattention framework.

Let firms in sector i exhibit heterogeneous degrees of inattention. Specifically, in each period, the degree of inattention of firm k in sector i is drawn from a sector-specific distribution $x \sim F_i$. Firms monitor the absolute size of fluctuations in the sector-relevant state variable $|\Delta s_{t,i}|$, where $\Delta s_{t,i} = s_{t,i} - s_{t-1,i}$. Only firms with a degree of inattention x that is less than $|\Delta s_{t,i}|$ update their information. Consequently, the share of firms updating their information in sector i is given by

$$F_{t,i} = Pr\{x < |\Delta s_{t,i}|\} = F_i(|\Delta s_{t,i}|) \tag{7}$$

Large changes in the sector-relevant state encourage more firms to update their information. Consequently, the time-varying share of firms updating their information in each sector corresponds to the state-dependent sectoral price flexibility. This approach enables the study of state-dependent pricing while maintaining the model's tractability.[1]

It's worth noticing that my inattention model aligns with behavioral inattention frameworks, such as those by Gabaix (2019), rather than with the rational inattention models such as Sims (2003); Reis (2006); Maćkowiak and Wiederholt (2009) among others. This choice prioritizes analytical tractability over fully capturing the specifics of the inattention mechanism. In doing so, the non-state-dependent version of my model closely resembles a Calvo-type price stickiness model, except for the expectation formation, which is orthogonal to my analysis of the Phillips curve's cost-push term. This setup allows for a direct comparison between the predictions of the state-dependent model and a non-state-dependent one keeping in mind that the latter mimics the standard Calvo framework.

3.3 Households

A representative household decides on its final consumption good Y_t and the number of hours worked $L_{t,i}$ in each sector in each sector to maximize its expected lifetime utility, given the budget constraint. The expected lifetime utility of the household is given by

$$E_0 \sum_{t=0}^{\infty} \delta^t \left\{ \log(Y_t) - \sum_i e^{\chi_{t,i}} \cdot \frac{(L_{t,i})^{1+\gamma}}{1+\gamma} \right\}$$

The final consumption Y_t good is a combination of sector-specific consumption goods $C_{t,i}$ given by

$$Y_t = \prod_i C_{t,i}^{\beta_{t,i}} \tag{8}$$

with $\sum_i \beta_{t,i} = 1$. The parameters for sectoral labor and consumption preferences, denoted as $\chi_{t,i}$ and $\beta_{t,i}$, may exogenously vary over time, as indicated by the subscript t.[2] The household's budget constraint is as follows

$$P_t C_t + Q_t B_t = B_{t-1} + \sum_i W_{t,i} L_{t,i} + T_t$$

[1] A similar technique for modeling partial adjustment within a group has been applied in generalized menu-cost models. In these models, the cost of price adjustment is heterogeneous across firms, which results in partial price adjustment (Caballero and Engel (2007)).

[2] This time variability introduces additional sources of fluctuations into the model, beyond those induced solely by sectoral productivity shocks. This allows for the inclusion of more data in the model-based empirical analysis discussed in the next section, helping to assess the robustness of the baseline results.

where P_t is the consumer price index, B_t is a riskless discount bond which trades at price Q_t, and T_t are net transfers, including lump sum taxes and subsidies as well as profits from firm ownership. Optimal allocation of consumption across sectors yields sectoral consumption demand

$$P_{t,i}C_{t,i} = \beta_{t,i} \cdot P_t Y_t \tag{9}$$

with the consumer price index given by $P_t = \prod_i \left(\frac{P_{t,i}}{\beta_{t,i}}\right)^{\beta_{t,i}}$. Optimal consumption-leisure trade-off yields sectoral labor supply

$$W_{t,i} = e^{\chi_{t,i}} \cdot L_{t,i}^{\gamma} P_t Y_t \tag{10}$$

3.4 Monetary policy

Monetary policy controls aggregate nominal spending by controlling money supply, that is[3]

$$P_t \cdot Y_t = M_t \tag{11}$$

3.5 Equilibrium

In a competitive equilibrium, all markets clear, given the optimal behavior of firms and households. Product market clearing in sector i implies that the product of sector i is either consumed or used as an intermediate input, that is

$$Y_{t,i} = C_{t,i} + \sum_j X_{t,ji} \tag{12}$$

4 Log-linear model

I log-linearize the model around the efficient steady state. An efficient steady state is a time-invariant equilibrium in which markups are $\mathcal{M}_i = 1$ for every sector i.

Let me define the cost-based input-output matrix Ω such that its ij-the element Ω_{ij} is a share of input j in the total cost of producing output i, $\Omega_{ij} = (1 - \alpha_i)\omega_{ij}$. Then $L = (I - \Omega)^{-1}$ denotes the corresponding *Leontief inverse* matrix, see Baqaee and Farhi (2020). Throughout the paper, I denote column vectors $[X_1, ..., X_N]'$ with

[3] This condition can be also interpreted and a cash in advance constant imposed on a demand side, see La'O and Tahbaz-Salehi (2022).

corresponding bold letters $\boldsymbol{X}$. Log-deviation of X from the steady state is denoted by small x, that is $x = log(X) - log(\bar{X})$.

Next, I present the key log-linear equations used in the subsequent analysis. Detailed derivations can be found in Appendix A. The model consists of two conceptual blocks of equations: the demand block and the supply block. The demand block is independent of the price-setting framework and price flexibility, while the supply block is influenced by the price-setting framework.

4.1 Sectoral demand system

Log-linear systems of sectoral consumption demand and sectoral labor supply are obtained from Equations (9) and (10) and given by

$$\boldsymbol{p_t} + \boldsymbol{c_t} = \boldsymbol{b_t} + (p_t + y_t) \cdot \mathbf{1} \tag{13}$$

$$\boldsymbol{w_t} = \boldsymbol{\chi_t} + \gamma \cdot \boldsymbol{l_t} + (p_t + y_t) \cdot \mathbf{1} \tag{14}$$

where $p_t + y_t = m_t$ is aggregate nominal spending, $\boldsymbol{b_t} = log(\boldsymbol{\beta_t}) - \log(\bar{\boldsymbol{\beta}}_{\boldsymbol{t}})$ captures sectoral consumption demand shifts, and $\boldsymbol{\chi_t}$ captures sectoral labor supply shifts; $\mathbf{1}$ is the vector of ones. As described above, bold letters represent column vectors ($\boldsymbol{p_t}$ is vector of sectoral prices, $\boldsymbol{c_t}$ sectoral consumptions, $\boldsymbol{w_t}$ sectoral wages, $\boldsymbol{l_t}$ sectoral hours worked).

Sectoral wages. The system of equations describing the log-linear link between wages and markups is obtained by combining the product market clearing condition (12) with the conditions for the optimal input allocation (2)-(3), the link between sectoral prices and marginal costs (5), and the log-linear consumption demand and labor supply systems (13)-(14). The resulting system of equations is given by

$$\boldsymbol{w_t} = (p_t + y_t) \cdot \mathbf{1} + \frac{1}{1+\gamma} \cdot \boldsymbol{\chi_t} + \frac{\gamma}{1+\gamma} I_\xi^{-1} L' I_\beta \cdot \boldsymbol{b_t} - \frac{\gamma}{1+\gamma} I_\xi^{-1} L' I_\xi \cdot \boldsymbol{\mu_t} \tag{15}$$

where $\boldsymbol{\mu_t}$ is a vector of log-deviations of sectoral markups, $L = (I - \Omega)^{-1}$ is the Leontief inverse of the input-output matrix Ω, $I_\xi = diag\{\boldsymbol{\xi}\}$ is the diagonal matrix with sectoral steady-state *Domar weights* ξ_i on the diagonal.[4]

[4] Domar weights quantify the size of a sector based on its sales share relative to total final sales. Specifically, the Domar weight for sector i is given by $\xi_i = \frac{P_i Y_i}{PC}$, as detailed in Baqaee and Farhi (2020). I compute Domar weights ξ_i at the efficient steady state, where the cost-based and revenue-based Domar weights are equivalent.

Sectoral prices. The system of equations describing the log-linear link between sectoral prices and sectoral markups is obtained by combining sectoral marginal cost equations (4), log-linear wage equations (15) and the definition of sectoral markups (5). The resulting system of equations is

$$\boldsymbol{p_t} = (p_t + y_t) \cdot \mathbf{1} + \tilde{L}\boldsymbol{\mu_t} + \left[-L\boldsymbol{a_t} + \frac{1}{1+\gamma} L I_\alpha \cdot \boldsymbol{\chi_t} + \frac{\gamma}{1+\gamma} L I_\alpha I_\xi^{-1} L' I_\beta \cdot \boldsymbol{b_t} \right] \quad (16)$$

where $\tilde{L} = L(I - \frac{\gamma}{1+\gamma} I_\alpha I_\xi^{-1} L' I_\xi)$, $I_\alpha = diag\{\boldsymbol{\alpha}\}$ is diagonal matrix with labor shares in sectoral costs α_i on the diagonal. Aggregating the above system with the steady-state consumption weights $\boldsymbol{\beta}$, I obtain aggregate final output

$$y_t = \boldsymbol{\xi'} \cdot \boldsymbol{a_t} + \frac{1}{1+\gamma} \boldsymbol{\xi'} I_\alpha \cdot \boldsymbol{\chi_t} - \frac{1}{1+\gamma} \boldsymbol{\xi'} \cdot \boldsymbol{\mu_t} \quad (17)$$

where the first two terms $y_t^e = \boldsymbol{\xi'} \cdot \boldsymbol{a_t} + \frac{1}{1+\gamma} \boldsymbol{\xi'} I_\alpha \cdot \boldsymbol{\chi_t}$ constitute the efficient output and the third term $\tilde{y}_t = -\frac{1}{1+\gamma} \boldsymbol{\xi'} \cdot \boldsymbol{\mu_t}$ represents the output gap arising due to non-zero markups (this consumption-based combination of markups captures the standard aggregate demand arising in New-Keynesian models).

4.2 Sector-relevant state definition

From the sectoral price system (16), the sectoral marginal cost obtains as $mc_{t,i} = p_{t,i} - \mu_{t,i}$, which in vector form yields the following system of equations

$$\boldsymbol{mc_t} = (p_t + y_t) \cdot \mathbf{1} + (\tilde{L} - I) \cdot \boldsymbol{\mu_t} + \left[-L\boldsymbol{a_t} + \frac{1}{1+\gamma} L I_\alpha \cdot \boldsymbol{\chi_t} + \frac{\gamma}{1+\gamma} L I_\alpha I_\xi^{-1} L' I_\beta \cdot \boldsymbol{b_t} \right] \quad (18)$$

In the system (18), the term in square brackets represents the equilibrium effect of exogenous sector-specific shocks on the sectoral marginal cost, given a fixed level of money supply and sectoral markups.These shocks can stem from changes in sectoral productivity $\boldsymbol{a_t}$, sectoral consumption demand $\boldsymbol{b_t}$, or sectoral labor supply $\boldsymbol{\chi_t}$. I use this term in square brackets to define the sector-relevant state variable $s_{t,i}$ for every sector. The corresponding sector-relevant state vector is

$$\boldsymbol{s_t} = -L\boldsymbol{a_t} + \frac{1}{1+\gamma} L I_\alpha \cdot \boldsymbol{\chi_t} + \frac{\gamma}{1+\gamma} L I_\alpha I_\xi^{-1} L' I_\beta \cdot \boldsymbol{b_t} \quad (19)$$

Definition 1 (Sector-relevant state)**.** Sector-relevant state for sector i, denoted as $s_{t,i}$, is a linear combination of sectoral productivities, sectoral consumption demand shifters, and sectoral labor supply shifters. In this combination, each sector is weighted according to the strength of its impact on the marginal costs in sector i.

Note that the weights are related to the Leontief inverse matrix. Intuitively, if sector i is strongly connected to sector j within the input-output network, then the changes in sector j will impact the marginal cost in sector i. This means that shocks in sector j are relevant for the marginal cost in sector i.

The change in the relevant state over time is given by

$$\boldsymbol{\Delta s_t} = \boldsymbol{s_t} - \boldsymbol{s_{t-1}} \tag{20}$$

and the sectoral price flexibility depends on the absolute size of this change, that is $F_{t,i} = F_i(|\Delta s_{t,i}|)$, as described in the previous section.

Finally, I assume that all exogenous forces in the model follow random walks, that is, $\boldsymbol{a_t} = \boldsymbol{a_{t-1}} + \boldsymbol{\epsilon_t^a}$, $\boldsymbol{b_t} = \boldsymbol{b_{t-1}} + \boldsymbol{\epsilon_t^b}$, and $\boldsymbol{\chi_t} = \boldsymbol{\chi_{t-1}} + \boldsymbol{\epsilon_t^\chi}$. Then, the change in the sector-relevant state constitutes an innovation, that is $Cov(\Delta s_{t,i},\ s_{t-1,i}) = 0$.

4.3 Sectoral supply system

The price-setting behavior subject to information friction yields the log-linear supply-side link between sectoral prices and sectoral markups, as derived from Equations (6)-(5). In this derivation, I use partial log-linearization, treating all $F_{t-s,i}$ as time-varying coefficients.[5] The resulting system of equations is

$$(I - F_t) \cdot (\boldsymbol{p_t} - \boldsymbol{p_{t-1}}) = -F_t \cdot \boldsymbol{\mu_t} + (I - F_t) \cdot \boldsymbol{e_{t-1}} \tag{21}$$

where F_t is a diagonal matrix with sectoral flexibililities $F_{t,i}$ on the main diagonal (the parameters governing $F_{t,i}$ are estimated in the next section); $\boldsymbol{e_{t-1}}$ is vector collecting past expectations about the present marginal cost growth, such that $e_{t-1,i} = F_{t-1,i}E_{t-1}\Delta mc_{t,i} + \sum_{h=1}^{\infty}\left\{F_{t-1-h,i} \cdot \left[\prod_{s=0}^{h-1}(1 - F_{t-1-s,i})\right] \cdot E_{t-1-h}\Delta mc_{t,i}\right\}$ is predetermined in period t, $\Delta mc_{t,i} = mc_{t,i} - mc_{t-1,i}$. The sequence $\{F_{h,i}\}_{h=-\infty}^{t}$ of past and present shares of information updating firms is treated as given in this log-linearization.[6] The system of equations (21) provides the equilibrium price-markup

[5] This approach is possible because $F_{t-s,i}$ depend solely on the past or present realized sector-relevant state variables which are fully exogenous.

[6] Note that in the sticky information framework, prices depend not on current expectations about the future, but on the past expectations about the present. This means that the sequence of past price flexibility, rather than the expected sequence of future price flexibility, influences the equilibrium prices.

link through which sectoral markups are made endogenous.

5 Empirical evidence of state-dependent pricing

In this section, I estimate the sector-specific price flexibility and its state dependence for the U.S. economy. To do this, I parameterize sector-specific price flexibility $F_i(|\Delta s_{t,i}|)$ to include both non-state-dependent and state-dependent components. I then derive the model's response of sectoral prices to sector-relevant state innovations. This response reveals the properties of price flexibility: a strong response indicates more flexible prices, while a non-linear response indicates state dependence. Since the sector-relevant state variable is unobserved, I construct it from the demand block of the model using the observed monthly series for sectoral price and quantity data. By estimating the model's price response to sector-relevant state innovations, I obtain estimates for price flexibility and its state dependence in each sector. Next, I describe the methodology, data construction, and estimation process. Then I present the estimation results.

5.1 Methodology

This subsection lays out the derivation of the econometric specification based on the model price response to sector-relevant state innovation. From the demand system (16), the sectoral price vector is related to the sector-relevant state vector as $\boldsymbol{s_t}$ as

$$\boldsymbol{p_t} = m_t \cdot \mathbf{1} + \tilde{L} \cdot \boldsymbol{\mu_t} + \boldsymbol{s_t}$$

The above system implies that the contemporaneous response of sectoral prices to sector-relevant state innovations, $\boldsymbol{\Delta s_t}$, includes both a direct effect and the indirect effects through changes in sectoral markups and monetary policy, with changes in markups arising due to the presence of price rigidity. Combining the demand system (16) with the supply system (21) we obtain the link between sectoral price changes $\boldsymbol{\Delta p_t} = \boldsymbol{p_t} - \boldsymbol{p_{t-1}}$ and sector-relevant state innovations $\boldsymbol{\Delta s_t}$ given by

$$(I + \tilde{L}F_t^{-1}(I - F_t)) \cdot (\boldsymbol{\Delta p_t} - \boldsymbol{e_{t-1}}) = \boldsymbol{\Delta s_t} + \boldsymbol{\tilde{v}_t} \tag{22}$$

where $\boldsymbol{\tilde{v}_t} = m_t \cdot \mathbf{1} + \boldsymbol{s_{t-1}} - \boldsymbol{p_{t-1}} - \boldsymbol{e_{t-1}}$. See Appendix C for derivations. Note, that the term $\boldsymbol{\tilde{v}_t}$ contains only predetermined variables $\boldsymbol{p_{t-1}}$, $\boldsymbol{s_{t-1}}$, $\boldsymbol{e_{t-1}}$ and monetary policy variable m_t, and, hence, is independent of $\boldsymbol{\Delta s_t}$ as long as the monetary policy does not react to $\boldsymbol{\Delta s_t}$ within one month period (I use monthly data for estimation).

Even if sector-relevant state innovations $\boldsymbol{\Delta s_t}$ were observed, estimating the price flexibility parameters contained in the matrix F_t from the system (22) is a non-trivial task since this system consists of N equations intertwined by the presence of production network. To see how the production network affects the system (22), consider a special case of a quasi-horizontal production structure without cross-sectoral input-output links ($\tilde{L} = I$). In this case, the system (22) can be re-written as $\boldsymbol{\Delta p_t} = F_t \cdot \boldsymbol{\Delta s_t} + \boldsymbol{v_t}$ (where $\boldsymbol{v_t} = F_t \cdot \boldsymbol{\tilde{v}_t} + \boldsymbol{e_{t-1}}$). Since the matrix of sectoral price flexibilities F_t is diagonal, the system turns into a system of independent equations, which can be estimated equation-by-equation – one equation for each sector (that is, $\Delta p_{t,i} = F_{t,i} \cdot \Delta s_{t,i} + v_{t,i}$). The response of sector i price to sector i relevant-state innovation captures the sectoral price flexibility in sector i.

Now I build a similar system of independent sector-specific equations for the general case ($\tilde{L} \neq I$). Rearranging the terms in the system (22) yields the following system of independent sector-specific equations

$$\boldsymbol{\Delta p_t} = F_t \cdot [\tilde{L}^{-1}\boldsymbol{\Delta s_t} + (I - \tilde{L}^{-1})\boldsymbol{\Delta p_t}] + \boldsymbol{v}_t \tag{23}$$

where $\boldsymbol{v}_t = F_t \cdot [\tilde{L}^{-1}\boldsymbol{\tilde{v}_t} - (I - \tilde{L}^{-1})\boldsymbol{e_{t-1}}] + \boldsymbol{e_{t-1}}$. Since the matrix F_t is diagonal with sectoral price flexibilities $F_{t,i} = F_i(|\Delta s_{t,i}|)$ on the main diagonal, i-th equation in the above system contains only sector i price flexibility parameters, meaning that this system can be estimated equation-by-equation, with one equation per sector.

I impose a linear functional form on sectoral price flexibility such that it consists of the non-state-dependent and state-dependent components

$$F_i(|\Delta s_{t,i}|) = \bar{F}_i + f_i \cdot log\frac{|\Delta s_{t,i}|}{E|\Delta s_{t,i}|} \tag{24}$$

where $E|\Delta s_{t,i}|$ is the average absolute size of the relevant productivity state fluctuations (relevant state volatility). With this functional form, the parameter $\bar{F}_i$ corresponds to the average price flexibility over time in sector i, that is, the degree of price flexibility under the average size of sector-relevant state fluctuations in sector i. The parameter f_i measures the degree of state dependence in price adjustment. This parameter shows how much price flexibility varies with the size of the absolute changes in the sector-relevant state. The goal of the empirical exercise is to estimate the average price flexibility $\bar{F}_i$ and the degree of state dependence f_i for each sector of the U.S. economy. For an economy with N sectors, there are $2 \times N$ parameters to be estimated.

Returning back to the system of independent equations (23), let us denote its left-hand-side variables as $\boldsymbol{y_t} = \boldsymbol{\Delta p_t}$ and the corresponding right-hand-side variables as $\boldsymbol{x_t} = \tilde{L}^{-1}\boldsymbol{\Delta s_t} + (I - \tilde{L}^{-1})\boldsymbol{\Delta p_t}$. Using the parameterized function F_i, I obtain N sector-specific equations of the form

$$y_{t,i} = \bar{F}_i \cdot x_{t,i} + f_i \cdot log\frac{|\Delta s_{t,i}|}{E|\Delta s_{t,i}|}x_{t,i} + v_{t,i} \tag{25}$$

These equations can be estimated independently from each other. The only complication is that $x_{t,i}$ is endogenous as it contains the (endogenous) sectoral price changes. At the same time, the sector-relevant state changes $\Delta s_{t,i}$ are exogenous and can serve as an instrument for $x_{t,i}$. In Appendix C, I formally show that $\Delta s_{t,i}$ is not correlated with the residual $v_{t,i}$ and hence is a valid instrument for $x_{t,i}$.

Estimating N sector-specific equations (25) using IV approach yields a set of average sectoral flexibilities $\{\bar{F}_i\}_{i=1}^N$ measuring non-state-dependent price flexibility, and a set of sensitivities to sector-relevant state changes $\{f_i\}_{i=1}^N$ measuring the degree of state-dependence of price flexibility in each sector. Since $v_{t,i}$ is heteroskedastic and autocorrelated I use consistent standard errors to determine estimate statistical significance.

5.2 Constructing sector-relevant states

The empirical method described above requires a set of sector-relevant state innovations $\boldsymbol{\Delta s_t}$ which I construct from the demand block of the model using the observed monthly price and quantity data. Next, I lay out the details of this construction.

First, let us assume that sectoral productivity changes are the only driving force in the economy, that is $b_{t,i} = 0$ and $\chi_{t,i} = 0$ for all sectors. In what follows I refer to such specification of the model as "baseline". In the "baseline" model, we can compute sectoral markups $\boldsymbol{\mu_t}$ from the system (15) and then use them to compute sector-relevant state variables $\boldsymbol{s_t}$ from the system (16), as long as we observe sectoral wages $\boldsymbol{w_t}$, sectoral prices $\boldsymbol{p_t}$, as well as aggregate consumer price p_t and final consumption y_t. This is a minimal possible set of the data needed for estimation.

Accounting for the possible additional presence of sectoral consumption demand shocks and sectoral labor supply shocks ($b_{t,i}$ and $\chi_{t,i}$) requires more data on sectoral quantities. Sectoral demand shifts $\boldsymbol{b_t}$ can be computed from sectoral consumption demand equations (13), as long as we additionally observe sectoral consumption $\boldsymbol{c_t}$.

Sectoral labor supply shifts $\boldsymbol{\chi_t}$ can be computed from sectoral labor supply equations (14), as long as we additionally observe sectoral hours worked $\boldsymbol{l_t}$. I employ this extended specification together with these additional monthly quantity series to test the robustness of the "baseline" results to the model specification.

When constructing the relevant-state measures, the caveat is that some sectors are missing in the data and the number of missing sectors changes over time. Hence for any t, I compute sectoral markups $\boldsymbol{\mu_t}$ and corresponding sector-relevant states $\boldsymbol{s_t}$ only for those sectors for which both wages and prices are observed. The details of these computations are provided in Appendix C.

5.3 Data

The data used in this analysis can be divided into two broad groups: the data used for model calibration and the sectoral and aggregate monthly time-series data used for estimating price flexibility.

Model calibration. To compute the intermediate goods, labor, and consumption shares in each sector, I employ the 2007 "Use table" from the BEA (US Bureau of Economic Analysis) inputs-outputs account data. In this table, sectors are classified using BEA codes. In what follows I bring all the sector-specific series to this classification to make them compatible with the available production network structure. I assume that each sector produces only one commodity, and remove those commodities that do not have a sector correspondence and vice-versa. Further, I remove sectors related to government spending, non-comparable imports, and the rest of the world adjustment. I also remove sectors for which the sum of intermediate and labor costs is zero. I compute labor shares in each sector as a ratio of labor costs to total costs. I compute intermediate input share as a ratio of a given intermediate input cost to the total cost. Finally, I compute consumption shares as the ratio of consumption expenditure in a given sector to the total consumption expenditure. I set the Frisch labor supply elasticity to 1.

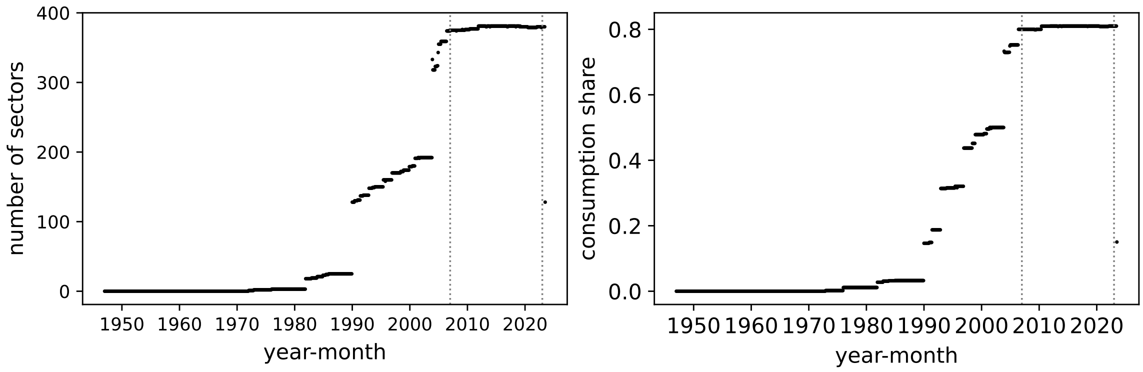
Sectoral/aggregate time series. To construct model-implied sector-relevant state series in the "baseline" model, I employ monthly time series for sectoral wages and prices, and the aggregate prices and consumption indices. Monthly wages by sector are available from the "Current Employment Statistics" (CES) from the U.S. BLS and classified with a specific CES classification. Monthly sectoral producer price indices are from the U.S. BLS and classified according to the NAICS classification.

Since the BEA input-output matrix uses BEA sector classification codes, I convert the wage and price data to the BEA classification to match the sectors of the input-output matrix. The details are provided in Appendix C. The aggregate consumption spending and its price index are from BEA.

The extended specification of the model also requires sectoral consumption and hours worked data. I take the former from the BEA database and the latter from the CES database.

Figure 1 plots the number of sectors for which both prices and wages are available in a given year and month (left Panel) and the consumption share coverage (right Panel) for each year and month. The data availability improves over time and starts covering the majority of sectors by 2007. Due to this data availability constraint, my analysis focuses on the period after 2007. For this period ∼370 sectors are available covering ∼80% of consumption basket.

Figure 1: Availablility of sectoral price and wage data



Left Panel: number of sectors for which price and wage observations are available in a given month. **Right Panel**: share of consumption covered by the available sectors in a given month. Vertical dotted lines mark the period for which the large and stable number of sectors is available (2007-2023).

5.4 Estimation results

The estimation procedure yields two sets of sectoral parameters: sectoral average price flexibility measures $\bar{F}_i$ and sectoral state dependence of price flexibility f_i. These parameters determine sectoral price flexibility $F_{t,i}$ at time t according to Equation (24). Table 1 shows the share of sectors with statistically significant parameter estimates. Around 85% of sectors have a statistically significant degree of average price flexibility, suggesting that even within a short one-month period most sectoral prices react to shocks to a certain extent. Around 70% sectors have a statistically significant degree of state dependence, meaning that the majority of sectors in the U.S. economy (weighted by consumption share) feature some degree fo state dependence in price adjustment.

Table 1: Share of statistically significant estimates

	signif. at 90% level	signif. at 95% level
Average flex. ($\bar{F}_i$)	0.85	0.84
State-dep. param. (f_i)	0.70	0.64

Note: Sectors are weighted by their corresponding consumption shares β_i

Table 2 plots a summary of the cross-sectoral distribution of estimated parameters. The estimates of average price flexibility vary between 0 and 1 with a median of around 0.27, which means that in the median sector around 27% of firms reset their information within one month period; in other words, in the median sector, prices remain unchanged at least for four months, which corresponds to the evidence of Bils and Klenow (2004) who report median price duration of 4.3 months. However, the range of the average price flexibility estimates across sectors is quite broad. The distribution of state dependence parameters suggests the median degree of state dependence of 0.19, which means that a sectoral shock of size exceeding the average size by 1 standard deviation, leads to an additional increase in sectoral price response of 19 percent compared to a non-state-dependent pricing framework.

Figure 2 Panel (a) plots the histogram of the average price flexibility estimates in each sector. The pattern of average price flexibility suggests that commodity-related and upstream sectors such as oil and metals have more flexible prices, while various downstream manufacturing and services sectors have less flexible prices. Figure 2 Panel (b) plots the histogram of the cross-sectoral distribution of state dependence estimates. Sectors with both low and high degrees of state dependence include manufacturing and services, hence this histogram does not reveal any obvious pattern for the link between state dependence and the broad type of sector.

Table 2: Distribution of statistically significant estimates

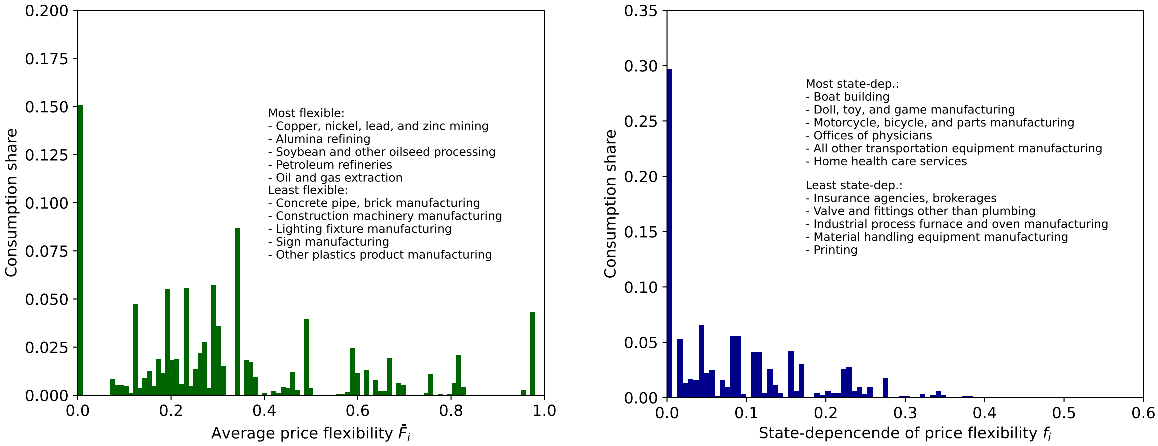
	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Average flex. ($\bar{F}_i$)	0.052	0.177	0.277	0.349	0.473	0.989
State-dep. param. (f_i)	0.013	0.092	0.189	0.203	0.293	0.663

Note: Only sectors with statistically significant estimates at 90% level.

Figure 2: Price flexibility estimates

(a) Average price flexibility

(b) State-dependence of price flexibility

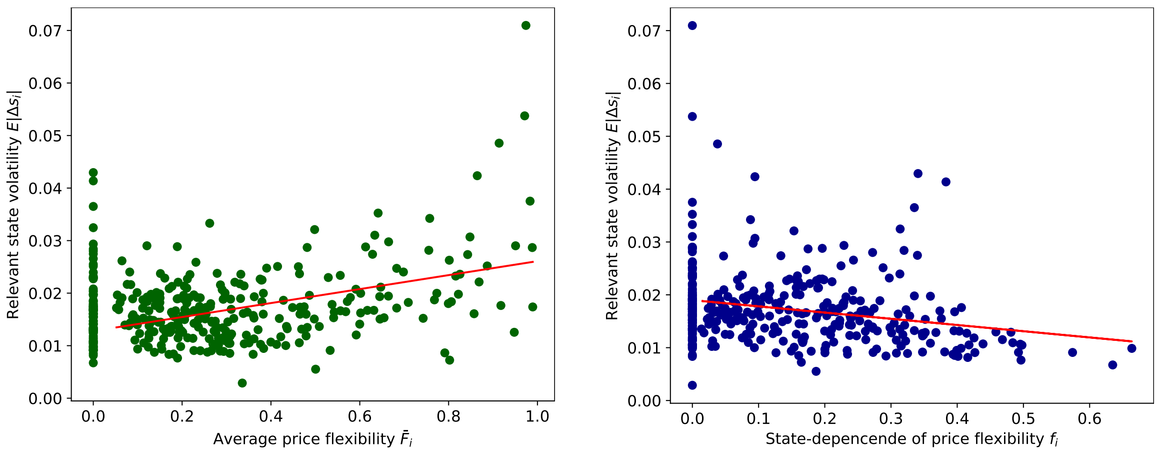


Histogram of average price flexibility estimates $\bar{F}_i$ (a) and state-dependence parameter estimates f_i (b) across 364 sectors; sectors are weighted by consumption shares β_i; variation is plotted only for 90%-level significant estimates; **estimates insignificant at 90% level are forced to zero**; interpretation of state-dependence parameter f_i: 1.p.p. increase in $|\Delta s_{t,i}|$ above its time average leads to price flexibility increase of $0.01 \cdot f_i$.

The state-dependent pricing literature emphasizes the positive link between price flexibility and economic volatility, see Vavra (2014). Next, I analyze how my average price flexibility and the state dependence parameters estimates relate to the volatility of the sector-relevant state. Figure 3 plots the parameter estimates against the corresponding relevant state volatilities. From Panel (a) we see that the higher average volatility in a sector is associated with higher average price flexibility and the cross-sectoral correlation is 0.43. This suggests that sectors with more volatile conditions have higher price flexibility on average. From Panel (b) we see that the higher volatility in a sector is associated with a lower degree of state dependence with a cross-sectoral correlation of -0.24, suggesting that more volatile sectors have less state dependence in their price adjustment. This result implies that the less volatile (and hence less flexible on average) sectors tend to change their price flexibility more due to unexpectedly large or small shocks.

Figure 3: Relevant state volatility and price flexibility

(a) Average price flexibility (b) State-dependence of price flexibility



Average price flexibility estimates $\bar{F}_i$ and state-dependence parameter estimates f_i are plotted against the time average volatility of sector-relevant productivity state $E|\Delta s_i|$; sectors are weighted by consumption shares β_i; estimates insignificant at 90% level are forced to zero; red lines correspond to linear regressions within the group of significant estimates; **correlation coefficient for Panel (a) is 0.43 and correlation coefficient for Panel (b) is -0.24**.

Additional exercises. I also estimate the parameters of price flexibility using the model with more shocks (and employing sectoral consumption and labor data). In Appendix C I compare the corresponding price flexibility estimates as well as sector-relevant state volatility to the baseline estimates and find that they are strongly correlated. In the subsequent quantitative analysis, I check the robustness of the baseline results about the cost-push inflation against the alternative results obtained using the alternative price flexibility and state dependence estimates.

My estimates of sector-specific average price flexibility have a conceptual counterpart of Calvo parameters in the literature. In Appendix C I compare my estimates to the model-free estimates of the average frequency of price adjustment by Pasten et al. (2020) and obtain a reasonable degree of correlation equal to 0.53.[7]

6 Phillips curve and cost-push inflation

Given the significant empirical role of state dependence in price adjustments across most U.S. sectors, I now turn to the central question of this project: How does state-dependent pricing shape cost-push inflation? To address this question theoretically, I derive the Phillips curve for consumer price inflation. The Phillips curve

[7] I am thankful to the authors for providing me their estimates for comparison.

residual captures the aggregate cost-push effect within the model. I then provide a decomposition of this residual, which is particularly useful for analyzing the impact of state-dependent pricing.

6.1 Phillips curve

I derive the Phillips curve where cost-push inflation (the Phillips curve residual) is expressed in terms of production network parameters, sectoral price flexibilities, and relative price gaps. Relative price gaps, defined in the spirit of the menu-cost literature, measure the difference between efficient prices and actual prices from the previous period. These price gaps represent the desired price adjustments within each sector from the perspective of a social planner. Next, I provide a formal definition of the relative price gaps.

Definition 2 (Sectoral relative price gaps)**.** Let the efficient price in sector i, $p^{\star}_{t,i}$ be a counterfactual price that is obtained under zero markups (all $\mu_{t,i} = 0$). Vector of sectoral price gaps $\boldsymbol{\pi^{\star}_t}$ is the difference of the current efficient prices $\boldsymbol{p^{\star}_t}$ and the previous period true prices $\boldsymbol{p_{t-1}}$, that is $\boldsymbol{\pi^{\star}_t} = \boldsymbol{p^{\star}_t} - \boldsymbol{p_{t-1}}$. Then, the relative price gaps denoted as $\boldsymbol{\hat{\pi}^{\star}_t}$, represent price gaps measured relatively to the corresponding aggregate consumer price gap $\hat{\pi}^{\star}_t = \sum\limits_i \beta_i \hat{\pi}^{\star}_{t,i}$, that is $\boldsymbol{\hat{\pi}^{\star}_t} = \boldsymbol{\pi^{\star}_t} - \hat{\pi}^{\star}_t \cdot \mathbf{1}$.[8]

Given the definition of the relative price gap, the following proposition establishes the model-based Phillips curve for consumer price inflation. This curve expresses consumer price inflation as the sum of demand inflation, cost-push inflation, and expectations-driven inflation.

Proposition 1. (Consumer price inflation Phillips curve). The Phillips curve for consumer price inflation is

$$\pi_t = \underbrace{\kappa_t \cdot \tilde{y}_t}_{\text{demand inflaton}} + \underbrace{(1-\kappa_t) \cdot \boldsymbol{\beta'} M_t F_t \cdot \boldsymbol{\hat{\pi}^{\star}_t}}_{\text{cost inflation}} + \underbrace{(1-\kappa_t) \cdot \boldsymbol{\beta'} M_t F_t \cdot \boldsymbol{\tilde{e}_{t-1}}}_{\text{expectations inflation}} \tag{26}$$

where $\boldsymbol{\hat{\pi}^{\star}_t}$ is a vector of relative sectoral price gaps, $\kappa_t = \frac{\boldsymbol{\beta'} M_t F_t \mathbf{1}}{1-\boldsymbol{\beta'} M_t F_t \mathbf{1}}$ is the slope of the Phillips curve with $M_t = (I + \tilde{L} F_t^{-1}(I - F_t))^{-1} F_t^{-1}$, $\boldsymbol{\tilde{e}_{t-1}} = \tilde{L} F_t^{-1}(I - F_t)\boldsymbol{e_{t-1}}$ is the vector of expectation-related terms.

[8]Note that from the system (16), the efficient prices are related to the sector-relevant states as $\boldsymbol{p^{\star}_t} = m_t \cdot \mathbf{1} + \boldsymbol{s_t}$.

See proof in Appendix B. The first term in the Phillips curve (26) relates inflation to the output gap and corresponds to a demand component of inflation. The second term corresponds to the cost-push inflation. The third term contains predetermined past expectations about the marginal cost growth rate. In the remainder of this section, I focus on the properties of the Phillips curve residual term, which I define as $u_t = \boldsymbol{\beta}' M_t F_t \hat{\boldsymbol{\pi}}^\star_{\boldsymbol{t}}$.[9]

6.2 Cost-push effect: main and input-output components

Price rigidity in a multisectoral input-output network economy prevents prices from adjusting to their efficient levels through two channels. The first channel is that price rigidity within a sector prevents prices from matching the marginal cost. The second channel is that price rigidity in input sectors causes the marginal cost itself to deviate from the efficient level, meaning that even firms that adjust their prices cannot set them to the efficient level. Both channels contribute to shaping cost-push inflation.

To separate these two channels I decompose the cost-push inflation u_t into two components, labeled the "main" and the "input-output" components. The main component captures the effect of heterogeneous price rigidity across final goods sectors, assuming that marginal costs are at their efficient level. The input-output component captures the effect of price rigidity propagation through input-output links, which leads to the deviation of marginal costs (and consequently reset prices) from their efficient levels.

Proposition 2. (Phillips curve residual decomposition). Cost-push effect $u_t = \boldsymbol{\beta}' M_t F_t \hat{\boldsymbol{\pi}}^\star_{\boldsymbol{t}}$ can be decomposed into the sum of the main component and the input-output component

$$u_t = \underbrace{\boldsymbol{\beta}' F_t \cdot \hat{\boldsymbol{\pi}}^\star_{\boldsymbol{t}}}_{\text{main component } = u_t^m} - \underbrace{\boldsymbol{\beta}'(I - M_t) F_t \cdot \hat{\boldsymbol{\pi}}^\star_{\boldsymbol{t}}}_{\text{i-o component } = u_t^{i-o}} \tag{27}$$

See proof in Appendix B. To understand the nature of the above decomposition consider a vector of sectoral reset prices (prices set by those firms who reset their price in period t). The reset prices are equal the marginal cost and, using marginal

[9] I drop $(1 - \kappa_t)$ from cost inflation to focus on sectoral distortions for a given slope of Phillips curve κ_t.

cost expression in the system (18), are given by

$$\boldsymbol{p_t^{reset}} = \boldsymbol{mc_t} = \underbrace{\boldsymbol{p_t^\star}}_{\text{efficient price}} + \underbrace{(\tilde{L} - I)\boldsymbol{\mu_t}}_{\text{markup effect}}$$

The reset prices consist of the efficient prices and the effect of sectoral markups. The main component of the decomposition in Proposition 2 describes the residual that arises when all reset prices are set to their efficient levels. The input-output component captures the effect of inefficiencies propagating through input-output links.

6.3 Main component

Now I focus on the properties of the main component of the cost-push effect and analyze the role of state-dependent pricing in shaping the size and sign of this component.[10] The main component can be interpreted as the covariance between sectoral price flexibilities and sectoral price gaps, taken with the consumption weights

$$u_t^m = \boldsymbol{\beta'} F_t \cdot \boldsymbol{\hat{\pi}_t^\star} = cov_\beta(F_{t,i},\ \pi_{t,i}^\star)$$

which follows form the covariance definition and the fact that $\boldsymbol{\beta'}\boldsymbol{\hat{\pi}_t^\star} = 0$.

Let price flexibility in each sector consist of the non-state-dependent and state-dependent parts: $F_{t,i} = \bar{F}_i + \Delta F_{t,i}$ the non-state-dependent part is different across sectors but does not change over time. The state-dependent part fluctuates depending on the shocks that hit the economy. Then, the main component can be written as a sum of two covariances

$$u_t^m = \underbrace{cov_\beta(\bar{F}_i,\ \pi_{t,i}^\star)}_{\text{Non-st.-dep. pricing}} + \underbrace{cov_\beta(\Delta F_{t,i},\ \pi_{t,i}^\star)}_{\text{St.-dep. pricing}}$$

where the first term captures the cost-push effect created by non-state-dependent price rigidity through the heterogeneous degree of price rigidity across sectors. The second term captures the cost-push effect created by state-dependent pricing.

Under state-dependent pricing, price flexibility generally depends on the size of the desired price adjustment measured by the price gap $\pi_t^\star$.[11] To build intuition, let

[10] In the quantitative section, I show that the main component is quantitatively more important in shaping the cost-push effect than the input-output component.

[11] The price gaps can be related to the corresponding relevant state change. To see this consider an economy, being in an efficient equilibrium in period $t-1$, such that $\boldsymbol{p_{t-1}} = m_{t-1} \cdot \mathbf{1} + \boldsymbol{s_{t-1}}$. The vector of efficient prices is $\boldsymbol{p_t^\star} = m_t \cdot \mathbf{1} + \boldsymbol{s_t}$. As long as the money supply remains constant, the

this dependence take the simplest possible form $\Delta F_{t,i} = k \cdot |\pi_t^\star|$, $k > 0$. Then, the main component of the cost-push effect can be written as

$$u_t^m = \underbrace{cov_\beta(\bar{F}_i,\ \pi_{t,i}^\star)}_{\text{Non-st.-dep. pricing}} + \underbrace{k \cdot cov_\beta(|\pi_{t,i}^\star|,\ \pi_{t,i}^\star)}_{\text{St.-dep. pricing}}$$

The non-state-dependent and state-dependent components of the above expression can have opposite signs. The sign of the non-state-dependent component depends on whether the largest price gap occurs in a sector with high or low price flexibility. For example, if the largest positive price gap occurs in a sector with low price flexibility, the non-state-dependent pricing might result in a negative cost-push effect due to a negative correlation between price flexibility and price gaps. In contrast, the sign of the state-dependent component depends on whether the largest price gap is positive or negative. Under state-dependent pricing, the sector with the largest price gap tends to have the most flexible prices. Therefore, when the largest price gap is positive, the state-dependent cost-push effect will also be positive, which can contrast with the non-state-dependent part of the cost-push effect. In summary, state-dependent pricing can alter both the magnitude and the sign of the cost-push effect.

Figure 4 provides a simple three-sector example illustrating the possible implications of state-dependent pricing for cost-push inflation. The grey bars represent price gaps, which show the desired price adjustments in each sector. Under non-state-dependent pricing, the degree of price flexibility in each sector is predetermined. For example, let Sector 1 have fully flexible prices, while Sectors 2 and 3 have fully rigid prices. In this scenario, only Sector 1 adjusts its prices, as indicated by the green bars. This results in a negative cost-push effect driven by the downward price adjustment in Sector 1. In contrast, with state-dependent pricing, the degree of price flexibility varies according to the size of the desired price change. In this case, only Sector 3 adjusts its prices, as indicated by the blue bars, because it has the largest desired price change. This leads to a positive cost-push effect, driven by the upward price adjustment in Sector 3.

This example shows that, for a given distribution of desired price changes, non-state-dependent pricing leads to cost-push *deflation* driven by Sector 1, while state-dependent pricing results in cost-push *inflation* driven by Sector 3. Therefore, the sign of cost-push inflation depends on the pricing framework.

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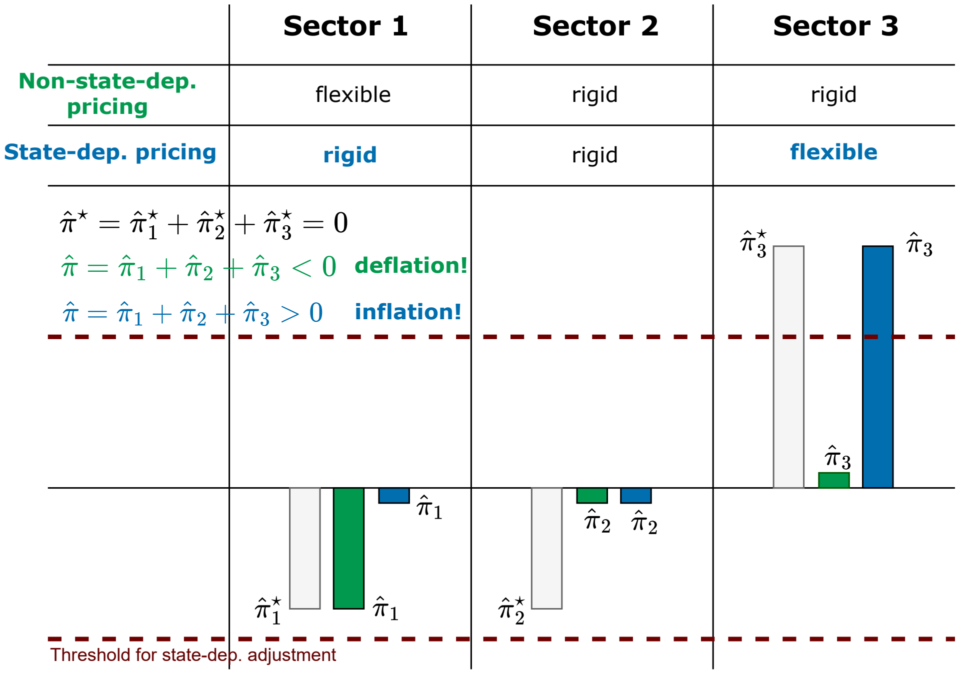
vector of price gaps is $\boldsymbol{\pi_t^\star} = \boldsymbol{\Delta s_t}$.

Figure 4: Three-sector economy: non-state-dependent and state-dependent pricing



$\hat{\pi}_i$ denote actual price adjustment in each sector.

6.4 I-O structures with a single effect

Next, I analyze the properties of production structures that result in either the main component or the input-output component of the cost-push effect. Specifically, I identify the structures needed to feature only one of these components while eliminating the other. This analysis is based on Proposition 2. I begin by characterizing an economy that features only the input-output component of the cost-push effect.

Corollary 1. (Single final good economy – only I-O component). Consider an economy with a single final good where the consumption shares are $\beta_1 = 1$ and $\beta_i = 0$ for all $i \neq 1$. In this economy, only the input-output component of the cost-push effect is present, meaning $u_t^m = 0$. Furthermore, if the only sector with rigid prices is the final good sector, the cost-push effect is zero, $u_t = 0$.

See proof in Appendix B. In an economy with a single final good, the only source of the cost-push effect is a distortion in the marginal cost of this final good caused by upstream price rigidity. This resulting cost-push effect is entirely captured by the input-output component. Without upstream price rigidity, sectoral shocks do not create any cost-push inflation in a single final good economy.[12]

Therefore, the presence of multiple consumption goods is necessary for having the main component of the cost-push effect. The main component captures the fact that for a given marginal cost distribution, the marginal cost of the final consumption basket may be inefficiently high or low because prices of different consumption goods have different degrees of price flexibility. Indeed, if price flexibilities are the same across sectors: $F_{i,t} = F$ for all i, the main component disappears.[13] Most production structures exhibit both main and input-output components of the cost-push effect. However, it is instructive to characterize an economy that features only the main component of the cost-push effect.

Corollary 2. (Quasi-horizontal economy – only main component). Consider an economy with multiple final good sectors and no vertical links except the roundabout production in each sector (meaning that each sector uses the part of its own output as its intermediate input) such that labor shares are $\alpha_i = \frac{1}{1+\gamma}$ for all i, and the input-output matrix is $\Omega = I - I_\alpha$. Such economy features only the main component of the cost-push effect, that is $u^{i-o} = 0$.

See proof in Appendix B. Note that the production structure needed to exclude the input-output component is not purely horizontal; it involves a specific amount of roundabout production in each sector. This is because sectoral markups affect marginal cost in two ways: through intermediate input prices and labor costs. On one hand, larger markups increase the marginal cost by increasing the intermediate input prices. On the other hand, larger markups result in lower wages in equilibrium, which decreases marginal cost. Remember, that the main component captures the cost-push effect under the efficient marginal cost. Therefore, a particular degree of roundabout production is needed to keep the marginal cost at its efficient level, ensuring that the decrease in marginal cost due to inefficient changes in labor costs is exactly offset by the increase in marginal cost due to inefficient changes in intermediate input prices.[14]

[12]For this reason, productivity shocks in a one-sector New Keynesian (NK) model with flexible wages do not create any cost-push effect. However, in a one-sector economy with sticky wages (rigidity in marginal costs), a cost-push effect does emerge, as discussed by Galí (2015).

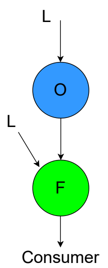
[13]If $F_{i,t} = F$ for all i we have $u_t^m = F\boldsymbol{\beta}'\hat{\boldsymbol{\pi}}_t^\star = 0$ because the consumption-weighted sum of relative price gaps is zero.

[14]Note that in a purely horizontal economy with no roundabout production (such that the Leontief inverse is $L = I$), the input-output component still exists because the cost of labor input still becomes distorted in equilibrium.

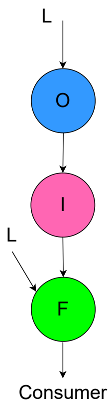
6.5 Commodity shock examples

The cost-push effect is often linked to commodity shocks, such as those in the oil sector. Next, I provide several simple examples to illustrate how a commodity shock impacts cost-push inflation across different input-output (I-O) structures and how state-dependent pricing influences this effect. I show that state-dependent pricing may amplify the cost-push effect in vertical chain economies—where the cost-push effect is driven solely by the input-output component—but does not reverse its sign compared to a non-state-dependent framework. In contrast, in an economy with multiple final goods, state-dependent pricing can reverse the sign of the cost-push effect of a commodity shock, with this reversal occurring through the main component of the cost-push effect.

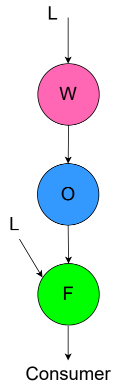
Figure 5: Example economies with commodity sectors



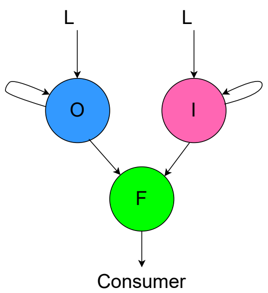
(a) Two-sector chain



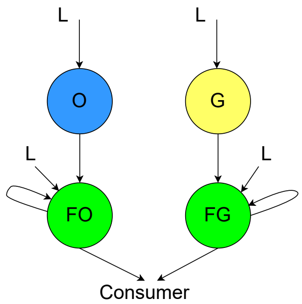
(b) Three-sector chain



(c) Sticky wage economy



(d) Multiple inputs



(e) Two-commodity economy

Example 1: Two-sector vertical chain. Consider a two-sector vertical chain economy in which the upstream sector is the Oil sector and the downstream sector be Final good sector (Figure 5a). The oil sector has fully flexible prices $F^O = 1$ (in line with empirical evidence) while the final good sector has partially rigid prices $F^F \leq 1$. Let this economy be initially at a steady state and the productivity shock in the oil sector ϵ^{Oil} occurs. The corresponding cost-push effect is

$$u_t = \frac{1+\gamma}{D} \cdot \frac{1-F^O}{F^O} \cdot (1-\alpha^F)\alpha^F \cdot \epsilon^{Oil}$$

where $D = (1+\gamma+f^O)\cdot(1+\gamma+f^F) - (1-\alpha^F)\gamma f^O \cdot f^F > 0$ and $f^F = \frac{1-F^F}{F^F}$, $f^O = \frac{1-F^O}{F^O}$.[15] For derivation see Appendix B.

As long as Oil sector has fully flexible prices $F^O = 1$, the Oil shock does not cause a cost-push effect since there is no distortion in the marginal cost of production ($u_t = 0$), see Corollary 1.

Example 2: Intermediate good. Consider a three-sector vertical chain with an intermediate good sector (Figure 5b). Oil sector has fully flexible prices $F^{Oil} = 1$ as before but the intermediate sector has partially rigid prices $F^I \leq 1$. Price distortion in the intermediate good sector creates cost distortion in the final good sector. The cost-push effect of Oil productivity shock is

$$u_t = \frac{1+\gamma}{D} \cdot \frac{1-F^I}{F^I} \cdot (1-\alpha^F)\alpha^F \cdot \epsilon^{Oil}$$

where $D = (1+\gamma+f^I)\cdot(1+\gamma+f^F) - (1-\alpha^F)\gamma f^I \cdot f^F > 0$ and $f^F = \frac{1-F^F}{F^F}$, $f^I = \frac{1-F^I}{F^I}$. For derivation see Appendix B.

When productivity in Oil sector goes down ($\epsilon^{Oil} < 0$) we have a cost-push *deflation*. State-dependent pricing (the fact that F^I and F^F depend on the shock size) may affect the size of the cost-push effect of the shock but cannot reverse its sign.

The negative cost-push effect from a negative commodity shock might seem counterintuitive, as one would normally expect such a shock to increase production costs and cause cost-push inflation. However, this example is useful for understanding why the cost-push effect can manifest in this way. After an adverse oil shock, the cost of oil rises. Since the intermediate sector uses oil as an input, the price of intermediate goods should also increase. However, because prices in the intermediate sector are sticky, they rise by less than the efficient level. As a result, the marginal cost in the final sector is lower than it should be, leading to a negative cost-push effect.

[15]In the examples of this section I make a technical assumption that $(1-\alpha^F)\gamma < 1$ where α^F is labor share in final production. This assumption ensures that intermediate input is an important factor of production.

Example 3: "Sticky wages" economy. Consider a vertical chain economy where the most upstream sector has partially rigid prices, while the intermediate sector has fully flexible prices. In this setup, the upstream sector can be seen as the sticky wages sector, the intermediate sector as the oil sector, and the final sector as the consumption goods sector (Figure 5c). The corresponding price flexibilities are $F^O = 1$, $F^W \leq 1$ and $F^F \leq 1$. The cost-push effect resulting from an oil productivity shock is

$$u_t = -\frac{1+\gamma}{D} \cdot \frac{1-F^W}{F^W} \cdot (1-\alpha^F) \cdot \epsilon^{Oil}$$

where $D = (1+\gamma+f^W)\cdot(1+\gamma+f^F) - (1-\alpha^F)\gamma f^W \cdot f^F > 0$ and $f^F = \frac{1-F^F}{F^F}$, $f^W = \frac{1-F^W}{F^W}$. For derivation see Appendix B.

In this economy, a decline in oil productivity leads to cost-push inflation, which aligns with the intuition that a negative productivity shock in the oil industry should create a positive cost-push effect. When oil productivity falls, production decreases, and less labor is needed. Consequently, wages should ideally decrease. However, because wages are sticky, they remain too high. This results in a higher-than-efficient marginal cost for producing oil and, ultimately, for producing final goods. This inefficiently high marginal cost leads to positive cost-push inflation. Similar to the previous example, state-dependent pricing may influence the magnitude of the cost-push effect but cannot change its sign.

Example 4: Multiple inputs. Consider an economy where a single final good is produced using two material inputs: oil and an intermediate good (Figure 5d). In this setup, the oil sector has fully flexible prices ($F^{Oil} = 1$), while the intermediate good sector has partial price flexibility ($F^I \leq 1$)). For simplicity, I assume that the final good sector also has fully flexible prices ($F^F = 1$). After an oil shock (ϵ^{Oil}), the cost-push inflation is

$$u_t = -\alpha^I(1-\alpha^I)\cdot(1-F^I)\cdot\epsilon^{Oil}$$

where α^I share of input I in good F. For derivation see Appendix B.

Similar to the previous example, a negative oil productivity shock leads to positive cost-push inflation. The state-dependence of price flexibility can influence the magnitude of the cost-push effect by altering F^I, but not its sign. However, the mechanism driving the cost-push effect of the oil shock in this case differs somewhat from the mechanisms in the earlier examples.

In this economy, a negative oil productivity shock increases the marginal cost of producing the final good and decreases the demand for intermediate inputs, provided that the substitutability between oil and intermediate goods is not too high. Ideally, the price of intermediate goods should decrease in response. However, due to price rigidity in the intermediate goods sector, prices do not adjust as they should. Consequently, the price of intermediate goods remains inefficiently high, leading to an inefficiently high marginal cost for producing the final good, which results in cost-push inflation.

In examples 1-4, adjustment of price flexibility due to state-dependent pricing could affect the size of a cost-push effect but never change its sign. Next, let us consider an example, in which the same shock can lead to the opposite sign of the cost-push effect if pricing is state-dependent. This example involves extending the economy ti have multiple final goods, which introduces the main component of the cost-push effect.

Example 5: Two-commodity economy. In examples 1-4, adjustments in price flexibility due to state-dependent pricing can affect the magnitude of the cost-push effect but not its direction. Next, we will consider an example where state dependence can lead to a reversal in the sign of the cost-push effect. This example involves multiple final goods, which introduces the main component of the cost-push effect.[16]

Consider an economy consisting of two upstream goods (Oil and Grain) and two final goods (Oil-intensive and Grain-intensive) with equal shares in consumption. Oil-intensive final good uses oil as input while grain-intensive final good uses grain as input (Figure 5e). Upstream commodity sectors have fully flexible prices $F^{Oil} = F^{Grain} = 1$ and final good sectors have partially rigid prices $F^{FO} \leq 1$ and $F^{FG} \leq 1$. As before, the economy is initially at a steady state and is perturbed by one of the two commodity shocks - oil or grain shocks $\epsilon^{Oil}, \epsilon^{Grain}$. The corresponding cost-push effect is

$$u_t = -\frac{1}{4} \cdot (F^{FO} - F^{FG}) \cdot (\epsilon^{Oil} - \epsilon^{Grain})$$

For derivation see Appendix B.

Assume first that price rigidity is non-state-dependent, with $F^{FO} > F^{FG}$, meaning that the oil-intensive final good always has more flexible prices compared to the grain-intensive final good. In this case, a negative oil shock leads to a positive cost-push effect, while a negative grain shock results in a negative cost-push effect. This outcome may seem counterintuitive because there is no obvious reason why a shock in one commodity sector would cause cost-push inflation, while a similar shock in

[16] To focus on the main component, I assume a specific degree of roundabout production required by Corollary 2, see Appendix B for details.

another sector would lead to cost-push deflation.

But what if price flexibility is state-dependent? In this case, price flexibility ranking differs depending on the type of shock: $F^{FO} > F^{FG}$ for an oil shock and $F^{FG} > F^{FO}$ for a grain shock. Thus, under state-dependent pricing, a negative shock in either commodity sector results in a positive cost-push effect. This is because state-dependent pricing causes the prices in the affected sector to become more flexible. This price flexibility adjustment reverses the sign of the cost-push effect for the grain shock compared to the non-state-dependent pricing case.

The mechanism behind the cost-push effect of an oil shock in this economy is as follows: When a negative oil shock occurs, oil prices rise, leading to higher prices for oil-intensive goods and reducing household real income. With lower income, households also reduce their demand for grain-intensive goods (assuming these goods are not "inferior" goods). This reduced demand should ideally cause the prices of grain-intensive goods to drop. However, due to price rigidity in the grain-intensive sector, these prices do not decrease as they should. As a result, the relative price of grain-intensive goods remains higher than optimal, leading to an inefficiently high cost of final consumption. This, in turn, results in cost-push inflation.

7 Quantitative analysis

The above theoretical analysis demonstrates that state-dependent pricing can significantly influence cost-push inflation in multi-sector economies, altering its magnitude or even its direction compared to a non-state-dependent pricing model. Additionally, my empirical analysis indicates that most sectors in the U.S. exhibit evidence of state dependence in their price adjustments. Motivated by these findings, I will now evaluate the quantitative role of state-dependent pricing in shaping the cost-push effect in the U.S. over time. The following section describes the quantitative analysis and its results.

7.1 Cost-push effect and state-dependence

I compute the model-based monthly cost-push effect in the U.S. using the theoretical Phillips curve residual expression derived in Section 6. For this, I calibrate each sector's price flexibility and state dependence based on the estimates obtained in Section 5.[17] To compute sectoral relative price gaps, I use the monthly sector-relevant state

[17] The rest of the model is calibrated as described in Section 5.

series constructed in Section 5, along with the observed sectoral prices. The presence of both non-state-dependent and state-dependent components in price flexibility allows me to evaluate the quantitative role of state dependence. I achieve this by constructing a counterfactual cost-push effect based on non-state-dependent pricing, which is obtained by setting all state-dependence parameters to zero ($f_i = 0$ for all i).

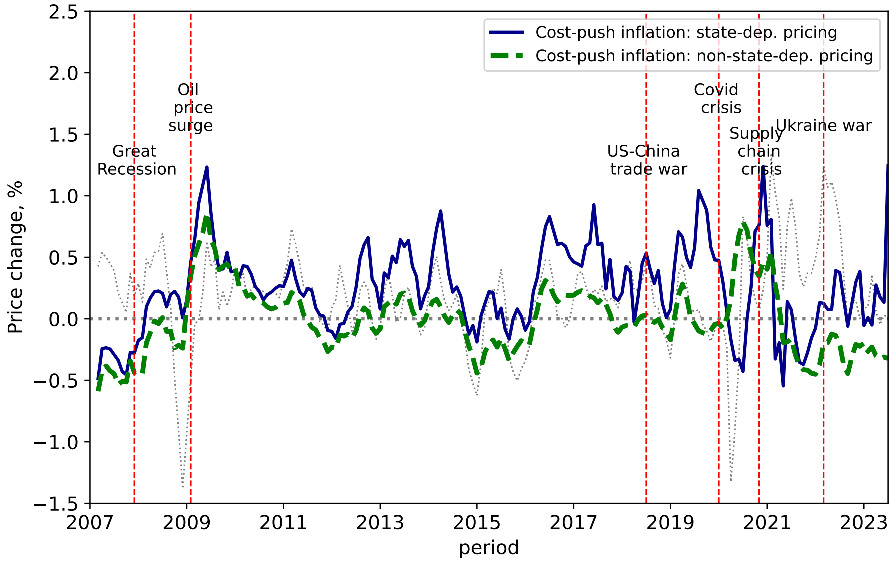
Figure 6 shows the resulting cost-push effect under state-dependent pricing (blue line) and the counterfactual cost-push effect under non-state-dependent pricing (green line). Overall, the empirically plausible degree of state dependence in each sector results in a more volatile cost-push effect compared to the non-state-dependent pricing model. State dependence plays different roles during different historical periods. For instance, in 2009, just after the Great Recession when oil prices increased substantially, both state-dependent and non-state-dependent pricing models produced a positive spike in the cost-push effect, with state dependence merely amplifying the effect.

In contrast, starting from the Covid crisis in 2019, the state-dependent model often yields a cost-push effect with a different sign compared to the non-state-dependent model. The state-dependent model shows a negative cost-push effect at the start of the Covid crisis, followed by a positive cost-push effect just after the crisis when the supply chain disruption began. Subsequently, since the full-scale Russia-Ukraine war broke out in 2022, the state-dependent pricing model shows a positive and growing cost-push effect. In contrast, the non-state-dependent pricing model gives quite different predictions: a positive cost-push effect during the Covid crisis, followed by negative cost-push inflation after the start of the Ukraine war.

Note that neither model predicts a long-lasting positive cost-push effect during the post-Covid period when observed inflation was persistently high (observed inflation is plotted as a grey line). While the state-dependent pricing model generates a transitory positive cost-push effect around the supply chain crisis, this effect quickly disappears in 2021, even as observed inflation remains high during this period. This suggests that the persistent post-Covid inflation cannot be entirely attributed to cost-push factors but instead has demand-driven or expectation-driven features.

Finally, historical decomposition over the observed period suggests that the state-dependent pricing model attributes about 45% of overall inflation fluctuations to the cost-push effect of shocks, while the non-state-dependent model – only 20%. Note also that the cost-push effect and demand effect in the model are often negatively correlated – positive cost-push effect is often accompanied by the suppressed demand.

Figure 6: Cost-push inflation and state-dependent pricing



Grey line plots observed CPI inflation; **blue line** plots the Phillips curve residual implied by the model under the empirical degree of price flexibility; **dashed green line** plots the Phillips curve residual when the effect of state-dependent pricing is absent (all $f_i = 0$).

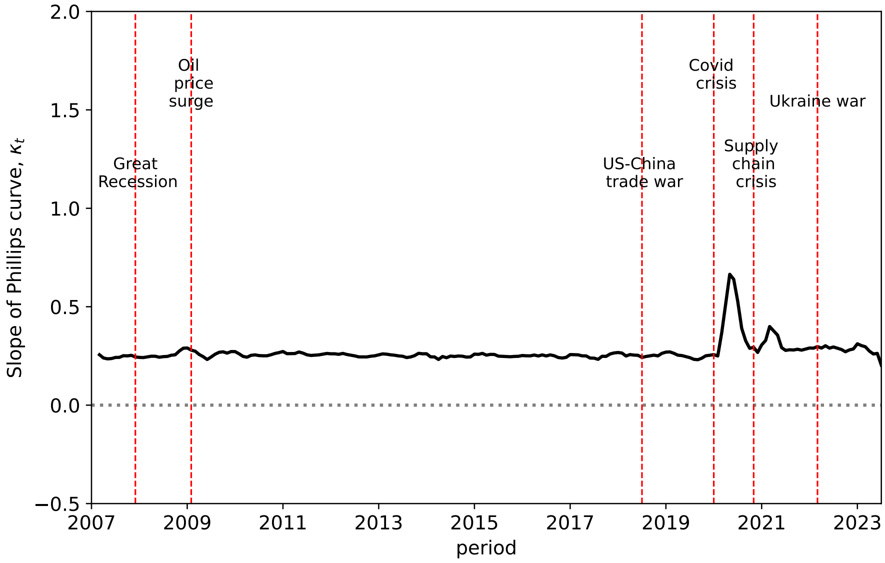
Additional exercises. In Appendix D, I perform the robustness check of the baseline model specification. For this, I compute the altrnative state-dependent and non-state-dependent residual based on the model specification with more shocks and using the corresponding price flexibility and relevant-state estimates (see Section 5 for details). The specification with more shock produces results similar to the baseline specification. Additionally, in Appendix D I compute the main component of the cost-push effect given by the decomposition in Proposition 2. Quantitatively, the bulk of fluctuations in the cost-push effect is attributed to the main component.

7.2 Slope of the Phillips curve

State-dependent pricing may imply a time-varying slope for the Phillips curve. To explore this, I compute the slope of the Phillips curve implied by my state-dependent pricing estimates over time, as shown in Figure 7. Generally, the slope of the Phillips curve under the state-dependent pricing model remains fairly constant, with the exception of the Covid period. During this period, the slope exhibits two notable peaks in 2020 and 2021. These spikes are primarily driven by the 2-digit sectoral group representing the Finance and Insurance sectors (see sectoral analysis below).[18]

[18] The model-free evidence of an increase and a subsequent decrease of the Phillips curve slope around the Covid period were also found by Cerrato and Gitti (2022).

Figure 7: Slope of the Phillips curve



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7.3 Phillips curve fit

I now investigate whether the Phillips curve residual implied by the state-dependent model provides a better explanation of observed inflation compared to its non-state-dependent counterpart in a conventional Phillips curve regression. To do this, I regress CPI inflation on standard Phillips curve variables: unemployment, expected and lagged inflation, and oil prices. I then sequentially add both the non-state-dependent and state-dependent residuals computed from the model to the regression. Table 3 presents the regression results. The regression using the non-state-dependent residual performs better than one using only oil price inflation. However, incorporating the state-dependent residual further improves the fit. Additionally, the effect of the state-dependent residual remains statistically significant even when accounting for the non-state-dependent residual.

Table 3: Phillips curve estimation with model implied residual

	Dependent variable:			
	CPI inflation			
	(1)	(2)	(3)	(4)
Unempl.	0.0001	-0.0003^{*}	-0.0002	-0.0005^{***}
	(0.0001)	(0.0002)	(0.0002)	(0.0002)
Lagged infl.	0.172^{**}	0.169^{**}	0.158^{**}	0.159^{***}
	(0.068)	(0.065)	(0.063)	(0.059)
Expected infl.	0.001	0.001	0.001^{**}	0.001^{**}
	(0.001)	(0.001)	(0.001)	(0.001)
Oil infl.	0.028^{***}	0.023^{***}	0.023^{***}	0.030^{***}
	(0.003)	(0.003)	(0.003)	(0.003)
u(non-st.-dep.)		0.282^{***}	0.124	0.190^{***}
		(0.073)	(0.087)	(0.063)
u(st.-dep.)			0.162^{***}	0.076^{**}
			(0.052)	(0.034)
Constant	-0.001	0.004^{*}	0.001	0.003^{*}
	(0.001)	(0.002)	(0.002)	(0.002)
Observations	156	156	156	187
R^2	0.440	0.491	0.522	0.508
Adjusted R^2	0.425	0.474	0.503	0.492
Note:				*p<0.1; **p<0.05; ***p<0.01

The period used in the estimation (1)-(3) is 2007M1-2019M12 to exclude the period of the non-stable slope of the Phillips curve; The period of estimation in (4) includes a full sample.

7.4 Analysis by sector

Next, I analyze how specific sectors contribute to the difference between the state-dependent and non-state-dependent pricing cost-push effects. To do this, I group the disaggregated sectors into 2-digit BEA-coded groups. Table 4 lists the resulting sector groups.

First, I assess the marginal importance of each 2-digit sector group in explaining

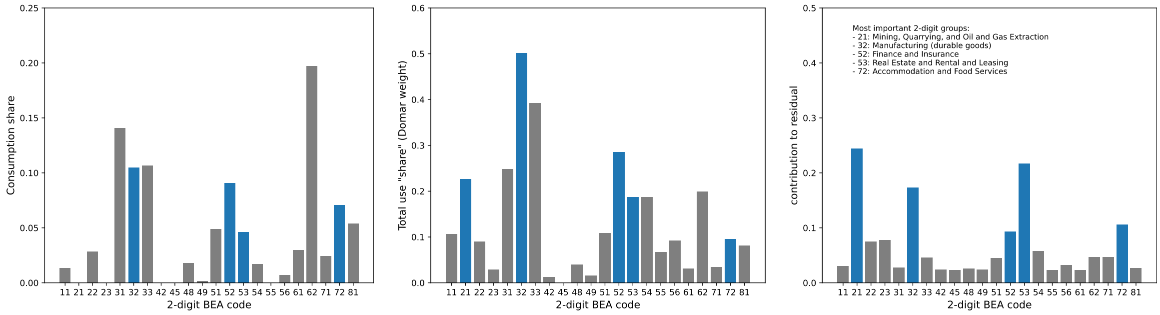
Table 4: 2-digit BEA sector names

2-digit BEA	Sector description
11	Agriculture, Forestry, Fishing and Hunting
21	Mining, Quarrying, and Oil and Gas Extraction
22	Utilities
23	Construction
31	Manufacturing (non-durable goods)
32-33	Manufacturing (durable goods)
42	Wholesale Trade
44 - 45	Retail Trade
48 - 49	Transportation
51	Information
52	Finance and Insurance
53	Real Estate and Rental and Leasing
54	Professional, Scientific, and Technical Services
55	Management of Companies and Enterprises
56	Administrative and Support and Waste Management and Remediation Services
61	Educational Services
62	Health Care and Social Assistance
71	Arts, Entertainment, and Recreation
72	Accommodation and Food Services
81	Other Services (except Public Administration)
92	Public Administration

the cost-push effect. To do this, I compute the counterfactual residual by excluding the contributions of sectors within that group. I then compare this new residual with the full residual by regressing the full residual on the new residual. The importance of each sector group is quantified as $1 - R^2$ from this regression, which represents the loss of fit compared to the full residual. Figure 8 illustrates the importance of each sector group in three contexts: consumption (panel A), production (panel B), and explaining the Phillips curve residual (panel C). Panel C highlights the five sector groups with the largest contributions to the cost-push effect. It is important to note that these key sector groups, identified in panel C, do not necessarily have the largest consumption or sales shares, as shown in panels A and B.

Figure 8: Most important sector groups

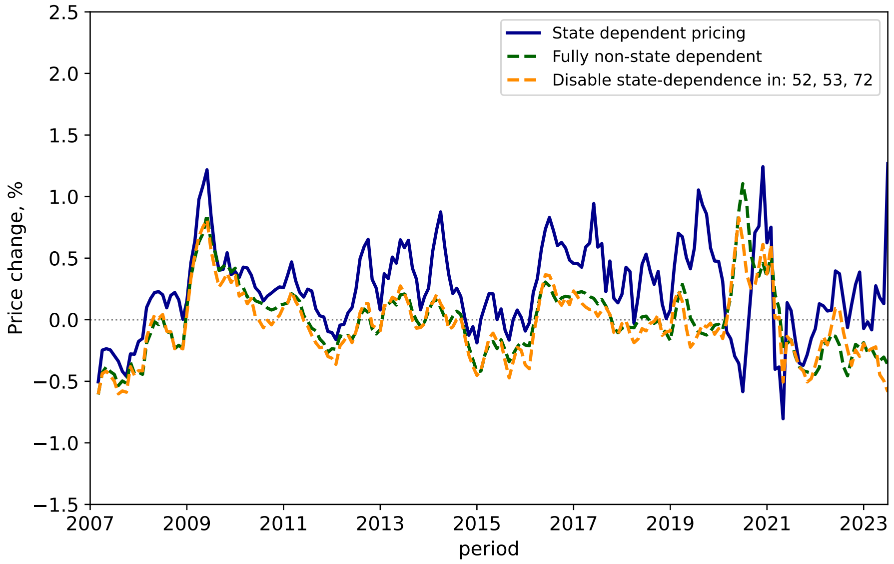
(a) Share in consumption (b) Share in total use (c) Cost-push effect



Panel (a): sum of sectoral consumption shares within each group; Panel (b): sum of sectoral Domar weights (shares in total use) within each group; Panel (c): the share of Phillips curve residual explained by a given 2-digit BEA sector group; computed by forcing the shocks in a given sector of interest to zero and calculating the (1- r-squared) from a total Phillips curve residual regression on the resulting counterfactual Phillips curve residual; **blue** highlights the group of sectors most important in explaining the dynamics of cost-push inflation.

Next, I disable state-dependent pricing in the selected sectoral groups to assess their contribution to the difference between the non-state-dependent and state-dependent Phillips curve residuals. In Figure 9, I plot the counterfactual residual with state dependence removed for three of the five most important sectoral groups. The results indicate that state dependence in these three service-related groups accounts for most of the impact of state-dependent pricing. Note that these three groups represent approximately one-quarter of the overall consumption basket.

Figure 9: Contribution of state-dependence in selected sector groups



Additional exercises. In Appendix D I calculate the cost-push effect attributable exclusively to the most important sectoral groups over time. The combined effect of these five key sectoral groups accounts for the majority of fluctuations in the cost-push effect throughout the observed period. Additionally, I analyze the cost-push effect attributed to sectors that were most influential during three significant historical periods: the Great Recession, the Covid crisis, and the Ukraine war. Each period is characterized by distinct sectoral groups that contribute most to the cost-push effect.

8 Conclusions

This paper explores the impact of state-dependent pricing on cost-push inflation within a multi-sectoral New Keynesian economy with a production network. I empirically estimate the degree of state dependence for various sectors in the U.S. and examine both the theoretical and quantitative roles of state-dependent pricing in influencing the cost-push effect.

My empirical approach involves estimating the sector-specific price flexibility and its degree of state dependence using detailed sectoral price and quantity data, along with a calibrated input-output network model. The estimates show that most sectors in the U.S. economy exhibit a statistically significant degree of state dependence.

Theoretically, I demonstrate that state-dependent pricing can result in cost-push inflation with differing magnitude and even the opposite sign compared to a non-state-dependent pricing framework. This significant implication holds even when the effects of inefficiency propagation through the production network are excluded.

In a model incorporating a realistic degree of state dependence, the effect of state dependence on cost-push inflation varies across different historical periods in the U.S. After the Great Recession, state dependence intensified the positive cost-push effect. Conversely, following the Covid crisis, it often led to a reversal in the sign of cost-push inflation compared to predictions from a non-state-dependent pricing model. Furthermore, state dependence within a particular subgroup of service sectors explains most of the differences between cost-push effects in state-dependent and non-state-dependent models.

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Appendices

A Model log-linearization

A.1 Sectoral wages

The product market clearing condition in sector i (12) can be written as $P_{t,i}Y_{t,i} = P_{t,i}C_{t,i}+\sum_j P_{t,i}X_{t,ji}$. Using the conditions for optimal input allocation (2), (3), and the link between sector price and sector marginal cost (5), we get $\frac{P_{t,i}X_{t,ij}}{MC_{t,i}\cdot Y_{t,i}} = \frac{\mathcal{M}_{t,i}P_{t,i}X_{t,ij}}{P_{t,i}\cdot Y_{t,i}} = (1-\alpha_i)\omega_{ij}$, we have $P_{t,j}X_{t,ji} = (1-\alpha_j)\omega_{ji}\frac{P_{t,j}Y_{t,j}}{\mathcal{M}_{t,j}}$. Substituting this result into the market clearing condition

$$P_{t,i}Y_{t,i} = P_{t,i}C_{t,i} + \sum_j (1-\alpha_j)\omega_{ji}\frac{P_{t,j}Y_{t,j}}{\mathcal{M}_{t,j}} \tag{A.1}$$

Consumption shares and Domar weights are connected through a well-known link (see Baqaee and Farhi (2020)).

Proposition (Consumption shares to Domar weights link)**.** $\boldsymbol{\xi} = L'\boldsymbol{\beta}$.

Proof. First, let us compute (A.1) at the efficient steady state and divide by $\bar{P}\bar{Y}$. We have the $\frac{\bar{P}_i\bar{Y}_i}{\bar{P}\bar{C}} = \frac{\bar{P}_i\bar{C}_i}{\bar{P}\bar{C}} + \sum_j(1-\alpha_j)\omega_{ji}\frac{\bar{P}_j\bar{Y}_j}{\bar{P}\bar{C}}$. Then, the steady state product market clearing condition can be expressed as $\xi_i = \beta_i + \sum_j(1-\alpha_j)\omega_{ji}\xi_j$, or in matrix form $\boldsymbol{\xi} = \boldsymbol{\beta} + W'\boldsymbol{\xi}$. This gives us the link between consumption shares and Domar weights: $\boldsymbol{\xi} = L'\boldsymbol{\beta}$. □

Log-linearizing (A.1) and dividing by $\bar{P}\bar{Y}$ yields

$$\xi_i(p_{t,i} + y_{t,i} - \mu_{t,i}) = \beta_i(p_{t,i} + c_{t,i}) - \xi_i\mu_{t,i} + \sum_j(1-\alpha_j)\omega_{ji}\xi_j(p_{t,j} + y_{t,j} - \mu_{t,j})$$

The demand for i-th sector consumption is $p_{t,i} + c_{t,i} = p_t + y_t$. Hence, we have

$$(p_i + y_i - \mu_i) = \frac{1}{\xi_i}\sum_j l_{ji}(\beta_j(p_t + y_t) - \xi_j\mu_j) = p_t + y_t - \frac{1}{\xi_i}\sum_j l_{ji}\xi_j\mu_j \tag{A.2}$$

where l_{ij} is $(i,\ j)$-th element of matrix L.

Labor demand in log-deviations is $w_{t,i} + l_{t,i} = p_{t,i} + y_{t,i} - \mu_{t,i}$ and labor supply is $w_{t,i} = p_t + y_t + \gamma l_{t,i}$. Combining labor demand and labor supply, we get the following expression for equilibrium wage

$$w_{t,i} = \frac{1}{1+\gamma}(p_t + y_t) + \frac{\gamma}{1+\gamma}(p_{t,i} + y_{t,i} - \mu_{t,i}) \tag{A.3}$$

Combining (A.2) and (A.3) yields

$$w_{t,i} = p_t + y_t - \frac{\gamma}{1+\gamma}\frac{1}{\xi_i}\sum_j l_{ji}\xi_j\mu_{t,j} \tag{A.4}$$

which in vector form gives equation 15.

A.2 Sectoral prices

From (4) log-linear marginal cost deviation is sector i is

$$mc_{t,i} = -a_{t,i} + \alpha_i w_{t,i} + (1-\alpha_i)\sum_j \omega_{ij} p_{t,j} \tag{A.5}$$

The link between sector price and sector marginal cost is $p_{t,i} = \mu_{t,i} + mc_{t,i}$. Combining these two results yields the following system of equations for sector prices

$$p_{t,i} = \mu_{t,i} - a_i + \alpha_i w_{t,i} + (1-\alpha_i)\sum_j \omega_{ij} p_{t,j} \tag{A.6}$$

This system of price equations can be written in matrix form as

$$\boldsymbol{p_t} = \boldsymbol{\mu_t} - \boldsymbol{a_t} + I_\alpha \boldsymbol{w_t} + W\boldsymbol{p_t} \tag{A.7}$$

Substituting wage (15) into (A.7), moving parts containing $\boldsymbol{p_t}$ to the left side and multiplying by matrix $L = (I-W)^{-1}$ gives

$$\boldsymbol{p_t} = L\boldsymbol{\mu_t} - L\boldsymbol{a_t} + (p_t + y_t)\cdot L\boldsymbol{\alpha} - \frac{\gamma}{1+\gamma} L I_\alpha I_\xi^{-1} L' I_\xi \boldsymbol{\mu_t} \tag{A.8}$$

Next, I establish a link between labor shares vector and Leontief inverse matrix.

Proposition (Labor shares and Leontief inverse.)**.** $L\boldsymbol{\alpha} = \mathbf{1}$.

Proof. Indeed, $L\boldsymbol{\alpha} = \mathbf{1} \Leftrightarrow (I-W)^{-1}\boldsymbol{\alpha} = \mathbf{1} \Leftrightarrow \boldsymbol{\alpha} = (I-W)\cdot\mathbf{1} = \mathbf{1} - (\mathbf{1} - \boldsymbol{\alpha}) = \boldsymbol{\alpha}$. □

Then, the system of price equations can be expressed as

$$\boldsymbol{p_t} = (p_t + y_t)\cdot\mathbf{1} - L\boldsymbol{a_t} + \tilde{L}\boldsymbol{\mu_t} \tag{A.9}$$

where $\tilde{L} = L(I - \frac{\gamma}{1+\gamma} I_\alpha I_\xi^{-1} L' I_\xi)$.

A.3 Final output

Log-linearization of consumer price index yields $p_t = \sum_i \beta_i p_{t,i} = \boldsymbol{\beta'} \cdot \boldsymbol{p_t}$. Multiplying both sides of price equations (16) by vector $\boldsymbol{\beta'}$ and noticing that $\boldsymbol{\beta'} \cdot \mathbf{1} = \sum_i \beta_i = 1$, we get

$$0 = y_t - \boldsymbol{\beta'} \cdot L \cdot a_t + \boldsymbol{\beta'} \tilde{L} \cdot \boldsymbol{\mu_t} \tag{A.10}$$

Next, as shown shown before $\boldsymbol{\beta'} L = \boldsymbol{\xi'}$. Then, $\boldsymbol{\beta'} \tilde{L} = \boldsymbol{\xi'} - \frac{\gamma}{1+\gamma} \boldsymbol{\xi'} I_\alpha I_\xi^{-1} L' I_\xi = \boldsymbol{\xi'} - \frac{\gamma}{1+\gamma} \boldsymbol{\alpha'} L' I_\xi = \boldsymbol{\xi'} - \frac{\gamma}{1+\gamma} \mathbf{1'} \cdot I_\xi = \frac{1}{1+\gamma} \boldsymbol{\xi'}$, where in the third step I use the previous result that $L\boldsymbol{\alpha} = \mathbf{1}$. Hence, we have the expression for output as a function of productivities and markups.

$$y_t = \boldsymbol{\xi'} \cdot \boldsymbol{a_t} - \frac{1}{1+\gamma} \boldsymbol{\xi'} \cdot \boldsymbol{\mu_t} \tag{A.11}$$

A.4 Price-markup link

Log-linearizing Equation (21), while treating all $F_{t-s,i}$ as time-varying coefficients

$$p_{t,i} = F_{t,i} \cdot mc_{t,i} + \sum_{h=1}^{\infty} \left\{ \left[\prod_{s=0}^{h-1} (1 - F_{t-s,i}) \right] \cdot F_{t-h,i} \cdot E_{t-h} mc_{t,i} \right\} \tag{A.12}$$

Let $mc_{t,i} = mc_{t-1,i} + \Delta mc_{t,i}$. Then, we can write

$$\begin{aligned} p_{t,i} = F_{t,i} mc_{t,i} + (1 - F_{t,i}) \left[F_{t-1,i} E_{t-1} mc_{t,i} + \sum_{h=1}^{\infty} \left\{ \left[\prod_{s=0}^{h-1} (1 - F_{t-1-s,i}) \right] \cdot F_{t-1-h,i} mc_{t,i} \right\} \right] = \\ = F_{t,i} mc_{t,i} + (1 - F_{t,i}) p_{t-1,i} + (1 - F_{t,i}) e_{t-1,i} \end{aligned}$$

where $e_{t-1,i} = F_{t-1,i} E_{t-1} \Delta mc_{t,i} + \sum_{h=1}^{\infty} \left\{ \left[\prod_{s=0}^{h-1} (1 - F_{t-1-s,i}) \right] \cdot F_{t-1-h,i} \Delta mc_{t,i} \right\}$ is predetermined at period t. Markup is $\mu_{t,i} = p_{t,i} - mc_{t,i}$. Hence, the price-markup link is

$$(1 - F_{t,i}) \cdot (p_{t,i} - p_{t-1,i}) = -F_{t,i} \mu_{t,i} + (1 - F_{t,i}) e_{t-1,i} \tag{A.13}$$

B Theoretical appendix

B.1 Phillips curve

Proof of Proposition 1 (Consumer price inflation Phillips Curve). Rewriting price equations (16) in terms of sectoral inflations gives

$$\boldsymbol{\pi_t} = -\boldsymbol{p_{t-1}} + p_{t-1}\mathbf{1} + (\pi_t + y_t)\mathbf{1} - La_t + \tilde{L}\mu_t$$

where $\tilde{L} = L(I - \frac{\gamma}{1+\gamma} I_\alpha I_\xi^{-1} L' I_\xi)$.
On the other hand, the markup-inflation link through price prigdity (21) can be written as

$$(I - F_t)\boldsymbol{\pi_t} = -F_t\boldsymbol{\mu_t} + (I - F_t)\boldsymbol{e_{t-1}}$$

where $F_t = diag\{F_{t,i}\}$, $\boldsymbol{e_{t-1}}$ is such that
$e_{t-1,i} = F_{t-1,i}E_{t-1}\Delta mc_{t,i} + \sum\limits_{h=1}^{\infty} \left\{ \left[\prod\limits_{s=0}^{h-1} (1 - F_{t-1-s,i}) \right] \cdot F_{t-1-h,i}\Delta mc_{t,i} \right\}$ is predetermined at period t.

Efficient relative prices are

$$\boldsymbol{\hat{p}_t^\star} = \boldsymbol{p_t^\star} - p_t^\star \cdot \mathbf{1} = y_t^e \cdot \mathbf{1} - L \cdot \boldsymbol{a_t}$$

In terms of price gaps $\boldsymbol{\hat{\pi}_t^\star} = \boldsymbol{\hat{p}_t^\star} - \boldsymbol{\hat{p}_{t-1}}$, price equation can be rewritten as

$$\boldsymbol{\pi_t} - \pi_t \cdot \mathbf{1} = \tilde{y}_t \cdot \mathbf{1} + \boldsymbol{\hat{\pi}_t^\star} + \tilde{L} \cdot \mu_t$$

Substituting markup-rigidity link into the previous equation and rearranging, we get

$$F_t(I + \tilde{L}F_t^{-1}(I - F_t))\boldsymbol{\pi_t} - F_t\mathbf{1}\pi_t = F_t\mathbf{1}\tilde{y}_t + F_t\boldsymbol{\hat{\pi}_t^\star} + \tilde{L}F_t^{-1}(I - F_t)\boldsymbol{e_{t-1}}$$

Let $M_t^{-1} = F_t(I + \tilde{L}F_t^{-1}(I - F_t))$. Multipling previous equation by M_t and then by $\boldsymbol{\beta'}$, we get Phillips curve

$$\pi_t(1 - \boldsymbol{\beta'}M_tF_t\mathbf{1}) = \boldsymbol{\beta'}M_tF_t\mathbf{1}\tilde{y}_t + \boldsymbol{\beta'}M_tF_t\boldsymbol{\hat{\pi}_t^\star} + \boldsymbol{\beta'}M_tF_t\tilde{L}F_t^{-1}(I - F_t)\boldsymbol{e_{t-1}}$$

Let $\kappa_t = \frac{\boldsymbol{\beta'}M_tF_t\mathbf{1}}{1-\boldsymbol{\beta'}M_tF_t\mathbf{1}}$. Then, Phillips curve takes the form stated in proposition. □

B.2 Cost-push effect decomposition

Proof of Proposition 2 (Phillips curve residual decomposition). Absence of input-output effect in price setting means that firms set their prices ignoring the inefficient component of their marginal costs. Instead they consider marginal costs being equal to the efficient prices $\boldsymbol{p_t^\star}$. Hence, the resulting sector prices are $\boldsymbol{p_t} = F_t \cdot \boldsymbol{p_t^\star} + (I - F_t)(\boldsymbol{p_{t-1}} + \boldsymbol{e_{t-1}})$, which yields $(I - F_t) \cdot (\boldsymbol{p_t} - \boldsymbol{p_{t-1}}) = F_t \cdot (\boldsymbol{p_t^\star} - \boldsymbol{p_t}) + (I - F_t) \cdot \boldsymbol{e_{t-1}}$.

Since $\boldsymbol{p_t^\star} - \boldsymbol{p_t} = -\tilde{L} \cdot \boldsymbol{\mu_t}$, we have $(I - F_t) \cdot (\boldsymbol{p_t} - \boldsymbol{p_{t-1}}) = -F_t \tilde{L} \cdot \boldsymbol{\mu_t} + (I - F_t) \cdot \boldsymbol{e_{t-1}}$. Under this link between inflation and markups, the Phillips curve is

$$\pi_t(1 - \boldsymbol{\beta'} F_t \mathbf{1}) = \boldsymbol{\beta'} F_t \mathbf{1} \tilde{y}_t + \boldsymbol{\beta'} F_t \boldsymbol{\hat{\pi}_t^\star} + \boldsymbol{\beta'} F_t \tilde{L} F_t^{-1} (I - F_t) \boldsymbol{e_{t-1}}$$

and the Phillips curve residual not-related to inefficiency in marginal cost is $u_t^h = \boldsymbol{\beta'} F_t \boldsymbol{\hat{\pi}_t^\star}$ □

Proof of Corollary 1 (Single final good economy(only I-O component)). Let $\boldsymbol{\pi_t^\star}$ be desired price changes. $\boldsymbol{\beta'} \boldsymbol{\pi_t^\star} = \pi_{1,t}^\star$ is the desired consumer price change. Then, price gaps (relative desired price changes) are $\boldsymbol{\hat{\pi}_t^\star} = \left[0, \hat{\pi}_{2,t}^\star, \ ..., \hat{\pi}_{N,t}^\star\right]$. As a result $u_t^h = \boldsymbol{\beta'} F_t \boldsymbol{\hat{\pi}_t^\star} = 0$

If $F_{1,t} < 1$ and $F_{i,t} = 1$ for all $i \neq 1$ then we have $[F_t^{-1}(I - F_t)]_{1,1} \neq 0$ and $[F_t^{-1}(I - F_t)]_{i,j} = 0$ otherwise. Then $M_t F_t = [I + \tilde{L} F_t^{-1}(I - F_t)]^{-1}$ is such that it has non-zero first column, ones on the diagonal and zeros otherwise. Then $\boldsymbol{\beta'} M_t F_t$ is a row vector with the first element being the only non-zero element. Hence, we have $\boldsymbol{\beta'} M_t F_t \boldsymbol{\hat{\pi}_t^\star} = 0$ since $\hat{\pi}_{1,t}^\star = 0$. □

Proof of Corollary 2 (Quasi-horizontal economy (only horizontal component)). If $\tilde{L} = I$ the net effect of markups on marginal cost is zero as intermediate cost effect exactly compensates the labor cost effect. In this case, $M_t = (I + \tilde{L} F_t^{-1}(I - F_t))^{-1} F_t^{-1} = I$ and the vertical component disappears.

In the case described by corollary, Leontief inverse is $L = I_\alpha^{-1}$, which gives $\tilde{L} = \frac{1}{1+\gamma} I_\alpha^{-1}$. To eliminate vertical component we need to have $\alpha_i = \frac{1}{1+\gamma}$ for all sectors i. □

B.3 Illustrative examples derivations

B.3.1 Vertical chain economies

Consider a general case of a two-sector vertical chain. U - upstream sector, D - downstream sector. F^U - upstream price flexibility, F^D - downstream price flexibility.

The share of upstream input in downstream production is w. Let productivity vector be $a' = [\epsilon^U,\ \epsilon^D]$. Price flexibility matrix is $F_t = \begin{pmatrix} F^U & 0 \\ 0 & F^D \end{pmatrix}$. I-O matrix is $W = \begin{pmatrix} 0 & 0 \\ w & 0 \end{pmatrix}$. Leontief inverse is $L = \begin{pmatrix} 1 & 0 \\ w & 1 \end{pmatrix}$. Consumption shares are $\boldsymbol{\beta'} = [0,\ 1]$ and Domar weigths are $\boldsymbol{\xi'} = \boldsymbol{\beta'} L = [w,\ 1]$. Labor shares $\alpha' = [1,\ (1-w)]$. Phillips curve residual is $u_t = \boldsymbol{\beta'} M_t F_t \hat{\boldsymbol{\pi}}^\star_t$ where $M_t F_t = (I + \tilde{L} F_t^{-1}(I - F_t))^{-1}$ and $\tilde{L} = \frac{1}{1+\gamma} \cdot \begin{pmatrix} 1 & -\gamma \\ w & 1 \end{pmatrix}$.

$M_t F_t = \frac{1+\gamma}{Det} \cdot \begin{pmatrix} 1+\gamma+f^D & \gamma f^D \\ -wf^U & 1+\gamma+f^U \end{pmatrix}$ where $f^U = \frac{1-F^U}{F^U}$, $f^D = \frac{1-F^D}{F^D}$ and $Det = (1+\gamma+f^U)\cdot(1+\gamma+f^D) - w\gamma f^U \cdot f^D > 0$. $\boldsymbol{\beta'} M_t F_t = \frac{1+\gamma}{Det} \cdot [-wf^U,\ 1+\gamma+f^U]$. Desired price changes are $\hat{\boldsymbol{\pi}}^\star_t = -[(1-w)\epsilon^U - \epsilon^D,\ 0]'$. Then, Phillips curve residual

$$u_t = \frac{1+\gamma}{Det} \cdot w((1-w)\epsilon^U - \epsilon^D) \cdot \frac{1-F^U}{F^U} \tag{A.14}$$

Example 1: two-sector vertical chain. In this example Oil sector is Upstream and Final good sector is Downstream. We have $F^U = F^O = 1$, $\epsilon^U = \epsilon^O$ and $\epsilon^D = 0$. As a result we have $u = \frac{1+\gamma}{Det} \cdot w((1-w)\epsilon^O) \cdot \frac{1-F^O}{F^O} = 0$.

Example 2: Intermediate good. Consider a three-sector vertical chain Oil $\to$ Intermediate good $\to$ Final good. Assume that intermediate good uses only oil and no labor. Let price flexibilities be $F^O = 1$, $F^I < 1$ and $F^F < 1$. Then, Oil and Intermediate good can be combined in one Upstream sector such that $F^U = F^I$ and $F^D = F^F$. Under the oil shock ϵ^O, we have $\epsilon^U = \epsilon^O$ and $\epsilon^D = 0$. Then, the residual is is $u = \frac{1+\gamma}{Det} \cdot w(1-w) \cdot \epsilon^O \cdot \frac{1-F^I}{F^I}$. When oil productivity goes down (oil price goes up), Phillips curve residual also goes down (consumer prices go down).

Example 3: "Sticky wage" economy. Consider a three-sector vertical chain Labor sector$\to$ Oil$\to$ Final good. Assume that final good uses only oil and no labor. Let price flexibilities be $F^L < 1$, $F^O = 1$ and $F^F < 1$. Then, Oil and Final good can be combined in one Downstream sector such that $F^U = F^L$ and $F^D = F^F$. Under the oil shock ϵ^O, we have $\epsilon^U = 0$ and $\epsilon^D = \epsilon^O$. Then, the residual is is $u = \frac{1+\gamma}{Det} \cdot -w\epsilon^O \cdot \frac{1-F^L}{F^L}$. When oil productivity goes down (oil price go up), Phillips curve residual goes up (consumer prices go up).

B.3.2 Multiple input/goods economies

Next, consider a two-sector horizontal economy with good 1 (G1) and (G2) such that only labor and own output is used for production of each good. Then production network is $W = I - I_\alpha$, $L = I_\alpha^{-1}$, $\tilde{L} = I$ and $M_t = I$ which eliminates vertical component of cost-push inflation. The shares of each good in consumption are s_1 and s_2 such that $s_1 + s_2 = 1$. Let each of these sectors be hit by a respective shock ϵ_1 and ϵ_2 and the respective price flexibilities be F_1 and F_2. Then $L\boldsymbol{a_t} = [(1-\alpha_1)^{-1} \cdot \epsilon_1,\ (1-\alpha_2)^{-1} \cdot \epsilon_2]'$. Then, $\hat{\boldsymbol{\pi}}_{\boldsymbol{t}}^{\star} = -[s_2((1-\alpha_1)^{-1} \cdot \epsilon_1 - (1-\alpha_2)^{-1} \cdot \epsilon_2),\ -s_1((1-\alpha_1)^{-1} \cdot \epsilon_1 - (1-\alpha_2)^{-1} \cdot \epsilon_2)]'$. Then cost-push inflation is $u = -s_1 \cdot s_2 \cdot (F_1 - F_2) \cdot ((1-\alpha_1)^{-1} \cdot \epsilon_1 - (1-\alpha_2)^{-1} \cdot \epsilon_2)$.

Example 4: Multiple inputs economy. Consider an economy where single final good is produced using two inputs Oil and Intermediate good. If price flexibility in final good sector is 1 and no labor is used in this sector, then this economy is a special case of a horizontal economy described above. We have $F_1 = F^O = 1$, $F_2 = F^I$, $s_1 = 1 - \alpha^I$, $s_2 = \alpha^I$, $\alpha_1 = \alpha_2 = 1$ and $\epsilon_1 = \epsilon^{Oil}$, $\epsilon_2 = 0$. As a result we have cost-push effect $u = -\alpha^I(1-\alpha^I) \cdot (1 - F^I) \cdot \epsilon^{Oil}$.

Example 5: Two-commodity economy. Consider an economy consisting of two commodities: Oil and Grain and two final goods: Oil-intensive final good and Grain-intensive final good. Commodity sectors have fully flexible prices, while final good sectors have partially rigid prices. If final goods sectors do not use any labor and use only respective commodities, then this economy can be represented as a special case of a two-sector horizontal economy described above with Oil commodity and Oil intensive final good representing the first sector and Grain commodity and Grain-intensive final good representing the second sector. Then, we have $F_1 = F^{FO}$, $F_2 = F^{FG}$, $\alpha_1 = \alpha_2 = 1$, $s_1 = s_2 = 0.5$ are consumption shares, $\epsilon_1 = \epsilon^{Oil}$ and $\epsilon_2 = \epsilon^{Grain}$. Then, cost-push effect is $u = -\frac{1}{4} \cdot (F^{FO} - F^{FG}) \cdot (\epsilon^{Oil} - \epsilon^{Grain})$

C Empirical appendix

C.1 Methodology appendix

C.1.1 Derivations

Combining the demand system (16) with the supply system (21) we obtain the following system of equations linking sectoral markups $\boldsymbol{\mu_t}$ and sector-relevant state changes

$\boldsymbol{\Delta s_t}$ as

$$(\tilde{L} + (I - F_t)^{-1} \cdot F_t) \cdot \boldsymbol{\mu_t} = -\boldsymbol{\Delta s_t} + [\boldsymbol{p_{t-1}} + \boldsymbol{e_{t-1}} - m_t \cdot \mathbf{1} - \boldsymbol{s_{t-1}}] \tag{A.15}$$

On the other hand, the price change can be expressed from the demand system (16) as

$$\boldsymbol{\Delta p_t} = m_t \cdot \mathbf{1} + \tilde{L} \cdot \boldsymbol{\mu} + \boldsymbol{\Delta s_t} + \boldsymbol{s_{t-1}} - \boldsymbol{p_{t-1}} \tag{A.16}$$

Expressing markups from (A.15), substituting into (A.16), and rearranging the terms yields the link between sectoral price changes and sector-relevant state innovations

$$(I + \tilde{L}F_t^{-1}(I - F_t)) \cdot (\boldsymbol{\Delta p_t} - \boldsymbol{e_{t-1}}) = \boldsymbol{\Delta s_t} + \boldsymbol{\tilde{v}_t} \tag{A.17}$$

where $\boldsymbol{\tilde{v}_t} = m_t \cdot \mathbf{1} + \boldsymbol{s_{t-1}} - \boldsymbol{p_{t-1}} - \boldsymbol{e_{t-1}}$.

The rearranged diagonal system for sectoral markups is

$$\boldsymbol{\Delta s_t} + \tilde{L}\boldsymbol{\mu_t} = F_t \cdot \left[\boldsymbol{\Delta s_t} + (\tilde{L} - I)\boldsymbol{\mu_t}\right] - (I - F_t) \cdot \boldsymbol{\tilde{v}_t}$$

Substituting (A.16) into the above system we get the diagonal system in the main text.

C.1.2 Computing sector relevant states and markups

Let all industies be indexed by $i \in \{1, ..., N\}$. At any period t the available k sectors have indices $\{i^1, ..., i^k\} \subseteq \{1, ..., N\}$. I construct $N \times k$ selection matrix S, such that $S[i^j, j] = 1$ and zero otherwise. Note, that $S^T S = I$. Then transformation $S\boldsymbol{u}$ transforms k-sized vector $\boldsymbol{u}$ to N-sized vector with zeros for unavailable sectors; $S^T\boldsymbol{v}$ transforms N-sized vector $\boldsymbol{v}$ to k-sized, by choosing only elements for available industires. Hence, we can write a system of k equations for k markups and productivities in terms of k wages and prices

$$\boldsymbol{\mu} = \frac{1+\gamma}{\gamma} \cdot S^T (I_\xi^{-1} L^T I_\xi)^{-1} S \cdot ((p+y) \cdot \mathbf{1} - \boldsymbol{w}) \tag{A.18}$$

$$\boldsymbol{s} = \boldsymbol{p} - S^T(\tilde{L}S \cdot \boldsymbol{\mu} + (p+y) \cdot \mathbf{1}) \tag{A.19}$$

C.1.3 Instrument validity

Proof. Note that $\tilde{v}_{t,i}$ is independent of $z_{t,i}$ as long as monetary policy does not react within a month to a productivity shock. Furthermore, $F_i(|z_{t,i}|)z_{t,i}$ has mean zero, since $z_{i,t}$ is zero mean normally distributed. Hence, we have

$$Cov(F_i(|z_{t,i}|)z_{t,i},\ F_i(|z_{t,i}|)\tilde{v}_{t,i}) = E(F_i(|z_{t,i}|)^2 z_{t,i}\tilde{v}_{t,i}) =$$
$$= \int\int F_i(|z_{t,i}|)^2 z_{t,i}\tilde{v}_{t,i} f_z f_{\tilde{v}} dz d\tilde{v} = \int_{\tilde{v}} \left[\int_z F_i(|z_{t,i}|)^2 z_{t,i} f_z dz\right] \tilde{v}_{t,i} f_{\tilde{v}} d\tilde{v} = 0$$

The last equality follows as inner integral equals to zero due to zero mean symmetric distribution of $z_{i,t}$. Hence, instruments constructed in this matter are valid. □

C.2 Dataset construction

This Appendix describes the construction of BEA-coded sectoral prices and wages.

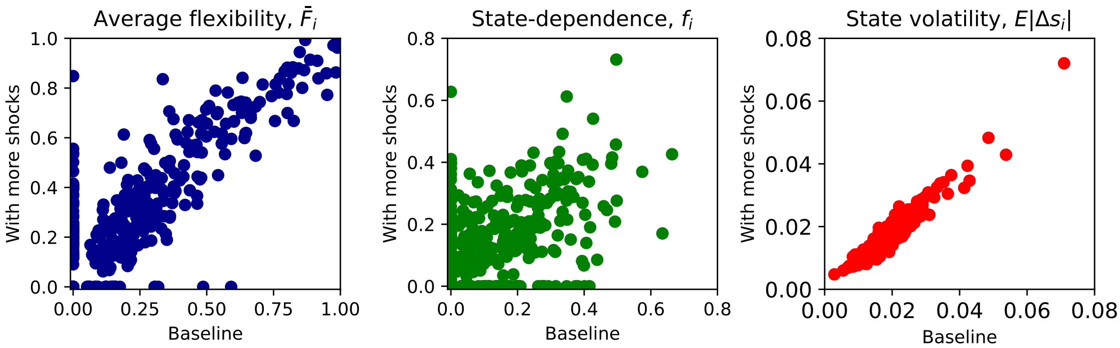
Sectoral wages (from CES to NAICS). Sectoral wages are initially classified with CES codes, with available correspondence from CES to NAICS codes. So first I transform the wages classification to NAICS-based. The main complication is that CES to NAICS mapping is not one-to-one as at least for some NAICS codes more than one CES sector exists.To overcome this complication I compute the weighted average wage for each NAICS sector as $w^{NAICS} = \sum \alpha_i w_i^{CES}$ where w_i^{CES} are CES-sector wages corresponding to a given NAICS sector code. Each weight α_i is computed as a ratio of the number of workers employed in sector i to the total number of workers in all CES sectros corresponding to a given NAICS sector. The number of employed workers is taken form the same CES dateset as the average number for the year 2012, to correspond to the year of the Input-Output table used.

NAICS to BEA concordance. The producer prices data is classified by NAICS codes as well as wages data (after the transformation from CES to NAICS described above). To apply this data to the available input-output tables I convert NAICS based sectoral data to BEA based sectoral data. BEA Bridge tables have a rough BEA-NAICS code correspondence, from which I make use to establish a concordance between NAICS codes and BEA codes. The problem is that the BEA-NAICS codes correspondence is not one-to-one. For those cases when one BEA code corresponds to several NAICS codes I need weights to evaluate the BEA-based price as a weighted average of the NAICS based prices. For this I need to compute the relative sector size of each NAICS sector withing a given BEA sector. The primary data source I use to compute NAICS sector sizes is the Annual survey of manufacturers from the US Census. I use the corresponding "Shipment value" quantities for the survey of 2012. The secondary data source is the Current Employment Survey. I use the number of employed people as an sector size variable, translated from CES into NAICS codes in the same manner as wages. First I try to compute NAICS sector weights in each BEA code using ASM data. If ASM data is unavailable, I use CES data. For those sectors, that are not covered by either dataset I use the uniformal weights.

NAICS to BEA matching procedure. Having constructed the mapping from NAICS to BEA codes with corresponding weights, I convert the NAICS data into the BEA data. I want to find a corresponding NAICS code for as many NAICS sectors from the NAICS-BEA mapping as possible. First, I find the the NAICS codes in the data that have the identical NAICS codes in the NAICS-BEA mapping. For the remaining NAICS codes from the BEA-NAICS mapping I try to find the correspondence at the more aggregated level. I subsequently remove 1,2 and 3 last digits of NAICS codes form the mapping and try to find the corresponding more aggregated sector in the data.

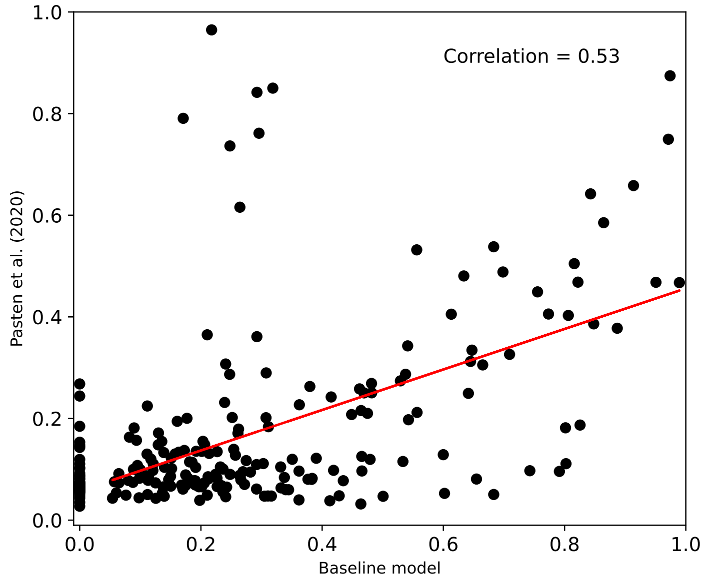
C.3 Additional results

Figure C.1: Baseline estimates vs. model with more shocks



Correlation of average flexibilities is 0.83; state-dependence parameters - 0.45; average state volatilities - 0.96.

Figure C.2: Baseline estimates vs. Pasten et al. (2020) estimates

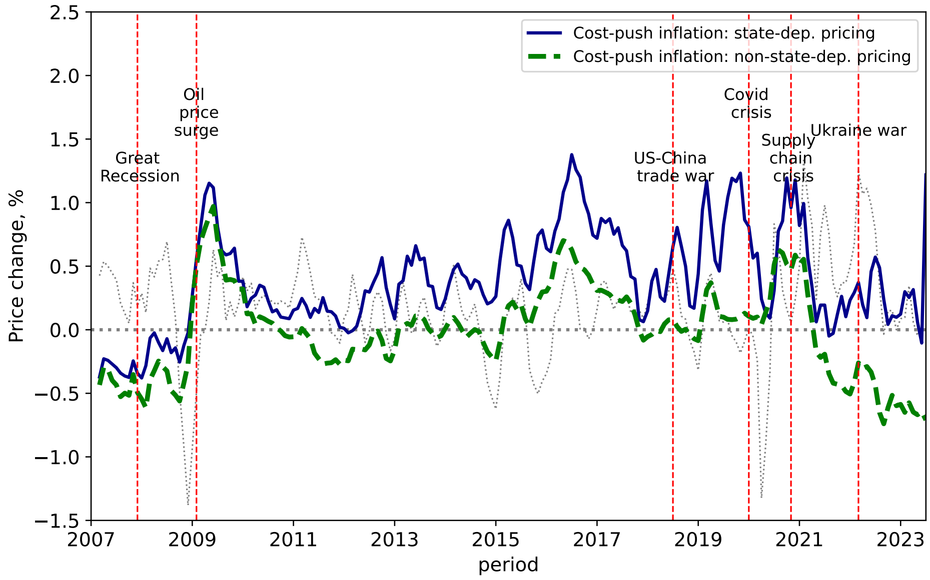


D Quantitative appendix

D.1 Model with more shocks

To check the robustness of baseline cost-push effect computations I now compute the alternative cost-push effect from the model with more shocks. In this computations, sector-relevant states are computed using more sectoral data and the parameters of price flexibility and state-dependence are estimated based on this alternative sector-relevant state.

Figure D.3: Phillips curve residual in model with more shocks



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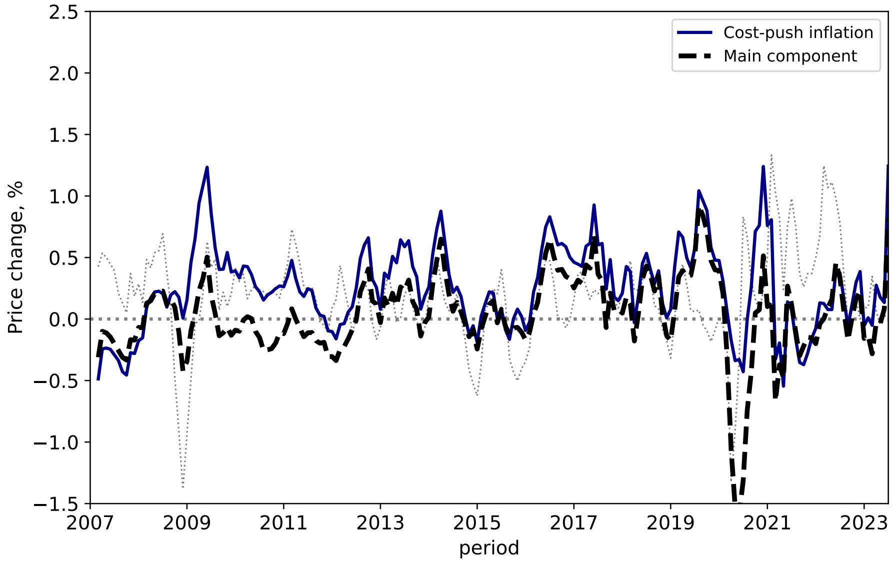
D.2 Cost-push effect decomposition

Now, I look into the quantitative importance of the main component of the cost-push inflation by applying the decomposition form Proposition 2. Figure D.4 shows that the main component largely shapes the fluctuations of the cost-push effect implying that the input-output component merely plays an amplifying/dampening role during different episodes. Hence, the theoretical results importance of the state dependence in shaping the main component of the cost-push effect apply to the large share of the cost-push inflation.

Figure D.4: Cost-push inflation and main component

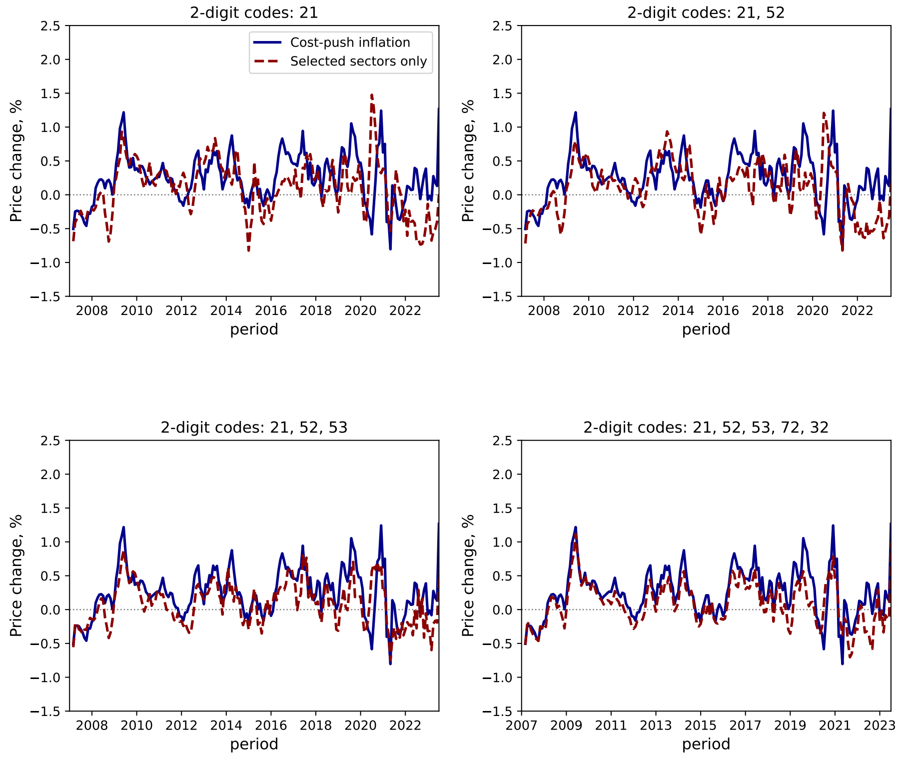


Grey line plots CPI inflation; **blue line** plots the Phillips curve residual implied by the model under estimated degree of price flexibility; **dashed black line** plots the main component of Phillips curve residual. CPI inflation and residual series are smoothed with a 3-month moving average.

D.3 Most important sectoral groups contribution

For these five most important groups, I compute counterfactual cost-push effects generated exclusively by fluctuations in sectors belonging to these groups. Figure D.5 panel A plots the residual induced by sector group 21 (Mining, Quarrying, and Oil and Gas Extraction) and indicates that this sector group alone can partially explain the cost-push effect of 2009 but does not explain any other episode. Adding other important groups 52, 53 (Finance and Insurance, Real Estate, and Rental and Leasing) on panel B, and 32, 72 (Manufacturing of durable goods, Accommodation, and Food Services) on panel C, improves the fit to full residual - many fluctuations can be attributed to these most important sectors.

Figure D.5: Cost-push inflation due to 2-digit sector groups



Red dashed line plots counterfactual residuals computed by shutting down the shocks in all sectors except a given 2-digit sector group.

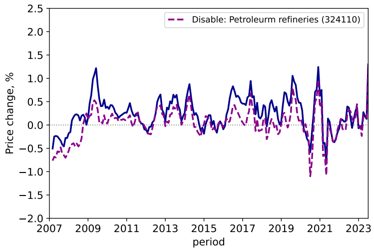
D.4 Sectoral contribution during particular episodes

Now, I investigate which sectors have contributed the most during three important historical episodes: the post-Great Recession, the post-Covid episode, and the Ukraine war. For this, I find the largest-seized elements of the sum constituting the main component of the cost-push effect within each episode of interest. Then, I compute counterfactual residual by switching off these sectors.

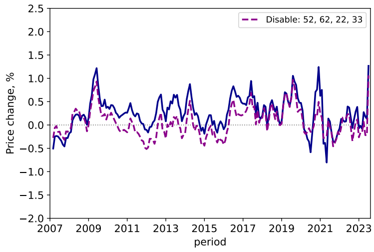
In 2009, a lot of cost-push effect was attributed to the "Petroleum refineries" sector alone. Figure D.6 (panel A) shows that switching off this sector substantially reduces the 2009 cost-push effect. The Covid and post-Covid episode was not attributed to any particular sector but rather to several groups simultaneously 52, 62, 22, 33 (Finance and Insurance, Health Care and Social Assistance, Utilities, Manufacturing (durable goods). Figure D.6 (panel B) shows that these groups explain most of the cost-push effect in 2020-2021. The 2022 surge of the cost-push effect is largely attributed to sector groups 53 and 72 (Real Estate and Rental and Leasing, Accommodation and Food Services) as shown on Figure D.6 (panel C).

Figure D.6: Cost-push inflation due to 2-digit sector groups

(a) disable Great Recession sectors



(b) disable Covid crisis sectors



(c) disable Ukraine war sectors