Pipeline pressures and sectoral inflation dynamics

Working Paper Research

by Frank Smets, Joris Tielens and Jan Van Hove

October 2018 No 351

NationalBank
OF BELGIUM
Eurosystem

Pipeline Pressures and Sectoral Inflation Dynamics[*]

Smets, Frank[1], Tielens, Joris[2,3], and Van Hove, Jan[3,4]

[1]European Central Bank, Ghent University and CEPR
[2]National Bank of Belgium
[3]KU Leuven
[4]KBC

Abstract

In a production network, shocks originating in individual sectors do not remain confined to individual sectors but permeate through the pricing chain. The notion of "pipeline pressures" alludes to this cascade effect. In this paper we provide a structural definition of pipeline pressures to inflation and use Bayesian techniques to infer their presence from quarterly U.S. data. We document two insights. (*i*) Due to price stickiness along the supply chain, we show that pipeline pressures take time to materialize which renders them an important source of inflation persistence. (*ii*) As we trace their origins to 35 disaggregate sectors, pipeline pressures are documented to be a key source of headline/disaggregated inflation volatility. Finally, we contrast our results to the dynamic factor literature which has traditionally interpreted the comovement of price indices arising from pipeline pressures as aggregate shocks. Our results highlight the role of sectoral shocks – joint with the production architecture – to understand the micro origins of disaggregate/headline inflation persistence/volatility.

Keywords: Pipeline pressures · Input–output linkages · Propagation
JEL classification: E31 · E32 · D85 · O51

---

[*] The authors wish to thank Raf Wauters, Andrew Foerster, Mark Watson and seminar participants at KU Leuven, National Bank of Belgium, European Central Bank. Part of this research was performed while Joris Tielens was visiting the European Central Bank. Joris Tielens gratefully acknowledges the financial support from the Research Foundation Flanders (FWO). Contract number 11W0317N. The views expressed in this paper are those of the authors and do not necessarily reflect the views of the European Central Bank, the National Bank of Belgium, the Eurosystem, KBC Group or any other institutions to which the authors are affiliated. All remaining errors are our own. E-mail: frank.smets@ecb.europa.eu, joris.tielens@nbb.be and jan.vanhove@kuleuven.be.

1 Introduction

Any modern economy is characterized by an interlinked production architecture in which sectors rely on each other for goods and services as inputs for production. Motivated by the seminal contributions of Long and Plosser (1983, 1987), an emerging body of research has documented the implications of these interactions for macroeconomic dynamics. Input–output production networks are now well–known to e.g., (*i*) amplify monetary policy shocks (Ozdagli and Weber (2016); Pasten et al. (2016); Ghassibe (2018)), (*ii*) affect the incidence of large economic downturns (Acemoglu et al. (2016)), (*iii*) generate macroeconomic volatility from microeconomic shocks (Carvalho and Gabaix (2013); Di Giovanni et al. (2014); Atalay (2017)), (*iv*) have important implications for macroeconomic nonlinearities (Baqaee and Farhi (2017)), etc. In this paper we study the implications of production networks for sectoral inflation dynamics.

The increasing availability of disaggregated price data has stimulated a vast literature that investigates the properties of sectoral price dynamics (e.g., Boivin et al. (2009); Maćkowiak et al. (2009); Altissimo et al. (2006); Kaufmann and Lein (2013); Andrade and Zachariadis (2016); De Graeve and Walentin (2015), etc.). This body of research invariantly relies on factor analytic methods to decompose sectoral and headline inflation indices into a "common" and a "sector–specific" part (as per Forni and Reichlin (1998)). A set of stylized facts has emerged from this literature; (*i*) Disaggregated ppi/pce inflation volatility is mostly due to sector–specific shocks. Aggregate shocks explain only a small fraction of movements in sectoral inflation. The reverse is true for headline inflation, which is mostly driven by aggregate shocks (since sectoral shocks cancel each other out in the aggregate). (*ii*) Persistence, of both disaggregate and headline inflation, is generated by aggregate shocks. The response to sector–specific shocks, by contrast, is close to instantaneous.

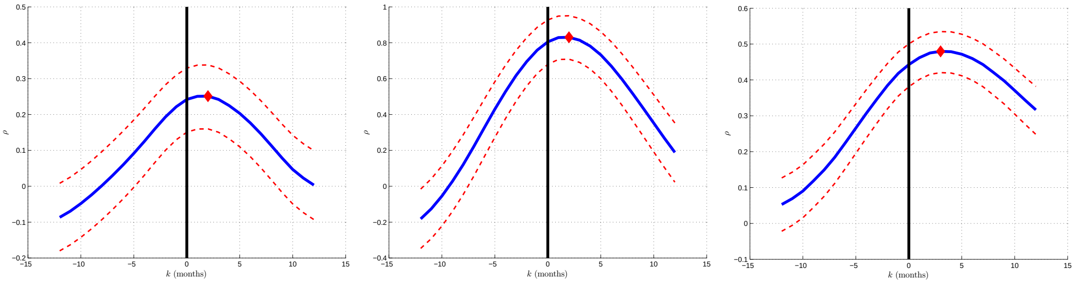
In view of an interlinked production network, recent work has voiced concerns that a dynamic factor model (dfm) is an unsuitable tool to properly sort between the role of aggregate and sectoral shocks in generating volatility and persistence.[1] Foerster et al. (2011) argue that sector–specific shocks propagate across the production architecture in a way which generates comovement across sectors.[2] A dfm then wrongfully interprets the origins of this comovement of prices as an aggregate shock (common component). As such, it mechanically underestimates the role of sectoral shocks in generating persistence and volatility.

Since they often represent sequential inputs, the construction of disaggregated ppi and pce price indices is consistent with this concern (U.S. Department of Labor (2011)). For example, the U.S. "crude materials ppi" includes the price of logs, while the "intermediate goods ppi" includes the prices of (paper)pulp, which is obtained from processing logs. The "finished goods ppi" includes the price of

---

[1] Measurement error in micro price data is known to affect these stylized facts as well, see e.g., De Graeve and Walentin (2015).

[2] See also Stella (2015); Atalay (2017); Atalay et al. (2018).



(a) $\rho(\pi_t^{(paper)pulp}, \pi_{t-k}^{Logs})$ (b) $\rho(\pi_t^{Paper}, \pi_{t-k}^{(paper)pulp})$ (c) $\rho(\pi_t^{Magazines}, \pi_{t-k}^{Paper})$

Figure 1: Autocorrelation functions. Data sources: BLS PPI database (ppi of Logs, Pulpwood and Paper) and BEA pce database (pce price index of Magazines and Journals). The red dashed lines are 95% confidence bounds.

industrial blank paper, which is manufactured using primarily (paper)pulp. Finally, the pce price index includes the price paid by consumers for final goods categories, such as printed newspapers and magazines. Figure 1 depicts the autocorrelation functions of the four inflation indices. The level and asymmetries of the lead–lag relationships are consistent which such a (slow) spillover process from upstream prices into downstream product categories.

Following the terminology in recent policy work (e.g., European Central Bank (2017); Federal Reserve System (2018)) and the popular press (e.g., Wall Street Journal (2018); Financial Times (2018)), we label this cascade effect of sectoral shocks as “pipeline pressures” and assess their impact on sectoral price dynamics. In doing so, we face three challenges; (*i*) infer pipeline pressures from the data, (*ii*) investigate whether they are empirically relevant and (*iii*) verify whether a dfm effectively has difficulties correctly disentangling pipeline pressures from aggregate shocks. We then assess the impact of pipeline pressures on aforementioned stylized facts.

We resolve the first challenge by developing a multi–sector dynamic stochastic general equilibrium model which allows us to formally define and quantify the concept of pipeline pressures.[3] Briefly, the model features multiple interactions among the various sectors (e.g., through the structural inclusion of an IO matrix) and accommodates the coexistence of producer and consumer prices. We include two sets of shocks; (*i*) Aggregate shocks (e.g., an economywide productivity shock) and (*ii*) sectoral shocks (e.g., a wage markup shock specific to the “Agriculture” sector).

We subsequently estimate the model using Bayesian techniques based on a mix of aggregate and sectoral U.S. data covering the period $1970Q1 - 2007Q4$. In order to verify whether pipeline pressures are empirically relevant, we use the Bayes factor to bilaterally compare the full model with a vintage of the

---

[3] The model nests, or shares features with, other multi–sectors models, e.g., Bouakez et al. (2009, 2014); Long and Plosser (1983); Horvath (1998); Carvalho and Lee (2011); Dixon et al. (2014); Bergholt (2015); Foerster et al. (2011); Pasten et al. (2016); Atalay (2017); Nakamura and Steinsson (2010).

model where an individual sector is isolated from price developments in other sectors. We document that most price indices are, to varying degrees, subject to cost pressures from upstream sectors. More precisely, all consumer prices are influenced by producer prices. In addition, producer prices of downstream sectors (e.g., "Services", "Manufacturing") are strongly subject to price developments in upstream sectors (e.g., "Mining" and "Agriculture"), whereas these upstream sectors face less pressures.

To address the third challenge, we use the Kalman filter to decompose historical U.S. ppi/pce inflation rates through the lens of our structural model. In contrast to a dfm, we consider a three–way decomposition; a part due to (i) structural aggregate shocks, (ii) direct sectoral shocks (i.e. the sectoral shocks in sector j on inflation in sector j) and (iii) pipeline pressures (i.e. the sectoral shocks in sector j' on inflation in sector j). We show that the smoothed time series obtained from the aggregate shocks comoves intimately with the common component from a dfm. Importantly, we show this comovement to increase further once pipeline pressures are taken into account, which reveals that the common component in a dfm framework captures both aggregate shocks and pipeline pressures.

We next structurally decompose the origins of sectoral volatility/persistence into $(i) - (iii)$. In contrast to the dfm literature, we show that sectoral shocks, by ways of pipeline pressures, are an important contributor to sectoral and headline inflation persistence. Following Basu (1995) and Blanchard (1982), sectoral shocks generate persistence in other sectors since price staggering along the production chain implies that shocks only slowly feed into other sectors' marginal costs and output prices. Pipeline pressures also contribute significantly to headline volatility: 21.47% (ppi) and 28.16% (pce), respectively. Across disaggregated indices, the role of pipeline pressures is heterogeneous, ranging from 0.86% for the ppi index "Agriculture and Forestry" to 43.25% for the "Healthcare" pce index.

An historical perspective on U.S. inflation shows that the role of pipeline pressures has varied over $1970Q1 - 2007Q4$. E.g., pipeline pressures during the 1979 and 1990 energy crises originate with direct shocks to the "Oil extraction ppi" which subsequently permeates to the "Utilities ppi", "Manufacturing ppi" and "Service ppi" and various pce indices. The aftermath of the double dip recession in the mid–eighties is shown to have triggered pipeline easing, where sectoral disinflationary shocks eased inflation in other sectors. The nineties are characterized as a period of moderate and less volatile inflation where pipeline pressures are mostly subdued.

Literature & Contribution. Although our work primarily adds to an empirical literature on price dynamics, we contribute to other strands of literature as well.

First, Bouakez et al. (2014) and Pasten et al. (2017) study the role of sectoral productivity shocks in generating aggregate ppi volatility. The former does not study the role of pipeline pressures, whereas the latter only does so theoretically. Here, we bring part of the intuition of Pasten et al. (2017) to the data and allow for a richer set of shocks a in less stylized set–up.[4] Close to our work is Auer et al. (2017), who show in a partial equilibrium framework that international trade flows contribute substantially to synchronizing headline ppi's across countries. The analysis compares the comovement of ppi's on the one hand and the (inferred) underlying costs shocks on the other and attributes the incremental comovement of price indices vis–à–vis costs to the impact of propagation across trade linkages. Our project identifies propagation directly as opposed to implicit inference from comparing measures of comovement.

Second, a set of empirical contributions has provided (reduced form) evidence that exogenous shocks propagate throughout the production structure of the economy; e.g., natural disasters (Carvalho et al. (2016); Barrot and Sauvagnat (2016); Boehm et al. (2015)), productivity shocks (Caliendo et al. (2017); Carvalho and Gabaix (2013); Acemoglu et al. (2012)), trade shocks (Acemoglu et al. (2015)), monetary policy shocks (Pasten et al. (2016); Ghassibe (2018)), financial shocks (Bigio (2015); Dewachter et al. (2016)), etc. In the stylized models underlying these empirical results, the central propagation process takes place via price setting. We are the first paper to formally test whether such pressures effectively take place.

Third, following the evidence in Clark et al. (1995), our model predicts that movements in particular price indices can lag behind movements in prices at early stages of production. The model performs well in this dimension in the sense that it captures the lead–lag relationships that are present in disaggregated price data. Our work thus provides justification for the practice of policymakers and forecasters looking for signs of an impending rise in the general price level by concentrating on events in particular sectors, e.g. (i) shifts in healthcare sector regulation (e.g. Affordable Care Act), (ii) stricter emissions and mileage standards in the automotive industry, (iii) productivity shocks in the computer and electronics industry, (iv) the shale gas boom in the mining sector, (v) disruptions in the real estate sector, etc.

The rest of the paper is structured as follows. Section 2 takes stock of a set of stylized facts from the literature. In section 3 we develop a model that endogenously reproduces these stylized facts, whilst controlling for pipeline pressures. Section 4 maps the structure of the model to the U.S. economy and provides details on the estimation. In section 5 we discuss how pipeline pressures affect the previously documented stylized facts. Section 6 complements the main analysis with a set of additional results and robustness checks. Finally, section 7 concludes and provides policy implications.

---

[4] The literature on the "micro origins of aggregate fluctuations", originating with Gabaix (2011) and Acemoglu et al. (2012) has almost invariantly focused on micro level productivity shocks (see e.g., Carvalho and Grassi (2016); Grassi (2017); Gabaix (2011); Acemoglu et al. (2012); Pasten et al. (2017); Carvalho and Gabaix (2013); Foerster et al. (2011); Di Giovanni et al. (2014); Stella (2015); Atalay (2017); Shea (2002)). Workhorse dsge models qualify productivity as only a marginal driver of inflation (e.g., Smets and Wouters (2007, 2003); Christiano et al. (2011); Adolfson et al. (2007)). Consequently, in this paper, we focus on other types of shocks as well.

2 Stylized facts

Consider the following decomposition of disaggregated inflation indices into a common and a sector–specific component

$$\pi_{it} = \boldsymbol{\lambda}_i' \boldsymbol{f}_t + \epsilon_{it}$$

where π_{it} denotes inflation of producer/consumer prices of sector i. The factor loadings $\boldsymbol{\lambda}_i$ measure the heterogeneous response of sector i to a vector of aggregate shocks $\boldsymbol{f}_t$ that affects all prices. The remainder, ϵ_{it}, is a purely sector–specific scalar process. It reflects the response of price i inflation to a shock specific to sector i. Following the decomposition at the micro level, headline inflation can be decomposed as

$$\pi_t = \boldsymbol{w}' \boldsymbol{\Lambda} \boldsymbol{f}_t + \boldsymbol{w}' \boldsymbol{\epsilon}_t$$

where $\boldsymbol{w}'$ is a vector of sectoral weights in the composite inflation index. With this two–way decomposition at hand, Boivin et al. (2009); Maćkowiak et al. (2009); Kaufmann and Lein (2013); Altissimo et al. (2006), decompose the variance, $\langle \sigma^2(\pi_{it}), \sigma^2(\pi_t) \rangle$, and persistence, $\langle \rho(\pi_{it}), \rho(\pi_t) \rangle$, of sectoral and headline inflation into a common part and a sector–specific part.

We reproduce this analysis in table 1–2, using disaggregated quarterly U.S. ppi and pce inflation indices introduced later in the paper. In keeping with the literature, we distill four stylized facts.[5]

1. Stylized fact 1a: $\frac{\sigma^2(\boldsymbol{\lambda}_i' \boldsymbol{f}_t)}{\sigma^2(\pi_{it})} < \frac{\sigma^2(\epsilon_{it})}{\sigma^2(\pi_{it})}$: Sectoral shocks originating in sector i generate the majority of volatility in sector i inflation.
2. Stylized fact 1b: $\frac{\sigma^2(\boldsymbol{w}' \boldsymbol{\Lambda} \boldsymbol{f}_t)}{\sigma^2(\pi_t)} > \frac{\sigma^2(\boldsymbol{w}' \boldsymbol{\epsilon}_t)}{\sigma^2(\pi_t)}$: Aggregate shocks generate the majority of volatility in headline inflation.
3. Stylized fact 2a: $\rho(\boldsymbol{\lambda}_i' \boldsymbol{f}_t) > \rho(\epsilon_{it})$: Aggregate shocks generate the majority of persistence in sector i inflation.
4. Stylized fact 2b: $\rho(\boldsymbol{w}' \boldsymbol{\Lambda} \boldsymbol{f}_t) > \rho(\boldsymbol{w}' \boldsymbol{\epsilon}_t)$: Aggregate shocks generate the majority of persistence in headline inflation.

[Insert table 1–2]

Persistence is measured following Boivin et al. (2009); an $AR(L)$ model is estimated for both components of the dfm and $\rho(\cdot)$ equals the sum of the coefficients on all lags.

Following Foerster et al. (2011), in the presence of production networks, $\boldsymbol{\lambda}_i' \boldsymbol{f}_t$ reflects comovement of price indices resulting from (i) aggregate shocks and (ii) sectoral shocks that have propagated through input–output linkages. Hence,

---

[5] The stylized facts regarding persistence are less outspoken compared to the literature because we use quarterly data, whereas the literature mostly relies on monthly data.

stylized facts $1a-b$ are potentially biased in favour of aggregate shocks. Moreover, since the work of Basu (1995), it is well–known that such propagation is sluggish.[6] The persistence patterns documented by stylized facts $2a-b$ might then in part reflect the slow propagation of sectoral shocks.

The objective of this paper is to investigate whether aforementioned stylized facts in the dfm framework change once we correctly disentangle pipeline pressures from aggregate shocks. For that purpose, we provide a three–way (instead of a two–way) decomposition of sectoral and headline inflation:

$$\begin{aligned}\pi_{it} &= \boldsymbol{\alpha}_t(\pi_i) + \boldsymbol{\beta}_t(\pi_i) + \boldsymbol{\gamma}_t(\pi_i)\\ \pi_t &= \sum_{i=1}^{N} w_i\big(\boldsymbol{\alpha}_t(\pi_i) + \boldsymbol{\beta}_t(\pi_i) + \boldsymbol{\gamma}_t(\pi_i)\big)\end{aligned}$$

where $\boldsymbol{\alpha}_t(\pi_{it})$ reflects aggregate, economywide shocks, $\boldsymbol{\beta}_t(\pi_{it})$ captures shocks specific to price index i and $\boldsymbol{\gamma}_t(\pi_{it})$ captures pipeline pressures; sectoral shocks that originate in other sectors but affect prices in sector i through production network interactions. In order to obtain aforementioned decomposition, we develop a multi–sector dynamic stochastic general equilibrium model in the next section.

3 The model

Production is shaped by a two–layered structure; a discrete set of sectors and a continuum of firms active within each sector. We discern three types of firms: (i) intermediate goods producers, (ii) final goods producers and (iii) capital goods producers. Each firm is active in one of J sectors, but intersectoral trade flows create a role for spillovers. The model features two sets of shocks; (i) economywide shocks, that affect all prices and (ii) sector–specific shocks (that are specific to individual price indices). The rest of the model is relatively standard and features a (i) household, (ii) government and (iii) monetary authority. Figure 2 contains a schematic overview of (a particular instance of) the model.

[Insert figure 2]

3.1 Households

Assume the existence of a representative household which consists of a continuum of members, with a fixed share μ_j working in production sector $j \in \{1, ..., J\}$. Household member h working in sector j maximizes lifetime utility at time t

$$\mathscr{U}_{jt}(h) = \sum_{s=t}^{\infty} \beta^{s-t}\big(U_{js|t-i}(h) - V_{js|t-i}(h)\big)$$

---

[6] See also relevant work by Huang (2006); Huang et al. (2004); Huang and Liu (2004).

where $U_{jt|t-i}(h)$ is period t utility of consumption, and $V_{jt|t-i}(h)$ is period t disutility of labour, for a member that was last able to re–optimize the wage i periods ago. $\beta \in (0,1)$ is the time discount factor. The components of period t utility are specified as follows;

$$U_{jt|t-i}(h) = \frac{(C_{t|t-i}(h) - \chi C_{t-1|t-i}(h))^{1-\sigma}}{1-\sigma}$$
$$V_{jt|t-i}(h) = \frac{L_{jt|t-i}(h)^{1+\varphi}}{1+\varphi}$$

Given wage re–optimization i periods ago, $C_{t|t-i}(h)$ denotes period t consumption and $L_{jt|t-i}(h)$ is hours worked by household member h. We assume the existence of a complete set of tradeable Arrow–Debreu securities. This, joint with the separability between consumption and hours, makes consumption independent of the wage history, i.e. $C_{t|t-i}(h) = C_{t|t}(h) = C_t(h)$.[7] In addition, because the representative household is of measure one, household member h consumption is also aggregate consumption: $C_t(h) = C_t$. We drop the h index whenever possible from now on.

Households buy consumption goods, sell labor services to firms and save. Maximization of lifetime utility is subject to a sequence of budget constraints. In period t, the budget constraint takes the following form (abstracting from Arrow–Debreu securities):

$$P_t C_t + \frac{B_t}{R_t Z_{b,t}} = \sum_{j=1}^{J} \int_{\bar{\mu}_{j-1}}^{\bar{\mu}_j} L_{jt}(h) W_{jt}(h) dh + B_{t-1} + D_t - P_t T_t$$

where P_t denotes the personal consumption expenditures (pce) price index faced by the household, D_t are dividends (firm profit channelled to the household), B_t denotes total savings in the form of government bonds, $Z_{b,t}$ is an aggregate risk shock and T_t are lump sum taxes, levied by the government. $\bar{\mu}_j = \sum_{l=1}^{j} \mu_l$ denotes the cumulative mass of workers employed in sectors $1, ..., j$. The term involving the integral then denotes total wage income.

The aggregate consumption bundle is defined as

$$C_t = \Big(\sum_{z=1}^{Z} \xi_z^{\frac{1}{\nu_c}} C_{zt}^{1-\frac{1}{\nu_c}} \Big)^{\frac{\nu_c}{\nu_c - 1}} \quad ; \quad \sum_{z=1}^{Z} \xi_z = 1; \xi_z \in [0,1]$$

where C_{zt} denotes a consumption bundle of goods from product category z. $\{\xi_z\}_{z=1}^{Z}$ are heterogeneous consumption weights. Optimal demand schedules are given by

$$C_{zt} = \xi_z \big(\frac{P_{zt}}{P_t}\big)^{-\nu_c} C_t \quad ; \quad P_t = (\sum_{z=1}^{Z} \xi_z P_{zt}^{1-\nu_c})^{\frac{1}{1-\nu_c}}$$

---

[7] See the discussion by Jensen (2011) and Bergholt (2015).

Where P_{zt} denotes the pce price index of product category z. In turn, the consumption bundle of products from category z is defined as

$$C_{zt} = \Big[\int_0^1 C_{zt}(q)^{\frac{1}{1+\epsilon_{c,z,t}}} dq\Big]^{1+\epsilon_{c,z,t}}$$

where $C_{zt}(q)$ denotes consumption of the goods/services variant of product category z which is produced by final goods producer q. It is appropriate to think of product category z as an item from the pce categories in the national accounts (e.g., $z =$ "Motorized vehicles"), with final goods producer q producing a particular brand (e.g., $q =$ "General Motors"). $\epsilon_{c,z,t} = \epsilon_c Z_{c,z,t} Z_{c,t}$ are stochastic markups. Here, $Z_{c,z,t}$ reflects a shock specific to product category z prices, whereas $Z_{c,t}$ affects all prices simultaneously.

Next, we move to the labor market in sector j. We construct sectoral labor markets as in Erceg et al. (2000), but add the friction that workers cannot move freely between sectors (cf. Carvalho and Nechio (2016)). Denote the mass of household members working in sector j by $\mu_j \in (0,1)$ with $\sum_{j=1}^{J} \mu_j = 1$. A competitive labor bundler buys hours from all the household members employed in the sector, and combines these hours into an aggregate labor service N_{jt}. This aggregator takes the form

$$N_{jt} = \Big((\frac{1}{\mu_j})^{\frac{\epsilon_{w,j,t}}{1+\epsilon_{w,j,t}}} \int_{\bar{\mu}_{j-1}}^{\bar{\mu}_j} L_{jt}(h)^{\frac{1}{1+\epsilon_{w,j,t}}} dh \Big)^{1+\epsilon_{w,j,t}}$$

$\epsilon_{w,j,t} = \epsilon_w Z_{w,j,t} Z_{w,t}$ is a stochastic wage markup in sector j (featuring an economywide ($Z_{w,t}$) and sector–specific ($Z_{w,j,t}$) component). The cost of this bundle is given by

$$W_{jt} = (\frac{1}{\mu_j} \int_{\bar{\mu}_{j-1}}^{\bar{\mu}_j} W_{jt}(h)^{-\frac{1}{\epsilon_{w,j,t}}} dh)^{-\epsilon_{w,j,t}}$$

Expenditure minimization yields the familiar downward–sloping demand curve for household member h's labor

$$L_{jt}(h) = \frac{1}{\mu_j}\Big(\frac{W_{jt}(h)}{W_{jt}}\Big)^{-\frac{1+\epsilon_{w,j,t}}{\epsilon_{w,j,t}}} N_{jt} = \Big(\frac{W_{jt}(h)}{W_{jt}}\Big)^{-\frac{1+\epsilon_{w,j,t}}{\epsilon_{w,j,t}}} L_{jt} \tag{1}$$

where $L_{jt} = N_{jt}/\mu_j$ is defined as the average effective labor hours per worker in sector j.

Each period, only a fraction $1-\alpha_j^w$ of the household members in sector j can reoptimize wages. The remaining α_j^w index wages according to an indexation rule $W_{jt}(h) = W_{jt-1}(h)\Pi_{t-1}^{\iota_w}\Pi^{1-\iota_w}$. When the household member gets the opportunity to re-optimize its wage, it chooses a new wage $W_{jt}^*(h)$ which maximizes expected future utility in the case that the new wage will remain effective forever, i.e.,

$$\max_{W_{j,t}^*(h)} \sum_{s=t}^{\infty} (\beta\alpha_j^w)^{s-t} \mathscr{U}_{j,s|t}(h)$$

subject to the budget constraint and sticky wages with partial indexation.

3.2 Government

The government has preferences over the Z product categories given by

$$G_t = \Big(\sum_{z=1}^{Z} \zeta_z^{\frac{1}{\nu_g}} G_{zt}^{1-\frac{1}{\nu_g}}\Big)^{\frac{\nu_g}{\nu_g - 1}} \quad ; \quad \sum_{z=1}^{Z} \zeta_z = 1; \zeta_z \in [0,1]$$

where G_{zt} denotes a consumption bundle of goods from category z. As before, $\{\zeta_z\}_{z=1}^{Z}$ are heterogeneous consumption weights. In turn, government consumption bundles are defined as

$$G_{zt} = \Big[\int_0^1 G_{zt}(q)^{\frac{1}{1+\epsilon_{c,z,t}}} dq\Big]^{1+\epsilon_{c,z,t}}$$

where $G_{zt}(q)$ denotes consumption of goods/services produced by final good producer $q \in z$. The government faces a period–by–period budget constraint of the form

$$P_t^g G_t + B_{t-1} = \frac{B_t}{R_t} + P_t T_t$$

Where aggregate government spending follows the process $\frac{G_t}{G} = Z_{g,t}$, where $Z_{g,t}$ is an exogenous process defined below.

3.3 Production

Production is governed by three types of firms; intermediate goods producers, final goods producers and capital producers.

Intermediate goods producers. Intermediate good producer f in sector j (denoted $f \in j$) produces output $Y_{jt}(f)$ according to a Cobb–Douglas production function augmented with fixed costs:

$$Y_{jt}(f) = \text{Max}\Big\{Z_{p,t} Z_{p,j,t} N_{jt}(f)^{\phi_j^n} M_{jt}(f)^{\phi_j^m} K_{jt}(f)^{\phi_j^k} - \Phi_j(f), 0\Big\} \tag{2}$$

where $N_{jt}(f)$, $M_{jt}(f)$ and $K_{jt}(f)$ represent labour, intermediate inputs and capital used by intermediate good producer $f \in j$, respectively. $Z_{p,t}$ and $Z_{p,j,t}$ denote Hicks neutral productivity shocks. The former is economywide, the latter is sector–specific to good j. $\Phi_j(f)$ is a fixed production cost that will be calibrated to ensure zero profit in steady state. We impose $\phi_j^n, \phi_j^m, \phi_j^k \in [0,1]$. Constant returns to scale in variable inputs implies the linear restriction $\phi_j^n + \phi_j^m + \phi_j^k = 1$.

The intermediate input bundle $M_{jt}(f)$ is defined as

$$M_{jt}(f) = \Big(\sum_{j'=1}^{J} \omega_{jj'}^{\frac{1}{\nu_m}} M_{jj't}(f)^{\frac{\nu_m - 1}{\nu_m}} \Big)^{\frac{\nu_m}{\nu_m - 1}} \tag{3}$$

where $M_{jj't}(f)$ denotes the bundle of intermediate goods that intermediate goods producer $f \in j$ buys from sector j'. $\omega_{jj'} \in [0, 1]$ is the weight of goods from sector j' in aggregate intermediate inputs used by intermediate goods producers in sector j. The input–output matrix, $\mathbf{\Omega} \in \mathbb{R}^{J \times J}$, introduces intersectoral trade flows in the model, and allows for shocks to cascade through the supply chain.

$M_{jj't}(f)$ is in turn an aggregator

$$M_{jj't}(f) = \Big(\int_0^1 M_{jj't}(f, f')^{\frac{1}{1+\epsilon_{m,j',t}}} df' \Big)^{1+\epsilon_{m,j',t}}$$

where $M_{jj't}(f, f')$ denotes the amount of goods produced by intermediate goods producer $f' \in j'$ sold to intermediate goods producer $f \in j$. $\epsilon_{m,j,t} = \epsilon_m Z_{m,j,t} Z_{m,t}$ where $Z_{m,j,t}$ reflects a markup shock specific to intermediate good j, whereas $Z_{m,t}$ affects all sectors.

Optimal sectoral and firm–specific demand follow as

$$M_{jj't}(f) = \omega_{jj'} \big(\frac{P_{j't}}{P^m_{jt}} \big)^{-\nu_m} M_{jt}(f)$$
$$M_{jj't}(f, f') = \big(\frac{P_{j't}(f')}{P_{j't}} \big)^{-\frac{1+\epsilon_{m,j',t}}{\epsilon_{m,j',t}}} M_{jj't}(f)$$

Where $P_{j't}(f')$ and $P_{j't}$ is the output price of intermediate good producer $f' \in j'$ and the producer price index of sector j', respectively. From the point of view of $f \in j$, the price (i.e. cost) index of the intermediate input bundle is

$$P^m_{jt} = \Big(\sum_{j'=1}^{J} \omega_{jj'} P_{j't}^{1-\nu_m} \Big)^{\frac{1}{1-\nu_m}}$$

We assume that intermediate goods producers face staggered price setting. Let $1 - \alpha_j^{ppi}$ denote the probability that a given intermediate goods producer in sector j is able to reset its prices. The fraction unable to re–optimize their prices, update them according to an indexation rule $P_{jt}(f) = P_{jt-1}(f)(\Pi^{ppi}_{jt-1})^{\iota_{ppi}} (\Pi^{ppi}_j)^{1-\iota_{ppi}}$, where $\Pi^{ppi}_{jt} \equiv \frac{P_{jt}}{P_{jt-1}}$ is the gross ppi inflation rate of sector j.

Total output, $Y_{jt}(f)$, is either (i) used as an intermediate input for production by other intermediate good producers, (ii) sold to final goods producers (introduced below) or (iii) used as an intermediate input for production of capital by capital producers (introduced below).

$$Y_{jt}(f) = \sum_{j'=1}^{J} \int_0^1 M_{j'jt}(f', f) df' + \sum_{j'=1}^{J} \int_0^1 I_{j'jt}(g, f) dg + \sum_{z=1}^{Z} \int_0^1 M_{zjt}(q, f) dq \tag{4}$$

Real firm dividends in period s are given by

$$D_{js,r}(f) = P_{js,r}(f)Y_{js}(f) - W_{js,r}N_{js}(f) - P^m_{js,r}M_{js}(f) - R_{js,r}K_{js,r}(f)$$

where the subscript r denotes real terms, i.e. $P_{js,r}(f) \equiv \frac{P_{js}(f)}{P_s}$, $P^m_{js,r} \equiv \frac{P^m_{js}}{P_s}$, $R_{js,r} \equiv \frac{R_{js}}{P_s}$ and $W_{js,r} \equiv \frac{W_{js}}{P_s}$. R_{js} denotes the rental rate of capital in sector j that is charged by capital producers (introduced below).

The firm optimally chooses $\{Y_{js}(f), P^*_{js}(f), M_{js}(f), N_{js}(f), K_{js}(f)\}^\infty_{s=t}$ in order to maximize the expected discounted stream of dividends

$$\mathbb{E}_t \sum_{s=t}^{\infty} \mathcal{Z}_{t,s} P_s D_{js,r}(f)$$

where the kernel $\mathcal{Z}_{t,s} = \beta^{s-t}\left(\frac{\Lambda_s}{\Lambda_t}\frac{P_t}{P_s}\right)$ is used to value profits because firms are owned directly by households. Profit maximization is subject to technology (2), Walras's law (4), demand schedules and price staggering with partial indexation. See appendix A for details.

Final goods producers. Final goods producer q produces its variant of product category z, $Y_{zt}(q)$, by assembling intermediate goods using the linear technology

$$Y_{zt}(q) = \varsigma M_{zt}(q) - \Phi_z(q) \tag{5}$$

where $\Phi_z(q)$ denotes fixed costs, ς is an innocuous productivity constant[8] and $M_{zt}(q)$ is a bundle of intermediates bought from intermediate goods producers

$$M_{zt}(q) = \left(\sum_{j=1}^{J} \kappa_{zj}^{\frac{1}{\nu_f}} M_{zjt}(q)^{\frac{\nu_f - 1}{\nu_f}}\right)^{\frac{\nu_f}{\nu_f - 1}}$$

where $\kappa_{zj} \in [0,1]$ and $\sum_{j=1}^{J} \kappa_{zj} = 1$. Furthermore, $M_{zjt}(q)$ denotes the amount of intermediate inputs final goods producer $q \in z$ buys from sector j. In turn,

$$M_{zjt}(q) = \left(\int_0^1 M_{zjt}(q,f)^{\frac{1}{1+\epsilon_{m,j,t}}} df\right)^{1+\epsilon_{m,j,t}}$$

where $M_{zjt}(q,f)$ denotes the amount of goods final goods producer $q \in z$ purchases from intermediate goods producer $f \in j$.

Final goods producers' real dividends in period s are given by

$$D_{zs,r}(q) = P_{zs,r}(q)Y_{zs}(q) - P^m_{zs,r}(q)M_{zs}(q)$$

Firm $q \in z$ optimally chooses $\{Y_{zs}(q), P^*_{zs}(q), M_{zs}(q)\}^\infty_{s=t}$ in order to maximize the

---

[8] ς is a normalization constant introduced for convenience when loglinearizing the model. Its value does not affect volatility or persistence of inflation, the main quantities of interest in this paper.

expected discounted stream of dividends

$$\mathbb{E}_t \sum_{s=t}^{\infty} \mathcal{Z}_{t,s} P_s D_{zs,r}(q)$$

We assume the final goods producers face staggered price setting following the Calvo (1983)–Yun (1996) framework. Let $1-\alpha_z^{pce}$ denote the probability that a given final goods producer of product z is able to reset its prices. The fraction of final good producers that are unable to re–optimize their prices, update them according to an indexation rule $P_{zt}(q) = P_{zt-1}(q)(\Pi_{zt-1}^{pce})^{\iota_{pce}}(\Pi_z^{pce})^{1-\iota_{pce}}$, where $\Pi_{zt}^{pce} \equiv \frac{P_{zt}}{P_{zt-1}}$ is the gross inflation rate.

Profit maximization is then subject to technology (5), Walras's law ($Y_{zt}(q) = C_{zt}(q) + G_{zt}(q)$), demand schedules and the sticky price scheme with partial indexation. See appendix A for details.

Final goods producers enter the model between the household and intermediate goods producers. Via $\boldsymbol{K} \in \mathbb{R}^{Z \times J}$, they map J producer prices to Z consumer prices. The presence of staggered price setting and markup shocks allows for a wedge between consumer prices $\{P_{zt}\}_{z=1}^{Z}$ and producer prices $\{P_{jt}\}_{j=1}^{J}$ we also observe in the data.

Capital producers. The physical stock of capital in sector j is maintained by a continuum of capital producers, each indexed by g. Capital producer $g \in j$ sets the utilization rate $U_{jt}(g)$, rents out the (utilized share of the) capital stock at time t to intermediate goods producers in sector j at the competitive rate R_{jt} and invests $I_{jt}(g)$.

The investment good is produced using the following technology

$$I_{jt}(g) = \Big(\sum_{j'=1}^{J} \psi_{jj'}^{\frac{1}{\nu_i}} I_{jj't}(g)^{\frac{\nu_i - 1}{\nu_i}}\Big)^{\frac{\nu_i}{\nu_i - 1}}; I_{jj't}(g) = \Big(\int_0^1 I_{jj't}(g,f)^{\frac{1}{1+\epsilon_{m,j',t}}} df\Big)^{1+\epsilon_{m,j',t}} \tag{6}$$

Where $I_{jj't}(g)$ denotes the amount of intermediate goods capital producer $g \in j$ procures from sector j'. Moreover, $I_{jj't}(g, f')$ denotes the amount of goods capital producer $g \in j$ purchases from intermediate goods producer $f' \in j'$. The cost of the composite investment good $I_{jt}(g)$ is then given by

$$P_{jt}^{i}(g) = \Big(\sum_{j'=1}^{J} \psi_{jj'} P_{j't}^{1-\nu_i}\Big)^{\frac{1}{1-\nu_i}}$$

The inclusion of the investment flow matrix, $\boldsymbol{\Psi} \in \mathbb{R}^{J \times J}$, allows for sectoral shocks originating in other sectors to cascade through this matrix and affect the cost of investment in sector j. The law of motion of capital ($\widetilde{K}_{jt+1}(g)$) takes the form

$$\widetilde{K}_{jt+1}(g) = \Big(1 - \Delta\big(U_{jt}(g)\big)\Big)\widetilde{K}_{jt}(g) + Z_{i,t} Z_{i,j,t}\Big(1 - S\big(\frac{I_{jt}(g)}{I_{jt-1}(g)}\big)\Big) I_{jt}(g)$$

where, as in Christiano et al. (2005), the investment adjustment cost function $S(\cdot)$ has the properties $S'(\cdot) \geq 0$, $S''(\cdot) \geq 0$ and $S(1) = 0$, $S'(1) = 0$, $S''(1) = \epsilon_I$. As in Greenwood et al. (1988), the rate of depreciation depends on the utilization rate of capital, with $\Delta'(\cdot) \geq 0$, $\Delta''(\cdot) \geq 0$ and $\Delta(1) = \delta$, $\frac{\Delta''(1)}{\Delta'(1)} = \epsilon_U$. $Z_{i,t}$ and $Z_{i,j,t}$ represent an economywide and sector–specific exogenous disturbance to the process by which investment goods are transformed into installed capital.

The capital producer optimally chooses $\{I_{js}(g), U_{js}(g), K_{js}(g)\}_{s=t}^{\infty}$ in order to maximize the expected discounted stream of dividends

$$\mathbb{E}_t \sum_{s=t}^{\infty} \mathcal{Z}_{t,s} P_s D_{js,r}(g)$$

The Lagrangean is given by

$$\mathbb{E}_t \sum_{s=t}^{\infty} \mathcal{Z}_{t,s} \Big[R_{js} K_{js}(g) - P^i_{js} I_{js}(g) - Q_{js}\big(\widetilde{K}_{js+1}(g) - \Big(1 - \Delta\big(U_{js}(g)\big)\Big) \widetilde{K}_{js}(g) - \\ Z_{i,s} Z_{i,j,s} \Big(1 - S\big(\frac{I_{js}(g)}{I_{js-1}(g)}\big)\Big) I_{js}(g)\big)\Big]$$

Where Q_{js} is the Lagrange multiplier on the law of motion of capital and $K_{js}(g) \equiv \widetilde{K}_{js}(g) U_{js}(g)$ denotes the amount of capital effectively rented out to intermediate goods producers.

3.4 Monetary policy

The monetary authority is assumed to follow a Taylor rule

$$\frac{R_t}{R} = \Big(\frac{R_{t-1}}{R}\Big)^{\rho_s} \Big[\Big(\frac{\Pi_t}{\Pi}\Big)^{\rho_\pi} \Big(\frac{GDP_t}{GDP}\Big)^{\rho_{gdp}}\Big]^{1-\rho_s} Z_{r,t}$$

where $\rho_s \in [0,1), \rho_\pi, \rho_{gdp}$ are monetary policy coefficients. $\Pi_t = \frac{P_t}{P_{t-1}}$ is headline pce inflation. $Z_{r,t}$ is a monetary policy shock and R is the steady state policy rate.

3.5 Market clearing and gross value added

We impose market clearing conditions in the bond, labour and goods market. These are included in appendix A. From the expenditure approach[9], real gross domestic product is equal to the sum of private/government consumption and investment at time t

$$GDP_t = \sum_{z=1}^{Z} P_{zt,r}(C_{zt} + G_{zt}) + \sum_{j=1}^{J} P^i_{jt,r} I_{jt}$$

---

[9] Or, alternatively, from the production and income approach in appendix A.

3.6 Exogenous processes

The model includes structural shocks at two levels of the economy; aggregate shocks (which are not specific to a particular price index) and micro shocks (specific to a particular producer/consumer price index).

Aggregate shocks. The set of aggregate shocks, $\mathcal{A}$, includes (i) a monetary policy shock ($Z_{r,t}$), (ii) an aggregate risk shock ($Z_{b,t}$), (iii) a government demand shock ($Z_{g,t}$), (iii) an aggregate wage ($Z_{w,t}$) and price markup shock to producer and consumer prices ($Z_{m,t}, Z_{c,t}$), (iv) an aggregate productivity shock ($Z_{p,t}$) and (v) an economywide investment shock ($Z_{i,t}$). Aggregate shocks follow an $AR(1)$ process[10]

$$\log(Z_{a,t}) = \rho_a \log(Z_{a,t-1}) + \sigma_a \varepsilon_{a,t} \qquad\qquad \varepsilon_{a,t} \sim N(0,1)$$

with $a \in \mathcal{A} = \{r, b, g, m, c, w, p, i\}$.

Micro shocks. Micro level shocks, $\mathcal{E}$, are shocks specific to an individual producer price j and consumer price z. They include price and wage markup shocks $\{Z_{m,j,t}\}_{j=1}^{J}$, $\{Z_{w,j,t}\}_{j=1}^{J}$, $\{Z_{c,z,t}\}_{z=1}^{Z}$, productivity shocks $\{Z_{p,j,t}\}_{j=1}^{J}$ and investment shocks $\{Z_{i,j,t}\}_{j=1}^{J}$. The micro stochastic processes follow $AR(1)$ processes

$$\begin{aligned} &\text{Producer price } j: && \log(Z_{e,j,t}) = \varrho_e \log(Z_{e,j,t-1}) + \varsigma_{e,j}\varepsilon_{e,j,t} && \varepsilon_{e,j,t} \sim N(0,1) \\ &\text{Consumer price } z: && \log(Z_{e,z,t}) = \varrho_e \log(Z_{e,z,t-1}) + \varsigma_{e,z}\varepsilon_{e,z,t} && \varepsilon_{e,z,t} \sim N(0,1) \end{aligned}$$

with $e \in \mathcal{E} = \{m, w, p, i, c\}$. All shocks are orthogonal.

3.7 Model mechanics and pipeline pressures

Model mechanics. Appendices $A - C$ solve the model, provide algebraic expressions for the steady state and log linearize the model around this steady state, respectively. The following subset of equations are key to understand inflation dynamics (where lowercase symbols denote loglinearized versions of their capitalized counterpart)

$$\begin{aligned} &\{\pi^{ppi}_{jt} = \gamma^{ppi}_{1,j}\mathbb{E}_t\pi^{ppi}_{jt+1} + \gamma^{ppi}_{2,j}\pi^{ppi}_{jt-1} - \gamma^{ppi}_{3,j}(p_{jt,r} - mc_{jt,r}) + \gamma^{ppi}_{3,j}(z_{m,t} + z_{m,j,t})\}_{j=1}^{J} \\ &\{mc_{jt,r} = -(z_{p,j,t} + z_{p,t}) + \phi^n_j w_{jt,r} + \phi^m_j p^m_{jt,r} + \phi^k_j r_{jt,r}\}_{j=1}^{J} \\ &\{p^m_{jt,r} = \sum_{j'=1}^{J} \omega_{jj'} p_{j't,r}\}_{j=1}^{J} \\ &\{q_{jt,r} = p^i_{jt,r} + \epsilon_I((i_{jt} - i_{jt-1}) + \beta\mathbb{E}_t(i_{jt} - i_{jt+1})) - (z_{i,j,t} + z_{i,t})\}_{j=1}^{J} \\ &\{p^i_{jt,r} = \sum_{j'=1}^{J} \psi_{jj'} p_{j't,r}\}_{j=1}^{J} \end{aligned}$$

---

[10] Except for the monetary policy shock, for which we take $\rho_r = 0$.

$$\{q_{jt,r} = -(r_t + z_{b,t} - \mathbb{E}_t(\pi^{pce}_{t+1})) + (1-\beta(1-\delta))r_{jt+1,r} + \beta(1-\delta)q_{jt+1,r}\}_{j=1}^{J}$$
$$\{\pi^{pce}_{zt} = \gamma^{pce}_{1,z}\mathbb{E}_t\pi^{pce}_{zt+1} + \gamma^{pce}_{2,z}\pi^{pce}_{zt-1} - \gamma^{pce}_{3,z}(p_{zt,r} - mc_{zt,r}) + \gamma^{pce}_{3,z}(z_{c,z,t} + z_{c,t})\}_{z=1}^{Z}$$
$$\{mc_{zt,r} = \sum_{j=1}^{J}\kappa_{zj}p_{jt,r}\}_{z=1}^{Z}$$

The first equation is a standard New Keynesian Phillips curve for sectoral producer prices. Due to the interlinked production architecture, producer prices set by other sectors, $\{p_{j't,r}\}_{j'=1}^{J}$, affect marginal costs of firms in sector j, $mc_{jt,r}$, in two ways. (i) First, through the cost of intermediates $p^m_{jt,r}$, which captures the feature that price setting cascades through the IO matrix $\mathbf{\Omega}$. (ii) Second, through the rental cost of capital $r_{jt,r}$; prices set in other sectors ripple through the investment flow matrix $\mathbf{\Psi}$ and affect the cost of investment, $p^i_{jt,r}$ and subsequently the cost of capital.[11] Consumer prices are modelled downstream to ppi's. Ppi inflation then not only permeates through $\mathbf{\Omega}$ and $\mathbf{\Psi}$, but also downward through the matrix $\boldsymbol{K}$, thereby affecting consumer prices.

General equilibrium effects introduce higher order interactions; E.g. although “Plastics and Rubber” is not a direct input to the production of “Transportation services”, it is an important input to production of “Motor vehicles”, which is a material input to “Transportation services”. Price dynamics of the “Plastics and Rubber” ppi is thus relevant for “Transportation services” inflation dynamics.

Note that the richness of sectoral shocks implies that price indices – even those that are tightly interlinked – can diverge for extended periods. E.g., a positive markup shock in the ppi of “(Paper)pulp” does not necessarily induce an increase of the ppi of “Industrial paper” if this increase in the cost of intermediate inputs is offset by a negative shock to wages in the “Industrial paper” sector. Moreover, as discussed below, such comovement is also tempered by the presence of price stickiness along the supply chain.

Defining pipeline pressures. We now formalize pipeline pressures. We focus on ppi's, the definition for consumer prices is completely similar (included in appendix D for completeness).

Let

$$\frac{\partial \pi^{ppi}_{jt+s}}{\partial \varepsilon_{a,t}} = \delta^{(s)}_j(a) \quad (a \in \mathcal{A}) \qquad \text{and} \qquad \frac{\partial \pi^{ppi}_{jt+s}}{\partial \varepsilon_{e,x,t}} = \delta^{(s)}_j(e,x) \quad (e \in \mathcal{E},\ x \in \{j', z\})$$

summarize the impulse response of ppi inflation in sector j at time $t+s$ to an aggregate shock $\varepsilon_{a,t}$ and micro shock $\varepsilon_{e,x,t}$ at time t, respectively.

For the first expression, the impulse response coefficients and adjoining shocks can be stacked in vectors $\boldsymbol{\delta}^{(s)}_j(\mathcal{A})$ and $\boldsymbol{\varepsilon}(\mathcal{A})_t$. Similarly, for the micro shocks;

---

[11] Note that, even in the absence of sectoral interlinkages, price developments in other sectors still affect marginal costs through wages in sector j. Since price developments in other sectors affect the general price level, they indirectly affect the household labour supply decision to other sectors. We found this channel to be empirically irrelevant, and ignore it in the remainder of the paper.

$\boldsymbol{\delta}_j^{(s)}(\mathcal{E})$ and $\boldsymbol{\varepsilon}(\mathcal{E})_t$. The former vector $\boldsymbol{\delta}_j^{(s)}(\mathcal{E})$ can be split into two components: $\boldsymbol{\delta}_{j,j}^{(s)}(\mathcal{E})$ and $\boldsymbol{\delta}_{j,-j}^{(s)}(\mathcal{E})$ (and their respective shocks $\boldsymbol{\varepsilon}_j(\mathcal{E})_t$ and $\boldsymbol{\varepsilon}_{-j}(\mathcal{E})_t$). The first one contains the impulse response coefficients of ppi j to shocks directly related to ppi j. The second vector captures the impulse response coefficients of ppi j to micro shocks related to all price indices other than j, denoted by '$-j$'. Combining these impulse response functions and shocks, producer price inflation in sector j at time t can recursively be rewritten as

$$\pi_{jt}^{ppi} = \boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty} + \boldsymbol{\beta}_t(\pi_j^{ppi})_{h=\infty} + \boldsymbol{\gamma}_t(\pi_j^{ppi})_{h=\infty} \tag{8}$$

with

$$\begin{aligned}
\boldsymbol{\alpha}_t(\pi_j^{ppi})_h &= \sum_{s=0}^{h-1}(\boldsymbol{\delta}_j^{(s)}(\mathcal{A}))'\boldsymbol{\varepsilon}(\mathcal{A})_{t-s} \\
\boldsymbol{\beta}_t(\pi_j^{ppi})_h &= \sum_{s=0}^{h-1}(\boldsymbol{\delta}_{j,j}^{(s)}(\mathcal{E}))'\boldsymbol{\varepsilon}_j(\mathcal{E})_{t-s} \\
\boldsymbol{\gamma}_t(\pi_j^{ppi})_h &= \sum_{s=0}^{h-1}(\boldsymbol{\delta}_{j,-j}^{(s)}(\mathcal{E}))'\boldsymbol{\varepsilon}_{-j}(\mathcal{E})_{t-s}
\end{aligned}$$

The equation disentangles inflation of price index j into a part that originates with aggregate shocks ($\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty}$), a direct effect of the micro shocks specific to sector j ($\boldsymbol{\beta}_t(\pi_j^{ppi})_{h=\infty}$) and propagation of micro shocks from elsewhere in the economy ($\boldsymbol{\gamma}_t(\pi_j^{ppi})_{h=\infty}$). $\boldsymbol{\gamma}_t(\pi_j^{ppi})_{h=\infty}$ is what we label pipeline pressures; the cascade effect of micro–level shocks through the pipeline. Note that $\boldsymbol{\alpha}_t(\pi_j^{ppi})_h + \boldsymbol{\beta}_t(\pi_j^{ppi})_h + \boldsymbol{\gamma}_t(\pi_j^{ppi})_h$ is the forecast error of the time t inflation forecast made h periods ago. It is then well–known that the variance of π_{jt}^{ppi} can be decomposed as

$$\sigma^2\left[(\pi_j^{ppi})_{h=\infty}\right] = \sigma^2\left[\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty}\right] + \sigma^2\left[\boldsymbol{\beta}_t(\pi_j^{ppi})_{h=\infty}\right] + \sigma^2\left[\boldsymbol{\gamma}_t(\pi_j^{ppi})_{h=\infty}\right]$$

with

$$\begin{aligned}
\sigma^2\left[\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty}\right] &= \sum_{s=0}^{h-1}\left(\boldsymbol{\delta}_j^{(s)}(\mathcal{A})\right)'\boldsymbol{\delta}_j^{(s)}(\mathcal{A}) \\
\sigma^2\left[\boldsymbol{\beta}_t(\pi_j^{ppi})_{h=\infty}\right] &= \sum_{s=0}^{h-1}\left(\boldsymbol{\delta}_{j,j}^{(s)}(\mathcal{E})\right)'\boldsymbol{\delta}_{j,j}^{(s)}(\mathcal{E}) \\
\sigma^2\left[\boldsymbol{\gamma}_t(\pi_j^{ppi})_{h=\infty}\right] &= \sum_{s=0}^{h-1}\left(\boldsymbol{\delta}_{j,-j}^{(s)}(\mathcal{E})\right)'\boldsymbol{\delta}_{j,-j}^{(s)}(\mathcal{E})
\end{aligned}$$

Headline ppi inflation can then be written as

$$\pi_t^{ppi} = \sum_{j=1}^{J}\eta_j(\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty} + \boldsymbol{\beta}_t(\pi_j^{ppi})_{h=\infty} + \boldsymbol{\gamma}_t(\pi_j^{ppi})_{h=\infty}) \tag{9}$$

$$= \boldsymbol{\alpha}_t(\pi^{ppi})_{h=\infty} + \boldsymbol{\beta}_t(\pi^{ppi})_{h=\infty} + \boldsymbol{\gamma}_t(\pi^{ppi})_{h=\infty}$$

where η_j is the model–implied weight of sector j in headline ppi (see appendix B). For the variance

$$\sigma^2\left[(\pi^{ppi})_{h=\infty}\right] = \sigma^2\left[\boldsymbol{\alpha}_t(\pi^{ppi})_{h=\infty}\right] + \sigma^2\left[\boldsymbol{\beta}_t(\pi^{ppi})_{h=\infty}\right] + \sigma^2\left[\boldsymbol{\gamma}_t(\pi^{ppi})_{h=\infty}\right]$$

with

$$\begin{aligned}
\sigma^2\left[\boldsymbol{\alpha}_t(\pi^{ppi})_{h=\infty}\right] &= \sum_{s=0}^{h-1} \boldsymbol{\eta}'(\boldsymbol{\Delta}^{(s)}(\mathcal{A}))'(\boldsymbol{\Delta}^{(s)}(\mathcal{A}))\boldsymbol{\eta} \\
\sigma^2\left[\boldsymbol{\beta}_t(\pi^{ppi})_{h=\infty}\right] &= \sum_{s=0}^{h-1}\sum_{j=1}^{J} \eta_j(\boldsymbol{\delta}^{(s)}_{j,j}(\mathcal{E}))'(\boldsymbol{\delta}^{(s)}_{j,j}(\mathcal{E}))\eta_j \\
\sigma^2\left[\boldsymbol{\gamma}_t(\pi^{ppi})_{h=\infty}\right] &= \sum_{s=0}^{h-1}\sum_{j=1}^{J} \eta_j(\boldsymbol{\delta}^{(s)}_{j,-j}(\mathcal{E}))'(\boldsymbol{\delta}^{(s)}_{j,-j}(\mathcal{E}))\eta_j \\
&\quad + \sum_{s=0}^{h-1}\left(\sum_{j=1}^{J}\sum_{j'\neq j}^{J} \eta_j(\boldsymbol{\delta}^{(s)}_{j,-j}(\mathcal{E}))'\mathbb{E}_s[\boldsymbol{\varepsilon}_{-j}(\mathcal{E})_s(\boldsymbol{\varepsilon}_{-j'}(\mathcal{E})_s)']\boldsymbol{\delta}^{(s)}_{j',-j'}(\mathcal{E})\eta_{j'}\right) \\
&\quad + 2\sum_{s=0}^{h-1}\left(\sum_{j=1}^{J}\sum_{j'\neq j}^{J} \eta_j(\boldsymbol{\delta}^{(s)}_{j,j'}(\mathcal{E}))'\mathbb{E}_s[\boldsymbol{\varepsilon}_{j'}(\mathcal{E})_s(\boldsymbol{\varepsilon}_{j'}(\mathcal{E})_s)']\boldsymbol{\delta}^{(s)}_{j',j'}(\mathcal{E})\eta_{j'}\right)
\end{aligned}$$

where the terms decompose headline volatility due to aggregate shocks, direct effect of sectoral shocks and pipeline pressures, respectively. The three terms in $\sigma^2\left[\boldsymbol{\gamma}_t(\pi^{ppi})_{h=\infty}\right]$ capture (i) variances of disaggregate ppi's due to pipeline pressures as well as comovement of prices in sector j and j' due to (ii) shocks in a third sector j'', or because (iii) prices in j are affected by prices in j'. The expectation matrix is a binary matrix due to the orthogonality of shocks and unit variances.

4 Estimation

The model is estimated using Bayesian inference. In this section we discuss the calibration and the formation of priors. We provide details on the estimation procedure and elaborate on the estimation results.

4.1 Calibration and priors

4.1.1 Calibration

Scalar parameters. Parameters not related to the multi–sector setup are calibrated to common values in the literature (table 3, panel A). As such, we take the discount factor, β, to be 0.99, set the depreciation rate to $\delta = 0.025$ and impose $\varphi = 2$, implying a Frisch elasticity of labor supply of 0.5. The coefficient of relative risk aversion is $\sigma = 1.5$. We set the across–sector elasticities of substitution $\nu_c, \nu_g, \nu_m, \nu_f, \nu_i$ to 2 and the within sector elasticity to $\epsilon_m, \epsilon_c, \epsilon_w = 0.5$.[12] The size of government final consumption relative to private final consumption is set equal to its post–WWII average, $\frac{g}{c} = 0.25$.

[Insert table 3]

Matrix parameters. The steady state interactions between the various agents in the model all have a natural counterpart in the data.

As shown in appendix B, $\omega_{jj'}$ in eq. (3) corresponds to the steady state share of sector j' in total intermediate goods expenditures of firms in sector j. $\mathbf{\Omega}$ then directly corresponds to the IO matrix published by the Bureau of Economic Analysis (BEA). In the U.S., sectors are categorized according to the North American Input Classification System (NAICS). At the most aggregated level, $\mathbf{\Omega}$ consists of 7 broad sectors; "Agriculture & Forestry", "Mining", "Utilities", "Construction", "Manufacturing", "Services" and the "Public sector". Table 4 documents the IO table for $J = 7$.[13]

Similarly, $\psi_{jj'}$ in eq. (6) corresponds to the steady state share of sector j' goods in sector j investment. Investment share, $\psi_{jj'}$, is then calibrated as dollar payments from industry j to industry j' expressed as a fraction of the total investment expenditures of sector j. These flows are documented by the BEA Investment Flow tables. Table 5 reports $\mathbf{\Psi}$ for $J = 7$.

$\phi_j^m, \phi_j^n, \phi_j^k$ correspond to the steady state share of expenditures of sector j on (i) material/service inputs, (ii) labour (wages) and (iii) capital expenditures in total expenditures of sector j. BEA tables report total expenditures of sectors on these three factors of production. The shares of each individual tranche of expenditures in total sector expenditures delivers $\phi_j^m, \phi_j^n, \phi_j^k$ for $j = 1, ..., J$, respectively. These are documented in table 6.

The BEA publishes Personal Consumption Expenditures (PCE) tables which contain detailed household consumption patterns across final consumption goods. The latter follow a PCE classification system. The empirical PCE weights directly map to the Z consumption weights ($\boldsymbol{\xi}$) in our model (which are steady state expenditures patterns of the household). Table 7 reports $\boldsymbol{\xi}$ for an aggregate level, $Z = 4$, over "Durables", "Non–durables", "Services" and "Public sector goods".

In steady state, $\boldsymbol{K}$ details the mix of intermediate goods required from sector j to produce final consumption good z. The BEA Bridge table decomposes final consumption goods into their sectoral origins. This bridge table (table 8) allows us (i) to trace the origins of private consumption goods (which follow the PCE classification system) into their underlying sectors (which follow the NAICS) and (ii) to structurally relate pce inflation of individual consumer products to ppi inflation of individual sectors.

---

[12] In line with Carvalho and Lee (2011); Pasten et al. (2016); Atalay (2017).

[13] Relevant details on the construction of the IO table are included in appendix E.

Finally, sectoral wage stickiness $\{\alpha_j^w\}_{j=1}^J$ is obtained from Bils et al. (2014), who derive these measures directly from micro wage data. The Calvo parameters of product category pce prices $\{\alpha_z^{pce}\}_{z=1}^Z$ and sectoral producer prices $\{\alpha_j^{ppi}\}_{j=1}^J$ are obtained from micro studies, Nakamura and Steinsson (2010) and Peneva (2011), respectively.

[Insert tables 4 – 8]

Level of analysis. For the estimation part of this project (remainder of this section), we concentrate on $J = 7$ broad sectors and $Z = 4$ product categories of the U.S. economy.

These J sectors approximately correspond to the Division level of the NAICS. Focusing on these seven sectors has four advantages. First, these sectors are natural partitions of the U.S. economy. Second, there are sufficient sectoral data available to estimate the model. Third, they are computationally manageable.[14] Lastly, at a more disaggregated level, the input–output tables of the U.S. economy have evolved significantly over time (see e.g. Foerster and Choi (2017)). At our level of aggregation, changes in the structure of the economy are negligible.[15]

The $Z = 4$ product categories are associated with the four broad consumption categories of the U.S. headline pce index. This is opposed to the generic distinction between "sticky–price" and "flexible–price" goods or "durable" vs. "non–durable" often found in two–sector models.[16]

4.1.2 Priors

All priors, documented in table 9, are taken in keeping with Smets and Wouters (2007), with some exceptions to accommodate the specificities of our model.

For the standard errors of aggregate shocks, σ_a, we specify inverse gamma priors with a mean 0.1 and a standard deviation of 2. This prior matches that found in workhorse dsge models which typically focus exclusively on aggregate shocks. The autoregressive parameters of aggregate processes are given a beta distribution with mean 0.85 and standard deviation 0.1.

The standard errors of sectoral shocks, $\varsigma_{e,x}$, are typically more volatile than aggregate shocks.[17] We thus specify priors with a mean 0.2 and a standard deviation of 2. We are agnostic as to whether sectoral shocks are more/less persistent

---

[14] We have experimented with more disaggregated versions of our model. Lack of sufficient disaggregated data hampered proper identification.

[15] In unreported results, available upon request, we show that our analysis is both qualitatively and quantitatively robust to using different vintages of U.S. IO tables over time.

[16] As a quality check, we examine the implications of aforementioned calibration for other steady state ratios not explicitly targeted. The results are documented in appendix E.5. Our results indicate that the model–implied steady states of economywide variables (e.g., gross output–to–gdp) relate very well to their empirical counterparts. Similarly for sectoral shares of (*i*) gross output, (*ii*) gross value added, (*iii*) employment and the (*iv*) capital stock. A good level of mutual consistency between the sectoral and aggregate level is required given that we will include variables at both levels as observables in the estimation (infra).

[17] See e.g., evidence by Carvalho and Lee (2011); Bouakez et al. (2014).

than aggregate shocks; we thus use a non–informative beta prior centered at 0.5 for the autoregressive parameters of sectoral $AR(1)$ processes.

Following Khan and Tsoukalas (2011), the capital utilization elasticity, ϵ_U, is given an inverse gamma prior with mean 0.15. We impose an inverse gamma prior with mean 4 for the parameter controlling investment adjustment costs ϵ_I. Regarding the parameters for indexation of prices and wages, we use a beta prior centered at 0.5. The habit parameter χ is assumed to be beta distributed with a prior mean of 0.5, which is standard in the literature. For the parameters governing the Taylor–rule, ρ_π and ρ_{gdp}, we impose normal distributions with a prior mean of 1.7 and 0.125 respectively, while the interest rate smoothing parameter ρ_s has a beta prior with mean 0.8.

[Insert table 9]

We make one simplifying assumption; Earlier estimation results did not suggest any relevant heterogeneity in the volatility of sectoral wage markups and sectoral investment shocks across sectors. In order to compress the parameter space, we equalize these parameters across sectors. Formally: $\{\varsigma_{w,1} = ... = \varsigma_{w,7}\}$ and $\{\varsigma_{i,1} = ... = \varsigma_{i,7}\}$.

4.2 Data

We estimate the model using quarterly data on the U.S. economy from $1970Q1-2007Q4$. Our set of observables are empirical counterparts to the model disaggregate $(\{\pi_{jt}^{ppi}, \pi_{zt}^{pce}, l_{jt}, w_{jt,r}, y_{jt}, i_{jt}\})$ and aggregate $(\{r_t, gdp_t, w_{t,r}, l_t, i_t, \pi_t^{pce}, \pi_t^{ppi}\})$ variables. Details on harmonization, detrending, seasonal adjustment, etc. of the data are included in appendix E. The observation equation that relates the empirical time series to the corresponding model variables is reported in appendix E as well.

In total, we use 29 observable time series. For some sectors, sectoral data is unavailable. This is inconsequential since parameters specific to those sectors will be identified through general equilibrium interactions with sectors for which we do include observables. The inclusion of aggregate observables on top of sectoral observables serves to support identification as well.

Given the potential role of measurement error in U.S. sectoral data (e.g., Shoemaker (2007)), we allow for measurement error in our observation equation. For sectoral (aggregate) variables, we calibrate the variance of the measurement errors such that they correspond to 10% (5%) of the variance of each data series (cf. Christiano et al. (2011)). In addition, the inclusion of measurement error prevents stochastic singularity due to the joint inclusion of aggregate variables and the underlying sectoral variables as observables.

4.3 Posterior parameter results

We comment briefly on some of the parameter estimates which are reported in the prior–posterior table 9.[18] We focus our discussion on the posterior mode, which is also used for all computations below.

The parameter estimates not specific to our model set–up align well with those documented in the literature. E.g., The capital utilization cost ($\epsilon_U = 0.120$) and investment adjustment cost ($\epsilon_I = 2.939$) are very close to those reported by Khan and Tsoukalas (2011), with whom we share the Greenwood et al. (1988) set–up. As per Smets and Wouters (2007), the degree of producer and consumer price indexation ($\iota_{ppi} = 0.080$, $\iota_{pce} = 0.192$) is small whereas that of wage indexation ($\iota_w = 0.426$) is moderately large. The monetary policy reaction function parameters $\rho_s = 0.771$ and $\rho_\pi = 1.820$ are standard whereas $\rho_{gdp} = 0.390$ is slightly larger than traditional estimates. Similar to Carvalho and Lee (2011), micro shocks are confirmed to be more volatile than their aggregate counterpart.[19] Aggregate shocks are not unambiguously more/less persistent than their micro level counterpart.[20]

5 Model analysis

This section documents our main results. First, we formally test whether pipeline pressures are a relevant feature of the model. We then disentangle historical inflation rates using both our model (a three–way decomposition) and a dfm (a two–way decomposition), and contrast our results. Finally, we decompose the sources of inflation (*i*) volatility and (*ii*) persistence and investigate the contribution of pipeline pressures to both statistics.

5.1 Testing for pipeline pressures

We use the Bayes factor to verify whether the data favour the model with pipeline pressures over models in which such propagation is mechanically shut down. We separately test for pipeline pressures (*i*) from producer prices to other producer prices and (*ii*) from producer prices to consumer prices.

To test for (*i*), we bilaterally compare 42 alternative models to the baseline model (labelled $\mathcal{M}$). In each of the alternative models, we force sector j and j' to operate in isolation from each other. That is, we impose $\omega_{jj'} = \psi_{jj'} = 0$ such that producer price setting in sector j is unresponsive to producer prices in sector j'. We denote this alternative model as $\mathcal{M}_{(\omega_{jj'}=0,\psi_{jj'}=0)}$.

---

[18] Prior–posterior plots are included in appendix F.

[19] For the purpose of estimation, sectoral shocks are scaled vis–à–vis their aggregate counterpart. E.g. for wage markup shocks, we estimate $\pi^w_{jt} = \beta\mathbb{E}_t(\pi^w_{jt+1}) + \iota_w(\pi^{pce}_{t-1} - \beta\pi^{pce}_t) + \gamma^w_j(mrs_{jt} - w_{jt,r} + z_{w,t}) + \widetilde{z}_{w,j,t})$. Hence, comparing the relative size of aggregate vs. sectoral shock volatility requires one to first undo the rescaling. After doing so (see appendix), we find that structural sectoral shocks are more volatile than their aggregate counterpart.

[20] In view of stylized fact $2a - b$: note that here we talk about persistence of structural shocks, not persistence of inflation.

The Bayes factors are reported in table 10, panel A. As per the interpretation in Kass and Raftery (1995), the magnitude of the Bayes factors reveals that in 35 out of 42 cases, the data strongly prefer the presence of pipeline pressures. Producer price developments in the "Manufacturing" and "Service" sector are strongly subject to price developments in other segments of the economy. On the other hand, price developments in the rest of the economy are moderately informative for price setting in the "Agriculture" sector. In 4 cases, the Bayes factor equals 1.00 given that $\mathcal{M}_{(\omega_{jj'}=0,\psi_{jj'}=0)} = \mathcal{M}$. In 3 cases, the data favour the model without pipeline pressures.

We next investigate whether pipeline pressures manifest themselves via the cost of capital or the cost of intermediates. For that purpose, we estimate models in which sectors do not rely on intermediates and capital, respectively (denoted by $\mathcal{M}_{(\phi_j^m=0)}$ and $\mathcal{M}_{(\phi_j^k=0)}$, respectively). Table 11 reveals that pipeline pressures via both channels are operative, except via the cost of capital in the "Mining" and "Utilities" sector.

Pipeline pressures from producer prices to consumer prices are tested in a similar vein, where $\mathcal{M}_{(\kappa_{zj}=0)}$ denotes the model in which the producer price of sector j is forced to be irrelevant for price setting of final consumption good z. Table 10, panel B reveals that in 20 out of 28 cases, the data prefer the baseline model with pipeline pressures. This is especially true for pressures faced by consumer products "Durables" and "Non–Durables" that originate with producer prices in the "Manufacturing" and "Service" sectors. This is unsurprising, given that these sectors are closer to the household than e.g., the upstream sectors "Agriculture" or "Mining". In 7 cases we have that $\mathcal{M}_{(\kappa_{zj}=0)} = \mathcal{M}$.

5.2 Dfm decomposition and pipeline pressures

In this section we provide evidence that the common component in the dfm decomposition reflects both aggregate shocks and pipeline pressures.

For that purpose, we first decompose historical U.S. ppi/pce inflation rates through the lens of our structural model. We use the Kalman smoother to derive the smoothed shocks for $1970Q1-2007Q4$ and the smoothed state of the economy in $1970Q1$. We next iteratively apply eqs. (8), (9) (for producer prices) and D.1., D.2. (for consumer prices) to decompose deviations of inflation rates from their steady states into three origins. We then contrast this decomposition with a two–way decomposition obtained from a dfm. We focus here on headline inflation (the results for disaggregate prices are similar and included in appendix G).

Figure 3 panel A, jointly plots three times series; (i) the part of headline ppi inflation due to aggregate shocks $(\boldsymbol{\alpha}_t(\pi^{ppi})_{h=\infty})$, (ii) the part of headline ppi inflation due to aggregate shocks *and* pipeline pressures $(\boldsymbol{\alpha}_t(\pi^{ppi})_{h=\infty} + \boldsymbol{\gamma}_t(\pi^{ppi})_{h=\infty})$, (iii) the common factors, extracted by a dfm $(\boldsymbol{\eta}'\boldsymbol{\Lambda}\boldsymbol{f}_t)$. We make two observations.

First, inflation due to aggregate structural shocks in our model closely tracks the common component extracted by a dfm. Hence, the bulk of the common component of the dfm truly reflects aggregate shocks. This finding also echoes the results in Forni and Gambetti (2010) that the common component in a dfm is to a large extent driven by only a limited number of macroeconomic shocks.

Second, once we control for pipeline pressures $(\boldsymbol{\alpha}_t(\pi^{ppi})_{h=\infty} + \boldsymbol{\gamma}_t(\pi^{ppi})_{h=\infty})$, our structural decomposition moves closer to the common component of the dfm decomposition. The shaded areas highlight the periods in which this is true. This result implies that the factors in the dfm reflect both aggregate shocks and comovement of price indices emanating from pipeline pressures.

[Insert figure 3]

We next investigate the implications of this result on the stylized facts inferred from the dfm framework.

5.3 Pipeline pressures and inflation variance

This subsection investigates the origins of inflation volatility (Stylized fact $1a - 1b$). In order to present more disaggregated results, we use the estimates of the baseline model with $\{J = 7, Z = 4\}$ to calibrate a disaggregated version of the economy with $\{J = 35, Z = 17\}$. The relevant structural tables and other details are included in appendix E. Table 12 and 13 report the forecast error variance decomposition ($FEVD$) of producer and consumer prices, respectively. Columns $(1) - (3)$ document the one quarter horizon ($FEVD(1)$), columns $(4) - (6)$ the infinite horizon ($FEVD(\infty)$). We summarize five observations.

[Insert table 12 and 13]

First, for disaggregate ppi/pce indices, at infinite horizon (columns $(4) - (6)$), our model reproduces stylized fact $1a$; disaggregated inflation volatility originates mainly with micro–level shocks specific to that price index (column (5), panel A). The reason is that the structural micro–level shocks are estimated to be more volatile than the structural aggregate shocks. Aggregate shocks are the second most important source of disaggregate ppi/pce volatility (column (4)), followed closely by pipeline pressures (column (6)).

Second, our model is also consistent with stylized fact $1b$: for headline inflation, the direct effect of sectoral shocks is small (column (5), panel B). The reason is that the direct effects of sectoral shocks average each other out in the headline index. Reversely, pipeline pressures and aggregate shocks generate comovement across multiple indices and therefore do not easily cancel out. They thus remain as the most important drivers of headline inflation. Aggregate shocks explain 69% and 46% of headline ppi and pce, respectively. Pipeline pressures are moderately less important, but still explain 21% and 28% of headline ppi and pce inflation. This is a key point in our analysis: sectoral shocks gain more relevance once their indirect effect via pipeline pressures is correctly identified from the data.

Third, a comparison across price indices reveals that pipeline pressures are more important for consumer prices than for producer prices. Within producer prices, we also observe that pipeline pressures are larger for downstream sectors (such as “Food and Beverages”, “Professional services”, etc.) than for sectors upstream in the U.S. economy (such as “Agriculture & Forestry”, “Oil and gas extraction”, “Mining, except oil and gas”, etc.). Note that our qualification of “upstream” and “downstream” is not readily apparent from the model, which features a roundabout production structure. E.g., in our model, the “Plastics and Rubber” sector relies on the “Petroleum” sector, which, in turn, relies on “Oil extraction”. But of course, the latter in turn requires “Plastics and Rubber” to produce as well. Since all sectors rely on intermediates, no single sector is unambiguously upstream/downstream. Our qualification of upstream/downstream relies purely on ad hoc knowledge that some sectors’ output is more “*raw*” than others. The fact that our model qualifies these sectors as less subject to pipeline pressures, is therefore appealing, but not obvious.[21]

Fourth, in terms of timing, we see that it takes time for pipeline pressures to manifest themselves; Column (3), which documents $FEVD(1)$, is always an order of magnitude smaller than column (6), which documents $FEVD(\infty)$. Again some heterogeneity is apparent. Pipeline pressures faced by “Petroleum and coal products” and “Food and beverages” are close to instantaneous. Reversely, pipeline pressures to the “Wholesale trade” sector take time to fully materialize. In subsection 6.1, we will analyse the sources of this heterogeneity further.

Lastly, we contrast our variance decomposition with that obtained from a dfm (column (7) and (8)). Simple correlation measures, in table 14, indicate that the dfm and our structural model decompose sectoral inflation volatility in very comparable way: Price indices that are relatively more subject to aggregate shocks in the structural model are also classified that way by the dfm. Moreover, since the factors in the dfm also capture pipeline pressures on top of macroeconomic shocks, accounting for the former improves the correlation between our model decomposition and the dfm.

[Insert table 14]

5.4 Pipeline pressures and inflation persistence

This section investigates the origins of inflation persistence (Stylized fact $2a-b$). Persistence in the structural model is measured in the same way as in the dfm by fitting an $AR(L)$ model separately to the three components of eqs. (8), (9) (for producer prices) and D.1., D.2. (for consumer prices). Our measure of persistence then equals the sum of the coefficients on all lags. E.g. persistence caused by aggregate shocks in sector j

$$\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty} = \sum_{l=1}^{L} \rho_{j,l}\boldsymbol{\alpha}_{t-l}(\pi_j^{ppi})_{h=\infty} + \epsilon_{j,t}$$

---

[21] In fact, it follows from a complex combination of price stickiness, Cobb–Douglas parameters and sectoral interactions.

$$\rho(\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty}) = \sum_{l=1}^{L} \rho_{j,l}$$

Where lag length L is selected based on the BIC information criterion.

[Insert table 15]

Table 15 documents that our model disentangles the origins of persistence in a similar way as the dfm; On average, disaggregate prices react close to instantaneously to micro shocks specific to that price index (column (2)). Aggregate shocks generate persistence (column (1)).

To understand why our model reproduces this stylized fact, we discuss a general property of the impulse response functions – $\delta_j^{(s)}(a)$, $\delta_j^{(s)}(e,j)$ – that underlay our definitions of $\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty}$ and $\boldsymbol{\beta}_t(\pi_j^{ppi})_{h=\infty}$. We focus on producer prices, the discussion applies to consumer prices as well.

Aggregate shocks ($\delta_j^{(s)}(a)$). Lets us consider what happens in the face of an aggregate shock, $\varepsilon_{a,t}$, that affects all sectors. To the extent that firms in sector j have sticky prices, they will only respond gradually to this aggregate shock. In addition, if firms in sector j' rely on inputs from sector j, $\omega_{j'j} > 0$ or $\psi_{j'j} > 0$, the sluggish price change in sector j will feed only slowly into the marginal costs of the firms in sector j' via $p^m_{j't,r}$ and $r_{j't,r}$ (via $p^i_{j't,r}$). Consequently, irrespective of the stickiness of prices in sector j', the impact of an aggregate shock is persistent given that marginal costs are "held back" by prices that have not yet adjusted, i.e. a contagion of price stickiness (cf. Carvalho and Lee (2011); Basu (1995)).

To illustrate this, figure 4 plots the impulse response functions of sectoral ppi inflation rates to an economywide wage markup shock, $\delta_j^{(s)}(w)$. All sectors, including the flexible price sector "Agriculture", only slowly respond to the aggregate shock given that part of their inputs (e.g. from the "Manufacturing" sector) take time to adjust.

[Insert figure 4]

Sectoral shocks – Direct effect ($\delta_j^{(s)}(e,j)$). The diagonal in figure 4 plots the change in sector j ppi inflation due to a wage markup shock in sector j, $\delta_j^{(s)}(w,j)$, and shows that the response of sector j prices is close to instantaneous. This causes the low persistence in table 15, column (2). The reason is that, in contrast to the aggregate shock scenario, there are no unadjusted prices that hold back marginal costs in sector j (cf. Carvalho and Lee (2011)). The speed of response is then solely driven by the level of price stickiness in sector j.[22]

[Insert figure 5, diagonal plots]

---

[22] Note that the differential persistence is not due to different persistence of the structural shocks: ρ_w and ϱ_w are estimated to be very similar.

In contrast to the dfm, our results in column (3) indicate that sectoral shocks can generate material persistence, via pipeline pressures. This contrasts sharply with the dfm literature which allocates any persistence of inflation indices fully to aggregate shocks.

Sectoral shocks – Pipeline pressures ($\delta_{j'}^{(s)}(e, j)$). In the presence of production linkages, the sectoral shock in sector j spills over to the marginal cost of sector j' through $\boldsymbol{\Omega}$ and $\boldsymbol{\Psi}$. If sector j' is a sticky price sector, it will only slowly adjust its prices to these pipeline pressure. Subsequently, all sectors that in turn rely on sector j' will face sluggish changes in their input costs and thus respond slowly to the shock originating in sector j. The presence of sticky price sectors along the supply chain thus cause pipeline pressures to be persistent. The off–diagonal graphs in figure 5 reflect this.[23]

[Insert figure 5, off–diagonal plots]

6 Additional results and robustness

This section documents a set of additional results. In the first subsection, we take a more granular look on the origins of pipeline pressures. We next gauge the magnitude (and origins) of pipeline pressures between $1970Q1 - 2007Q4$ by ways of an historical decomposition. Finally, we relate the model–implied lead–lag relationships of price indices with that present in disaggregated price data.

6.1 Trace inflation through the pipeline

We investigate from which sectors the pipeline pressures to individual price indices originate. For that purpose, we decompose $\boldsymbol{\gamma}_t(\pi_j^{ppi})_h$ and $\boldsymbol{\gamma}_t(\pi_z^{pce})_h$ into their sectoral origins. To economize notation, we ignore the role of shocks to consumer prices here.[24] For producer and consumer prices we then have that

$$\begin{aligned}\boldsymbol{\gamma}_t(\pi_j^{ppi})_h &\approx \sum_{j' \neq j}^{J} \Big(\sum_{s=0}^{h-1} \big(\boldsymbol{\delta}_{j,j'}^{(s)}(\mathcal{E})\big)' \boldsymbol{\varepsilon}_{j'}(\mathcal{E})_{t-s} \Big) = \sum_{j' \neq j}^{J} \boldsymbol{\gamma}_t(\pi_j^{ppi}; j')_h \\ \boldsymbol{\gamma}_t(\pi_z^{pce})_h &\approx \sum_{j'=1}^{J} \Big(\sum_{s=0}^{h-1} \big(\boldsymbol{\delta}_{z,j'}^{(s)}(\mathcal{E})\big)' \boldsymbol{\varepsilon}_{j'}(\mathcal{E})_{t-s} \Big) = \sum_{j'=1}^{J} \boldsymbol{\gamma}_t(\pi_z^{pce}; j')_h\end{aligned}$$

---

[23] Importantly, looking vertically across figure 5, we note that pipeline pressures generate comovement of sectoral inflation indices much similar to the effect of an aggregate shock. This affects the ability of a dfm to correctly discriminate between aggregate shocks and pipeline pressures: both are picked up by the dfm in the common component. The persistence of the common component then, in part, reflects persistent effects of sectoral shocks via pipeline pressures.

[24] This is inconsequential, given that we find them to be a very small source of pipeline pressures.

where vector $\boldsymbol{\delta}^{(s)}_{j,j'}$ ($\boldsymbol{\delta}^{(s)}_{z,j'}$) contains the period s irf coefficients of ppi j (pce z) to shocks in sector j', $\boldsymbol{\varepsilon}_{j'}(\mathcal{E})_{t-s}$. $\boldsymbol{\gamma}_t(\pi_j^{ppi};j')_{h=\infty}$ ($\boldsymbol{\gamma}_t(\pi_z^{pce};j')_{h=\infty}$) then quantifies the amount of pipeline pressures faced by ppi j (pce z) at time t that originates from sector j'. Table 16a documents $\frac{\sigma^2[\gamma_t(\pi_j^{ppi};j')_{h=\infty}]}{\sigma^2[\gamma_t(\pi_j^{ppi})_{h=\infty}]}$ and quantifies how important the pipeline pressures originating from sector j' are in total pipeline pressures faced by the ppi of sector j.

For ppi inflation, the role of the production structure of the U.S. economy is apparent in this decomposition. E.g. given its role as an important intermediate input supplier to the "Food and Beverages" sector, the "Agriculture" sector is an important source of pipeline pressures to the former (92.77%). Similarly, the "Chemical products" sector is an important determinant of "Plastics and Rubber products" price setting (27.04%). On the other hand, the "Construction", "Machinery" and "Computers and electronic products" sectors are only marginally involved in the U.S. input–output matrix $\boldsymbol{\Omega}$. Nonetheless, these sectors exert important pipeline pressures through the capital flow matrix $\boldsymbol{\Psi}$.

For pce inflation, table 17a documents how important pipeline pressures from sector j are in total pipeline pressures faced by pce inflation z. We observe that the financial sector (FIRE) is an important origin of pipeline pressures to many (non)durable consumer goods, (such as "Housing" (59.77%)) and services (such as "Transportation Services" (17.48%)), given that it is both directly and indirectly involved in the production of these goods/services.

[Insert table 16a, 17a]

The timing of pipeline pressures faced by ppi's is heterogeneous; e.g. from table 12 we know that pipeline pressures faced by the sector "Food and Beverages" are close to instantaneous (i.e. column (3) is close to (6)), whereas pressures faced by the "Construction" sector take time to build (i.e. column (3) is smaller than (6)). In order to investigate this, table 16b documents $\frac{\sigma^2[\gamma_t(\pi_j^{ppi};j')_{h=1}]}{\sigma^2[\gamma_t(\pi_j^{ppi})_{h=1}]}$ (i.e. $FEVD(1)$). Contrasting with table 16a, we see for example that the main source of pipeline pressures to the "Food and Beverages" ppi is the "Agriculture" sector. Given the price flexibility of the latter sector, these pressures already manifest themselves in full after one quarter. Reversely, pressures faced by the "Construction" ppi mainly originate from the "Professional and Business services (PROF)" and "FIRE" sector. Due to the sticky nature of these sectors, pressures emanating from both sectors take time to build.

The timing of pipeline pressures to pce inflation is also heterogeneous; e.g.; from table 17$a-b$ the pipeline pressures originating from the "Oil and gas extraction" sector and "Petroleum and coal" sector on the consumer prices of "Gasoline and other energy goods" are close to instantaneous. The reverse is true for e.g. the "Machinery" sector. Its impact on consumer prices (e.g. "Recreational goods and services") takes time to materialize.

W.r.t. timing, higher order effects are also important; e.g. although the "Computer and Electronic products" sector has relatively flexible prices, the pressure it exerts on downstream product categories, such as "Transportation services" and "Recreation services", often take time to fully materialize because its shocks first passes through sticky price sectors before they effectively reach more downstream prices.

[Insert table $16b, 17b$]

6.2 Historical pipeline decomposition

We now decompose historical pipeline pressures through the lens of our structural model (for brevity, we focus on producer prices only). For that purpose, we use the Kalman smoother to derive the smoothed shocks for $1970Q1 - 2007Q4$ and the smoothed state of the economy in $1970Q1$. This allows us to derive $\sum_{j' \neq j}^{J} \boldsymbol{\gamma}_t(\pi_j^{ppi}; j')_{h=\infty}$ (and $\sum_{j=1}^{J} \eta_j \sum_{j' \neq j}^{J} \boldsymbol{\gamma}_t(\pi_j^{ppi}; j')_{h=\infty}$), which decomposes pipelines pressures to ppi j (and headline ppi) at time t into its sectoral origins.[25] For tractability, the results in this section are based on the aggregated version of our model.

Figure 6 provides a breakdown of pipeline pressures to headline ppi inflation. Consistent with the analysis in the previous sections, pipeline pressures are a material source of headline volatility and persistence. In general, the "Manufacturing" and "Services" sector (which covers "Wholesale trade") have been important sources of pipeline pressures/easing to headline inflation in the first half of the sample, but are more subdued during the nineties and thereafter. The "Mining" sector (which mainly covers Oil and gas extraction), is a consistent source of pipeline pressures/easing.

[Insert figure 6]

The peaks in pipeline pressures during the oil crises periods (1979 energy crisis and 1990 oil price shock) are interpreted by the model as originating from the "Mining" sector (which mainly covers Oil and gas extraction). The aftermath of the double dip recession in the early eighties is shown to have triggered pipeline easing, where disinflationary shocks eased inflation across the production chain. The nineties are characterized as a period of moderate and less volatile inflation where pipeline pressures were mostly subdued.

The panels in figure 7 provide a similar decomposition for disaggregate indices.[26] Again, pipeline pressures are an important source of inflation persistence, except for the "Utilities" sectors (where pipeline pressures mainly originate from the more volatile "Mining" sector). Looking vertically across the graphs, one clearly observes that pipeline pressures are correlated across sectors; This again illustrates why it is difficult for a dfm to correctly disentangle $\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty}$ from

---

[25] We ignore measurement error in this exercise.

[26] For "Construction", "Services" and "Public sector", no ppi series are observed so that we decompose their smoothed values obtained from the Kalman smoother.

$\gamma_t(\pi_j^{ppi})_{h=\infty}$. Importantly, however, pipeline pressures are not fully synchronized across price indices. In some sectors, pipeline pressures build up quicker (and die out quicker) than in others because some sectors are closer to the sector from which the pipeline pressure originates. E.g. given its proximity to the "Mining" sector, pipeline pressures faced by the "Utilities" ppi that originate in the "Mining" sector are close to instantaneous. The pipeline pressure faced by the "Services" ppi that originate in the "Mining" sector are more lagged and persistent given that it takes time for this shock to fully permeate through the production structure of the U.S. economy before it reaches the service sector.

The panels in figure 7 show that in the "Agriculture" and "Mining" sectors, pipeline pressures mainly originate from the "Manufacturing" and "Service" sector – especially in the first half of the sample. The reverse is true for "Utilities" and "Manufacturing", where "Mining" is an important source of pipeline pressures. The "Mining" sector has been an important driver of "Services" inflation during the first half of the sample, but is mostly subdued thereafter. The "Manufacturing" sector is always a key source of pipeline pressures to the "Services" ppi. This is unsurprising, given that an important segment of the "Service" sector is "Wholesale trade", which sources its products mainly from the "Manufacturing" sector.

[Insert figure 7]

6.3 Lead–Lag relationships

In view of the presence of pipeline pressures, one interesting dimension of the model are the autocorrelations between the various price indices. In this subsection, we validate the model by comparing the autocorrelations of the various inflation indices in the actual data to those of simulated data (see e.g. Fuhrer and Moore (1995); Smets and Wouters (2007); Gertler et al. (2008)).

The empirical cross–correlations are estimated on the same data sample as that used in the estimation of the dsge model and cover the period from $1970Q2-2007Q4$. The model–based cross–correlations are based on $100,000$ random samples of length 152.[27]

The empirical and model–based cross–correlations between headline ppi and pce are reported in figure 8. The black line represents the autocorrelation function (ACF) of the data, the solid red line reports the ACF of the model and the dashed red lines delimit the ninety percent posterior interval of the model correlations.

[Insert figure 8]

The slightly skewed autocorrelation between ppi and pce inflation indicates a lead–lag relation from producer prices to consumer prices which our model is

---

[27] That is, we sample $1,000$ parameter points from the posterior, and for each we generate a random sample of length 152 (i.e. the length of the estimation period), 100 times.

able to replicate. In figure 9–10 we report similar autocorrelation plots for disaggregate price indices. These figures show that, overall, the model does well in capturing this dimension of the data.

[Insert figure 9 and 10]

7 Conclusion

Policymakers and forecasters often look for signs of an impending rise in the general price level by concentrating on price movements in particular sectors. The underlying presumption is the existence of a cascade effect where sectoral shocks propagate through input–output interactions and induce inflation in other sectors. Recent policy work (e.g., European Central Bank (2017); Federal Reserve System (2018)) and the popular press (e.g., Wall Street Journal (2018); Financial Times (2018)), have labelled this cascade effect metaphorically as "pipeline pressures".

In this paper, we develop a dynamic stochastic general equilibrium model in order to provide a structural definition of pipeline pressures and subsequently use Bayesian estimation techniques to infer their presence from the data. Pipeline pressures are shown to be an important contributor to sectoral and headline inflation volatility and a material source of persistence. This contrasts with evidence from dynamic factor models, which have de–emphasized the role of sectoral shocks for volatility and persistence in favour of aggregate shocks.

Our analysis delivers a set of important policy implications. First, our results underscore the aggregate inflationary implications of sectoral events, e.g. (*i*) shifts in healthcare sector regulation (e.g. Affordable Care Act), (*ii*) competition in the telecommunications sector, (*iii*) productivity shocks in the computer and electronics industry, (*iv*) the shale gas boom in the mining sector, (*v*) disruptions in the real estate sector, etc. Second, in line with the former, our analysis suggests that a production view of the economy entails a useful area of research for improving forecasting performance. Third, in view of subdued inflation and central banks missing inflation targets in recent years, our analysis advocates to pay more attention to sector–specific drivers of inflation.

We finally highlight two missing aspects of our analysis that future work might explore. One is to allow for strategic complementaries (as in Woodford (2011)), the other is to extend our model to an open economy set–up.

8 Tables

Table 1: Stylized facts; disaggregate inflation

		Consumer prices		Producer prices	
		Mean	Median	Mean	Median
Persistence	$\rho(\epsilon_{it})$	0.07	0.12	0.14	0.16
	$\rho(\boldsymbol{\lambda}_i'\boldsymbol{f}_t)$	0.57	0.62	0.44	0.51
Volatility	$100 \times \frac{\sigma^2(\epsilon_{it})}{\sigma^2(\pi_{it})}$	63.00	61.69	63.54	65.07
	$100 \times \frac{\sigma^2(\boldsymbol{\lambda}_i'\boldsymbol{f}_t)}{\sigma^2(\pi_{it})}$	37.00	38.31	36.45	34.92

Number of factors are determined by the Bai and Ng (2002) information criterion. Persistence is measured following Boivin et al. (2009); an $AR(L)$ model is estimated for both components of the dfm and persistence equals the sum of the coefficients on all lags. Lag length is selected based on the BIC information criterion. There is no natural lower bound on this persistence measure.

Table 2: Stylized facts; headline inflation

		Consumer prices	Producer prices
Persistence	$\rho(\boldsymbol{w}'\boldsymbol{\epsilon}_t)$	−0.04	−0.08
	$\rho(\boldsymbol{w}'\boldsymbol{\Lambda}\boldsymbol{f}_t)$	0.70	0.37
Volatility	$100 \times \frac{\sigma^2(\boldsymbol{w}'\boldsymbol{\epsilon}_t)}{\sigma^2(\pi_t)}$	35.54	26.35
	$100 \times \frac{\sigma^2(\boldsymbol{w}'\boldsymbol{\Lambda}\boldsymbol{f}_t)}{\sigma^2(\pi_t)}$	64.46	73.65

Number of factors are determined by the Bai and Ng (2002) information criterion. Persistence is measured following Boivin et al. (2009); an $AR(L)$ model is estimated for both components of the dfm and persistence equals the sum of the coefficients on all lags. Lag length is selected based on the BIC information criterion. There is no natural lower bound on this persistence measure.

Table 3: CALIBRATION OF PARAMETERS

Description	Parameter	Value
PANEL A: AGGREGATE PARAMETERS		
Elasticity of inter temporal substitution	σ	1.50
Discount factor	β	0.99
Inverse Frisch labour supply elasticity	φ	2.00
Markup, intermediate goods market	ϵ_m	0.20
Markup, final goods market	ϵ_c	0.20
Markup, labour market	ϵ_w	0.20
Elasticity of substitution intermediates	ν_f, ν_m, ν_i	2.00
Elasticity of substitution final consumption goods	ν_c, ν_g	2.00
Capital depreciation	δ	0.025
Size government	$\frac{g}{c}$	0.25
PANEL B: SECTORAL PARAMETERS		
Intermediates Input–Output matrix	$\boldsymbol{\Omega}$	See table 4
Investment flow matrix	$\boldsymbol{\Psi}$	See table 5
Labour share	$\boldsymbol{\phi}^n$	See table 6
Capital share	$\boldsymbol{\phi}^k$	See table 6
Intermediate goods/services share	$\boldsymbol{\phi}^m$	See table 6
Producer price stickiness	$\boldsymbol{\alpha}^{ppi}$	See table 6
Wage stickiness	$\boldsymbol{\alpha}^w$	See table 6
Private consumption weights	$\boldsymbol{\xi}$	See table 7
Government consumption weights	$\boldsymbol{\zeta}$	See table 7
Consumer price stickiness	$\boldsymbol{\alpha}^{pce}$	See table 7
Intermediate goods producers to final goods producers flow matrix	$\boldsymbol{K}$	See table 8

This table documents the parameters calibrated throughout the estimation of the model. $\frac{g}{c}$ is set equal to the average fraction of annual Government Consumption Expenditures to Personal Consumption Expenditures in the post WWII period. Elasticities and markups are taken identical to Pasten et al. (2016, 2017); Carvalho and Lee (2011).

Table 4: INPUT–OUTPUT MATRIX INTERMEDIATES ($\mathbf{\Omega}$): AGGREGATE LEVEL

	Agriculture & Forestry	Mining	Utilities	Construction	Manufacturing	Services	Public sector
Agriculture & Forestry	0.35	0.00	0.02	0.00	0.32	0.28	0.01
Mining	0.00	0.24	0.05	0.02	0.22	0.45	0.02
Utilities	0.00	0.32	0.02	0.02	0.08	0.54	0.02
Construction	0.00	0.02	0.00	0.00	0.57	0.40	0.00
Manufacturing	0.06	0.05	0.02	0.00	0.60	0.25	0.01
Services	0.00	0.00	0.02	0.01	0.18	0.74	0.04
Public sector	0.00	0.02	0.03	0.06	0.32	0.54	0.04

Parameters $\omega_{jj'}$ are constructed using the 1997 "Use" and "Make" tables provided by the BEA. Row sums do not add to one due to rounding.

Table 5: INVESTMENT FLOW MATRIX ($\mathbf{\Psi}$): AGGREGATE LEVEL

	Agriculture & Forestry	Mining	Utilities	Construction	Manufacturing	Services	Public sector
Agriculture & Forestry	0.00	0.00	0.00	0.11	0.70	0.18	0.00
Mining	0.00	0.50	0.00	0.07	0.31	0.12	0.00
Utilities	0.00	0.00	0.00	0.44	0.40	0.15	0.00
Construction	0.00	0.00	0.00	0.03	0.76	0.21	0.00
Manufacturing	0.00	0.00	0.00	0.13	0.60	0.25	0.00
Services	0.00	0.00	0.00	0.42	0.39	0.18	0.00
Public sector	0.00	0.00	0.00	0.44	0.22	0.32	0.02

Parameters $\psi_{jj'}$ are constructed using the 1997 "Use" and "Make" tables provided by the BEA. Row sums do not add to one due to rounding.

Table 6: Input shares labour, intermediates and capital (J=7)

j	Sector	NAICS	Labour (ϕ_j^n)	Intermediates (ϕ_j^m)	Capital (ϕ_j^k)	Price stickiness (α_j^{ppi})	Wage stickiness (α_j^w)
1	Agriculture & Forestry	11	0.10	0.58	0.32	0.00	0.78
2	Mining	21	0.20	0.45	0.34	0.22	0.84
3	Utilities	22	0.17	0.32	0.51	0.00	0.77
4	Construction	23	0.32	0.52	0.16	0.22	0.79
5	Manufacturing	31	0.21	0.64	0.16	0.24	0.74
6	Services	42 – 80	0.32	0.37	0.31	0.55	0.77
7	Public sector	9	0.54	0.31	0.15	0.89	0.77

Parameters ϕ_j^n, ϕ_j^m and ϕ_j^k are constructed using the 1997 "Use" tables provided by the BEA. Shares do not add to one due to rounding. α_j^{ppi} and α_j^w are obtained from Peneva (2011) and Bils et al. (2014), respectively.

Table 7: Price stickiness and consumption weights across product categories (Z=4)

z	Product Category	Private consumption (ξ_z)	Government consumption (ζ_z)	Price stickiness (α_z^{pce})
1	Durables	0.13	0.00	0.25
2	Non–Durables	0.29	0.00	0.16
3	Services	0.58	0.00	0.44
4	Public sector goods	0.00	1.00	0.28

Data are constructed using the 1997 PCE tables provided by the BEA. Shares do not add to one due to rounding. Price stickiness (α_z^{pce}) are obtained by suitably aggregating consumption categories from the Nakamura and Steinsson (2008) price–setting statistics. The household does not consume public sector goods $\xi_4 = 0$. The government only consumes public sector goods $\zeta_4 = 1$.

Table 8: Intermediates to final consumption flow table ($\boldsymbol{K}$): Aggregate level

	Agriculture & Forestry	Mining	Utilities	Construction	Manufacturing	Services	Public sector
Durables	0.00	0.00	0.00	0.00	0.45	0.54	0.00
Non-durables	0.03	0.00	0.00	0.00	0.50	0.47	0.00
Services	0.00	0.00	0.03	0.00	0.00	0.90	0.07
Public sector goods	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Parameters κ_{zj} are constructed using the 1997 bridge tables provided by the BEA. Row sums do not add to one due to rounding.

Table 9: Priors and posteriors of the estimated parameters

Parameter and description		Prior			Posterior	
		Type	Mean	S.D.	Mode	Confidence
A. Behavioural parameters						
χ	Habit parameter	β	0.50	0.10	0.479	$[0.404; 0.559]$
ϵ_I	Investment adjustment cost	inv-Γ	4.00	1.50	2.939	$[2.537; 3.486]$
ϵ_U	Capital utilization cost	inv-Γ	0.15	0.10	0.120	$[0.080; 0.193]$
ι_w	Indexation wages	β	0.50	0.15	0.426	$[0.368; 0.485]$
ι_{ppi}	Indexation producer prices	β	0.50	0.15	0.080	$[0.029; 0.143]$
ι_{pce}	Indexation consumer prices	β	0.50	0.15	0.192	$[0.087; 0.307]$
B. Monetary Policy						
ρ_s	Taylor rule, Smoothing	β	0.80	0.10	0.771	$[0.743; 0.795]$
ρ_π	Taylor rule, Inflation	$\mathcal{N}$	1.70	0.10	1.820	$[1.705; 1.943]$
ρ_{gdp}	Taylor rule, Gross domestic product	$\mathcal{N}$	0.125	0.05	0.390	$[0.349; 0.432]$
C. Autoregressive coefficients of aggregate shocks						
ρ_b	Risk	β	0.85	0.10	0.728	$[0.688; 0.766]$
ρ_g	Government demand	β	0.85	0.10	0.899	$[0.863; 0.924]$
ρ_w	Markup: wages	β	0.85	0.10	0.308	$[0.193; 0.405]$
ρ_m	Markup: producer prices	β	0.85	0.10	0.364	$[0.269; 0.455]$
ρ_c	Markup: consumer prices	β	0.85	0.10	0.902	$[0.674; 0.984]$
ρ_p	Productivity	β	0.85	0.10	0.788	$[0.655; 0.863]$
ρ_i	Investment	β	0.85	0.10	0.839	$[0.612; 0.908]$
D. Standard deviations of aggregate shocks						
σ_b	Risk	inv-Γ	0.10	2	0.172	$[0.144; 0.199]$
σ_g	Government demand	inv-Γ	0.10	2	0.483	$[0.431; 0.545]$
σ_w	Markup: wages	inv-Γ	0.10	2	0.052	$[0.036; 0.069]$
σ_m	Markup: producer prices	inv-Γ	0.10	2	0.020	$[0.017; 0.022]$
σ_c	Markup: consumer prices	inv-Γ	0.10	2	0.039	$[0.025; 0.071]$
σ_p	Productivity	inv-Γ	0.10	2	0.025	$[0.019; 0.033]$
σ_i	Investment	inv-Γ	0.10	2	0.041	$[0.024; 0.088]$
σ_r	Monetary policy	inv-Γ	0.10	2	0.084	$[0.074; 0.096]$

$\mathcal{N}$, β, inv-Γ denote the normal, beta and inverse gamma distribution, respectively. Posterior moments are computed from $750,000$ draws generated by the Random Walk Metropolis-Hastings algorithm, where the first $200,000$ are used as burn–in.

Table 9 *Continued*: PRIORS AND POSTERIORS OF THE ESTIMATED PARAMETERS

PARAMETER AND DESCRIPTION		Prior			Posterior	
		Type	Mean	S.D.	Mode	Confidence
E. Standard deviation of sectoral productivity shocks						
$\varsigma_{p,1}$	Agriculture & Forestry	inv-Γ	0.2	2	0.091	$[0.050; 0.240]$
$\varsigma_{p,2}$	Mining	inv-Γ	0.2	2	0.855	$[0.765; 0.950]$
$\varsigma_{p,3}$	Utilities	inv-Γ	0.2	2	0.610	$[0.564; 0.662]$
$\varsigma_{p,4}$	Construction	inv-Γ	0.2	2	0.078	$[0.049; 0.137]$
$\varsigma_{p,5}$	Manufacturing	inv-Γ	0.2	2	0.221	$[0.198; 0.241]$
$\varsigma_{p,6}$	Services	inv-Γ	0.2	2	0.075	$[0.053; 0.090]$
$\varsigma_{p,7}$	Public sector	inv-Γ	0.2	2	0.090	$[0.052; 0.192]$
F. Standard deviation of producer price markup shocks						
$\varsigma_{m,1}$	Agriculture & Forestry	inv-Γ	0.2	2	1.519	$[1.379; 1.667]$
$\varsigma_{m,2}$	Mining	inv-Γ	0.2	2	1.030	$[0.933; 1.145]$
$\varsigma_{m,3}$	Utilities	inv-Γ	0.2	2	0.238	$[0.215; 0.266]$
$\varsigma_{m,4}$	Construction	inv-Γ	0.2	2	0.717	$[0.651; 0.799]$
$\varsigma_{m,5}$	Manufacturing	inv-Γ	0.2	2	0.792	$[0.735; 0.866]$
$\varsigma_{m,6}$	Services	inv-Γ	0.2	2	0.116	$[0.102; 0.132]$
$\varsigma_{m,7}$	Public sector	inv-Γ	0.2	2	0.041	$[0.033; 0.049]$
G. Standard deviation of consumer price markup shocks						
$\varsigma_{c,1}$	Durables	inv-Γ	0.2	2	0.686	$[0.602; 0.772]$
$\varsigma_{c,2}$	Non-Durables	inv-Γ	0.2	2	1.580	$[1.370; 1.790]$
$\varsigma_{c,3}$	Services	inv-Γ	0.2	2	0.150	$[0.131; 0.169]$
$\varsigma_{c,4}$	Public sector goods	inv-Γ	0.2	2	0.092	$[0.049; 0.264]$
H. Standard deviation of sectoral wage markup shocks						
$\varsigma_{w,1}, \varsigma_{w,2}, \ldots, \varsigma_{w,7}$	All sectors	inv-Γ	0.2	2	0.111	$[0.087; 0.147]$
I. Standard deviation of sectoral investment efficiency shocks						
$\varsigma_{i,1}, \varsigma_{i,2}, \ldots, \varsigma_{i,7}$	All sectors	inv-Γ	0.2	2	2.185	$[1.722; 2.581]$
J. Autoregressive coefficients of sectoral shocks						
ϱ_p	Productivity	β	0.5	0.2	0.737	$[0.702; 0.771]$
ϱ_m	Markup: producer prices	β	0.5	0.2	0.800	$[0.776; 0.815]$
ϱ_c	Markup: consumer prices	β	0.5	0.2	0.889	$[0.851; 0.916]$
ϱ_w	Markup: wages	β	0.5	0.2	0.300	$[0.179; 0.385]$
ϱ_i	Investment	β	0.5	0.2	0.093	$[0.027; 0.193]$

$\mathcal{N}$ denotes the normal distribution, β the beta distribution, inv-Γ the inverse gamma distribution. Posterior moments are computed from $750,000$ draws generated by the Random Walk Metropolis-Hastings algorithm, where the first $200,000$ are used as burn-in.

Table 10: BAYES FACTOR: PIPELINE PRESSURES

		Agriculture	Mining	Utilities	Construction	Manufacturing	Services	Public Sector
		$j=1$	$j=2$	$j=3$	$j=4$	$j=5$	$j=6$	$j=7$
$\frac{\mathcal{L}\big(\mathcal{Y}_T\|\mathcal{M}\big)}{\mathcal{L}\big(\mathcal{Y}_T\|\mathcal{M}_{\omega_{j'j=0},\psi_{j'j=0}}\big)}$					Panel A			
$j'=1$	Agriculture		1.00	8×10^3	5.87	160.82	19.6	8.08
$j'=2$	Mining	1.00		7.56	7.56	2×10^3	1×10^3	4.34
$j'=3$	Utilities	1.00	7×10^4		0.05	15.66	2×10^7	2.59
$j'=4$	Construction	1×10^4	14.95	7.4		2×10^9	0.00	1.00
$j'=5$	Manufacturing	23.42	3.39	9.65	1×10^4		2×10^7	6.15
$j'=6$	Services	8.63	10.06	21.32	0.00	1×10^{10}		3×10^6
$j'=7$	Public Sector	7.58	1×10^7	9×10^6	106.08	15.57	235.16	
$\frac{\mathcal{L}\big(\mathcal{Y}_T\|\mathcal{M}\big)}{\mathcal{L}\big(\mathcal{Y}_T\|\mathcal{M}_{\kappa_{zj=0}}\big)}$					Panel B			
$z=1$	Durables	5.56	3.45	7.53	1.00	346.31	96.23	7.33
$z=2$	Non–Durables	3.44	4.32	7.56	1.00	2×10^7	7×10^4	7.78
$z=3$	Services	3.75	3.55	9.18	7.57	6.65	2×10^{28}	7.56
$z=4$	Public sector	1.00	1.00	5.80	1.00	1.00	1.00	0.00

The table documents the Bayes factors. The marginal likelihood is derived from the Laplace Approximation. Results are unaffected when using the Modified Harmonic Mean estimator. $\mathcal{Y}_T$ denotes the observed data. $\mathcal{M}$ refers to the model. In panel A, the restriction $\omega_{jj'} = 0$ is introduced directly into the log–linearised Philips curve. The restriction $\psi_{jj'} = 0$ is introduced directly into Tobins Q equation. An alternative procedure would be to introduce these restrictions *before* log linearising, in which case the restriction would affect (i) the steady state of the model and (ii) other model equations. We refrain from this procedure as we found this procedure to deteriorate the excellent mapping between the micro level and macro level, documented in appendix E.5. In the latter case, the inclusion of sectoral data and aggregate data (in the face of a poor structural mapping between the two levels) artificially blows up the Bayes factor in favour of the baseline model.

Table 11: BAYES FACTOR: INTERMEDIATES VS. CAPITAL

j	Sector	$\frac{\mathcal{L}\big(\mathcal{Y}_T\|\mathcal{M}\big)}{\mathcal{L}\big(\mathcal{Y}_T\|\mathcal{M}_{\phi_j^m=0}\big)}$	$\frac{\mathcal{L}\big(\mathcal{Y}_T\|\mathcal{M}\big)}{\mathcal{L}\big(\mathcal{Y}_T\|\mathcal{M}_{\phi_j^k=0}\big)}$
1	Agriculture & Forestry	19.75	78.65
2	Mining	3415.8	0.00
3	Utilities	793.43	0.01
4	Construction	175.22	727.79
5	Manufacturing	1×10^{12}	3×10^6
6	Services	6×10^{13}	21.88
7	Public sector	4.56	45.1

The table documents the Bayes factor. The marginal likelihood is derived from the Laplace Approximation. Results are unaffected when using the Modified Harmonic Mean estimator. $\mathcal{Y}_T$ denotes the observed data. $\mathcal{M}$ refers to the baseline model.

Table 12: Forecast Error Variance Decomposition: Producer Prices

Panel a

	Horizon: 1 quarter ($FEVD(1)$)			Horizon: ∞ quarters ($FEVD(\infty)$)			dfm: $\pi_{jt}^{ppi} = \boldsymbol{\lambda}_j' \boldsymbol{f}_t + u_{jt}$	
	Macro	**Micro**		**Macro**	**Micro**			
		Direct	Pipeline Pressures		Direct	Pipeline Pressures		
	$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=1}\right]}{\sigma^2(\pi_j^{ppi})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\beta}_t(\pi_j^{ppi})_{h=1}\right]}{\sigma^2(\pi_j^{ppi})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\gamma}_t(\pi_j^{ppi})_{h=1}\right]}{\sigma^2(\pi_j^{ppi})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty}\right]}{\sigma^2(\pi_j^{ppi})_{h=\infty}}$	$\frac{\sigma^2\left[\boldsymbol{\beta}_t(\pi_j^{ppi})_{h=\infty}\right]}{\sigma^2(\pi_j^{ppi})_{h=\infty}}$	$\frac{\sigma^2\left[\boldsymbol{\gamma}_t(\pi_j^{ppi})_{h=\infty}\right]}{\sigma^2(\pi_j^{ppi})_{h=\infty}}$	$\frac{\sigma^2(\boldsymbol{\lambda}_j'\boldsymbol{f}_t)}{\sigma^2(\pi_{jt}^{ppi})}$	$\frac{\sigma^2(u_{jt})}{\sigma^2(\pi_{jt}^{ppi})}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Agriculture & Forestry	4.77	94.50	0.73	5.46	93.68	0.86	9.11	90.89
Oil and gas extraction	3.80	93.08	3.12	4.28	92.25	3.47	7.16	92.84
Mining, except oil and gas	7.19	92.07	0.74	7.90	90.98	1.12	32.86	67.14
Support activities for mining	7.55	91.09	1.36	8.27	89.94	1.79	31.45	68.55
Utilities	13.96	82.67	3.37	14.84	81.33	3.83	11.80	88.20
Construction*	53.29	42.67	4.03	54.90	38.92	6.18	34.88	65.12
Wood products	23.19	66.70	10.11	23.98	64.98	11.04	17.26	82.74
Nonmetallic mineral products	24.77	70.59	4.64	26.58	65.02	8.40	26.79	73.21
Primary metals	23.21	74.32	2.47	24.78	71.85	3.37	49.61	50.39
Fabricated metal products	24.67	67.65	7.68	27.65	59.32	13.03	55.05	44.95
Machinery	28.84	69.02	2.13	31.19	65.89	2.92	49.08	50.92
Computer and electronic products*	24.84	73.87	1.28	26.75	70.91	2.34	21.59	78.41
Electrical equipment, and appliances	29.21	67.82	2.98	31.07	64.68	4.25	30.29	69.71
Motor vehicles, bodies and trailers*	25.71	72.92	1.37	28.91	69.46	1.63	19.67	80.33
Other transportation equipment*	24.26	72.74	3.00	25.02	70.01	4.97	16.31	83.69
Furniture and related products	29.44	67.6	2.96	30.77	64.51	4.72	36.41	63.59
Miscellaneous manufacturing	28.14	67.95	3.91	29.59	63.23	7.19	15.24	84.76
Food and beverage and tobacco products	24.31	51.86	23.84	26.13	50.30	23.58	22.06	77.94
Textile mills and textile product mills	20.13	75.12	4.75	21.29	70.50	8.21	20.37	79.63
Apparel and leather and allied products	22.77	75.49	1.74	25.17	72.47	2.36	15.12	84.88
Paper products	24.10	71.90	4.00	25.05	68.42	6.53	33.43	66.57
Printing and related support activities	23.89	66.22	9.89	30.77	49.88	19.36	41.54	58.46
Petroleum and coal products	21.00	37.75	41.25	23.01	36.74	40.25	58.94	41.06
Chemical products	24.06	71.38	4.56	26.23	65.32	8.45	51.76	48.24
Plastics and rubber products	27.18	70.82	2.00	29.32	67.70	2.97	38.72	61.28
Wholesale trade*	41.36	46.05	12.59	45.49	30.13	24.38	43.65	56.35
Retail*	39.09	48.22	12.68	43.13	33.09	23.77	44.31	55.69
Transportation and warehousing*	40.96	55.60	3.44	43.2	51.84	4.97	30.33	69.67
Information*	41.64	50.19	8.17	43.09	41.79	15.11	37.68	62.32
FIRE*	45.58	46.38	8.04	46.36	41.79	11.85	35.75	64.25
PROF*	33.19	62.22	4.59	35.53	54.61	9.86	32.45	67.55
EHS*	33.49	60.61	5.90	34.65	53.79	11.57	28.31	71.69
AERAF*	38.89	50.86	10.25	39.61	44.75	15.64	31.59	68.41
Other serivces (except Govt.)*	39.9	52.50	7.61	40.96	45.25	13.80	32.70	67.30
Public Sector*	1.89	96.25	1.86	7.64	86.55	5.81	12.47	87.53

Panel b

	Horizon: 1 quarter ($FEVD(1)$)			Horizon: ∞ quarters ($FEVD(\infty)$)			dfm	
	Macro	**Micro**		**Macro**	**Micro**			
		Direct	Pipeline Pressures		Direct	Pipeline Pressures		
	$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi^{ppi})_{h=1}\right]}{\sigma^2(\pi^{ppi})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\beta}_t(\pi^{ppi})_{h=1}\right]}{\sigma^2(\pi^{ppi})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\gamma}_t(\pi^{ppi})_{h=1}\right]}{\sigma^2(\pi^{ppi})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi^{ppi})_{h=\infty}\right]}{\sigma^2(\pi^{ppi})_{h=\infty}}$	$\frac{\sigma^2\left[\boldsymbol{\beta}_t(\pi^{ppi})_{h=\infty}\right]}{\sigma^2(\pi^{ppi})_{h=\infty}}$	$\frac{\sigma^2\left[\boldsymbol{\gamma}_t(\pi^{ppi})_{h=\infty}\right]}{\sigma^2(\pi^{ppi})_{h=\infty}}$	$\frac{\sigma^2(\boldsymbol{\eta}'\boldsymbol{\Lambda}\boldsymbol{f}_t)}{\sigma^2(\pi_t^{ppi})}$	$\frac{\sigma^2(\boldsymbol{\eta}'\boldsymbol{u}_t)}{\sigma^2(\pi_t^{ppi})}$
Headline ppi Inflation	71.08	16.76	12.16	69.09	9.43	21.47	73.64	26.35

Columns $(1)-(6)$ document various forecast error variance decompositions at the mode. Data underlying column $(7)-(8)$ are sectoral ppi indices obtained from the Bureau of Labour Statistics. Not all sectoral ppi indices are available. For the unobserved series (indicated with an asterisk), we use the smoothed series.

Table 13: Forecast Error Variance Decomposition: Consumer Prices

Panel a

	Horizon: 1 quarter ($FEVD(1)$)			Horizon: ∞ quarters ($FEVD(\infty)$)			dfm: $\pi_{zt}^{pce} = \boldsymbol{\lambda}_z' \boldsymbol{f}_t + u_{zt}$	
	Macro	**Micro**		**Macro**	**Micro**			
		Direct	Pipeline Pressures		Direct	Pipeline Pressures		
	$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi_z^{pce})_{h=1}\right]}{\sigma^2(\pi_z^{pce})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\beta}_t(\pi_z^{pce})_{h=1}\right]}{\sigma^2(\pi_z^{pce})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\gamma}_t(\pi_z^{pce})_{h=1}\right]}{\sigma^2(\pi_z^{pce})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi_z^{pce})_{h=\infty}\right]}{\sigma^2(\pi_z^{pce})_{h=\infty}}$	$\frac{\sigma^2\left[\boldsymbol{\beta}_t(\pi_z^{pce})_{h=\infty}\right]}{\sigma^2(\pi_z^{pce})_{h=\infty}}$	$\frac{\sigma^2\left[\boldsymbol{\gamma}_t(\pi_z^{pce})_{h=\infty}\right]}{\sigma^2(\pi_z^{pce})_{h=\infty}}$	$\frac{\sigma^2(\boldsymbol{\lambda}_z'\boldsymbol{f}_t)}{\sigma^2(\pi_{zt}^{pce})}$	$\frac{\sigma^2(u_{zt})}{\sigma^2(\pi_{zt}^{pce})}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Motor vehicles and parts	17.45	45.59	36.96	19.76	42.98	37.26	39.13	60.87
Furnishings and durable hh equipment	10.25	84.52	5.23	14.00	76.47	9.53	41.92	58.08
Recreational goods and vehicles	11.18	80.63	8.20	15.85	71.19	12.95	23.85	76.15
Other durable goods	8.80	85.67	5.53	13.96	74.85	11.19	24.47	75.53
Food and beverages PFOPC	10.94	60.12	28.94	12.31	57.48	30.21	36.65	63.35
Clothing and footwear	10.75	63.60	25.65	12.12	60.85	27.03	32.48	67.52
Gasoline and other energy goods	8.85	70.88	20.27	10.04	68.35	21.61	37.48	62.52
Other nondurable goods	7.08	86.87	6.06	10.91	79.10	9.99	41.17	58.83
Housing and utilities	18.69	62.77	18.54	20.89	57.63	21.48	40.26	59.74
Health care	26.55	38.38	35.07	38.65	18.10	43.25	48.07	51.93
Transportation services	18.19	70.82	10.99	21.45	63.20	15.35	29.32	70.68
Recreation services	19.81	62.32	17.87	29.57	41.20	29.23	32.82	67.18
Food services and accommodations	17.21	59.10	23.68	23.64	43.18	33.18	44.00	56.00
Financial services and insurance	23.27	45.80	30.93	32.83	28.20	38.97	52.02	47.98
Other services	18.36	69.12	12.52	26.63	50.64	22.72	24.63	75.37
NPISHs	14.08	75.58	10.34	20.53	60.92	18.55	43.70	56.30
Public sector goods*	5.98	9.97	84.05	9.33	4.12	86.55		

Panel b

	Horizon: 1 quarter			Horizon: ∞ quarters			dfm	
	Macro	**Micro**		**Macro**	**Micro**			
		Direct	Pipeline Pressures		Direct	Pipeline Pressures		
	$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi^{pce})_{h=1}\right]}{\sigma^2(\pi^{pce})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\beta}_t(\pi^{pce})_{h=1}\right]}{\sigma^2(\pi^{pce})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\gamma}_t(\pi^{pce})_{h=1}\right]}{\sigma^2(\pi^{pce})_{h=1}}$	$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi^{pce})_{h=\infty}\right]}{\sigma^2(\pi^{pce})_{h=\infty}}$	$\frac{\sigma^2\left[\boldsymbol{\beta}_t(\pi^{pce})_{h=\infty}\right]}{\sigma^2(\pi^{pce})_{h=\infty}}$	$\frac{\sigma^2\left[\boldsymbol{\gamma}_t(\pi^{pce})_{h=\infty}\right]}{\sigma^2(\pi^{pce})_{h=\infty}}$	$\frac{\sigma^2(\boldsymbol{\xi}'\boldsymbol{\Lambda}\boldsymbol{f}_t)}{\sigma^2(\pi_t^{pce})}$	$\frac{\sigma^2(\boldsymbol{\xi}'\boldsymbol{u}_t)}{\sigma^2(\pi_t^{pce})}$
Headline pce Inflation	43.14	32.45	24.40	45.54	26.30	28.16	64.46	35.53

Columns $(1)-(6)$ document various forecast error variance decompositions at the mode. Data underlying column $(7)-(8)$ are pce indices obtained from the Bureau of Economic Analysis. Not all disaggregated pce indices are available. For the unobserved series (indicated with an asterisk), we use the smoothed series.

Table 14: Correlation model vs. dfm

	$\frac{\sigma^2(\boldsymbol{\lambda}_z'\boldsymbol{f}_t)}{\sigma^2(\pi_{zt}^{pce})}$	$\frac{\sigma^2(\boldsymbol{\lambda}_j'\boldsymbol{f}_t)}{\sigma^2(\pi_{jt}^{ppi})}$
pce inflation		
$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi_z^{pce})_{h=\infty}\right]}{\sigma^2(\pi_z^{pce})_{h=\infty}}$	0.36^{*}	
$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi_z^{pce})_{h=\infty}\right]+\sigma^2\left[\boldsymbol{\gamma}_t(\pi_z^{pce})_{h=\infty}\right]}{\sigma^2(\pi_z^{pce})_{h=\infty}}$	0.49^{**}	
ppi inflation		
$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty}\right]}{\sigma^2(\pi_j^{ppi})_{h=\infty}}$		0.43^{**}
$\frac{\sigma^2\left[\boldsymbol{\alpha}_t(\pi_j^{ppi})_{h=\infty}\right]+\sigma^2\left[\boldsymbol{\gamma}_t(\pi_j^{ppi})_{h=\infty}\right]}{\sigma^2(\pi_j^{ppi})_{h=\infty}}$		0.55^{***}

${}^{***}p < 0.01, {}^{**}p < 0.05, {}^{*}p < 0.1$. Correlation between shares obtained from the structural model and dfm, respectively.

Table 15: Persistence decomposition inflation

		Macro	**Micro**		dfm	
			Direct	Pipeline Pressures		
		(1)	(2)	(3)	(4)	(5)
		$\rho(\boldsymbol{\alpha}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\eta}'\boldsymbol{\Lambda}\boldsymbol{f}_t)$	$\rho(\boldsymbol{\eta}'\boldsymbol{u}_t)$
π_t^{ppi}		0.332	0.080	0.793	0.374	−0.078
		$\rho(\boldsymbol{\alpha}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\lambda}_j'\boldsymbol{f}_t)$	$\rho(u_{jt})$
π_{jt}^{ppi}	Average	0.335	0.066	0.635	0.445	0.145
	Median	0.379	0.115	0.719	0.511	0.161
	Minimum	−0.423	−0.396	−0.181	0.112	−0.486
	Maximum	0.918	0.655	0.929	0.577	0.674
		$\rho(\boldsymbol{\alpha}_t(\pi^{pce}))$	$\rho(\boldsymbol{\beta}_t(\pi^{pce}))$	$\rho(\boldsymbol{\gamma}_t(\pi^{pce}))$	$\rho(\boldsymbol{\xi}'\boldsymbol{\Lambda}\boldsymbol{f}_t)$	$\rho(\boldsymbol{\xi}'\boldsymbol{u}_t)$
π_t^{pce}		0.570	0.275	0.901	0.702	−0.036
		$\rho(\boldsymbol{\alpha}_t(\pi_z^{pce}))$	$\rho(\boldsymbol{\beta}_t(\pi_z^{pce}))$	$\rho(\boldsymbol{\gamma}_t(\pi_z^{pce}))$	$\rho(\boldsymbol{\lambda}_z'\boldsymbol{f}_t)$	$\rho(u_{zt})$
π_{zt}^{pce}	Average	0.711	0.176	0.865	0.573	0.071
	Median	0.780	0.151	0.899	0.621	0.120
	Minimum	0.233	−0.064	0.777	0.171	−0.292
	Maximum	0.930	0.386	0.951	0.728	0.277

Point estimates in (1) − (3) are based on a simulated time series of length 500. Persistence is computed as the sum of the coefficients of the fitted $AR(L)$ process where lag length L is determined by the BIC information criterion.

Table 16a: Producer prices: Pipeline pressure decomposition (infinite quarter horizon)

	Agriculture & Forestry	Oil and gas extraction	Mining. except oil and gas	Support activities for mining	Utilities	Construction	Wood products	Nonmetallic mineral products	Primary metals	Fabricated metal products	Machinery	Computer and electronic products	Electrical equipment. and appliances	Motor vehicles. bodies and trailers	Other transportation equipment	Furniture and related products	Miscellaneous manufacturing	Food and beverage and tobacco products	Textile mills and textile product mills	Apparel and leather and allied products	Paper products	Printing and related support activities	Petroleum and coal products	Chemical products	Plastics and rubber products	Wholesale trade	Retail	Transportation and warehousing	Information	FIRE	PROF	EHS	AERAF	Other services. except government	Government
Agriculture & Forestry		05.09			04.82	02.28			01.23		03.97	03.03		06.53				24.56					01.89	05.73	01.03	02.73	01.95	05.16		13.86	07.54				02.16
Oil and gas extraction	01.06			01.69							01.69	01.23		01.98									71.82							07.43	03.88				
Mining, except oil and gas	03.15	08.41		01.08	08.46	03.18			06.15	01.12	07.19	03.97		04.98				02.29					01.00	02.09	01.51	02.46	02.24	05.89		15.93	11.79	01.12			02.27
Support activities for mining	02.07	54.03				01.98			01.08		08.55	02.23		03.89				01.51								01.28	01.28			07.50	07.02				01.25
Utilities	02.37	52.82	01.64			02.19					02.02	02.47		03.50				01.99								01.33	01.37	03.27		10.88	06.48				01.41
Construction	04.98	03.34	01.36		01.59		02.75	01.50	02.16	02.81	06.62	04.88	01.95	09.43				02.62					01.26	01.45	02.07	02.50	03.28	01.77	01.03	26.23	08.12	01.27			02.39
Wood products	77.50					01.15					01.18	01.27		01.74																04.48	02.81				
Nonmetallic mineral products	04.99	02.66	12.03		03.62	06.21			01.62	01.63	04.92	04.98		05.08				02.52						02.52		03.02	02.78	03.52	01.15	16.74	11.05	01.44			02.81
Primary metals	02.27	02.64	44.04		04.62	02.13				01.15	02.49	03.50		03.28				01.48						01.15		02.37	01.48	04.70		09.18	07.10				01.79
Fabricated metal products	03.64	01.68	01.26		01.96	03.99			29.13		04.30	04.25		04.91				02.21						01.79		02.98	02.63	01.61	01.06	14.94	09.70	01.43			02.77
Machinery	02.63	01.63			01.79	02.81			24.44	03.71		08.50	02.57	11.47				02.05						01.69	02.61	02.36	01.94	01.68		11.51	08.70	01.02			02.25
Computer and electronic products	05.19	02.18			02.75	04.84			05.01	02.37	05.68		01.32	07.17				03.45						02.28	01.42	04.13	03.16	02.19	03.03	18.70	15.99	01.69			03.06
Electrical equipment, and appliances	02.96	02.12	01.51		01.98	02.77			32.43	02.95	03.66	07.91		03.86				02.00						01.86	01.36	02.45	01.89	01.84		11.68	07.81				02.00
Motor vehicles, bodies and trailers	02.30	01.21	01.01		01.55	02.72			28.05	03.55	08.56	12.37						01.57						01.59	07.36	02.46	01.48	01.62		09.62	06.37				01.56
Other transportation equipment	04.00	01.69			01.75	03.70			07.13	02.98	05.34	17.41		08.35				02.78						01.73	01.38	02.80	02.63	01.79	01.08	14.79	10.77	01.46			02.18
Furniture and related products	08.55	01.67			01.99	03.11	12.55		06.19	01.93	03.75	04.79		05.32				02.41	01.18					02.65	07.18	02.75	02.57	02.00		13.01	08.11	01.21			02.53
Miscellaneous manufacturing	06.43	02.14			02.15	04.09			05.19	01.82	04.99	06.56		06.37				03.56						03.81	02.47	03.30	03.34	02.11	01.35	17.78	11.58	01.83			03.33
Food and beverage and tobacco products	92.77																													01.34	01.10				
Textile mills and textile product mills	17.76	01.98			02.09	03.46			01.30	01.15	03.89	04.60		04.66				02.24						17.74		02.95	02.45	01.82	01.01	13.54	09.51	01.28			02.66
Apparel and leather and allied products	05.42	01.09			01.68	01.97					02.16	02.48		02.89				02.61	47.60					02.64		01.99	01.50	01.44		08.91	08.96				01.68
Paper products	21.58	02.63			03.83	03.38	01.80		01.48	01.42	03.96	05.07		05.17				02.03						04.24		03.25	02.52	02.76	01.00	14.54	10.82	01.33			02.35
Printing and related support activities	05.18	02.16			01.60	05.49			01.54	01.51	05.91	05.93		07.42				02.69			08.75			02.91		03.56	03.45	01.70	01.35	18.36	11.23	01.82			02.60
Petroleum and coal products		97.03																																	
Chemical products	04.77	06.33	01.19		03.80	04.28			01.85	01.59	05.44	05.16		06.16				03.42								03.82	03.38	02.78	01.39	18.76	15.96	01.61	01.00		03.27
Plastics and rubber products	06.27	03.26			03.96	02.71			02.62	01.75	03.56	04.61		03.99				02.02			01.10			27.04		02.41	01.98	02.38		12.47	09.79	01.02			02.04
Wholesale trade	05.15	02.09			01.81	05.80			01.61	01.39	05.87	05.78		09.28				03.20						01.67			04.01	02.11	01.73	22.31	14.09	02.16	01.13		04.69
Retail	06.11	01.79			01.84	06.23			01.53	01.36	05.65	05.59		09.25				04.26						01.68		03.58		01.90	01.67	21.95	12.44	02.24	01.18		05.37
Transportation and warehousing	03.35	21.92			01.81	02.98			01.08	01.01	03.22	03.60		09.08				02.46					07.28	01.18		02.19	02.17		01.19	16.33	11.06	01.21			02.85
Information	06.30	02.24			02.15	04.92			01.54	01.37	04.80	07.69		07.80				04.13						01.81		03.20	03.42	01.92		20.61	14.68	02.05	01.52		03.13
FIRE	07.48	03.65			05.42	07.54			01.83	01.46	05.17	05.75		10.75				06.02						02.25		03.41	04.03	02.19	01.94		16.69	02.23	01.57		04.93
PROF	07.11	02.85			02.50	05.92			01.74	01.43	05.78	06.35		08.94				04.35						01.94		03.64	03.98	02.21	02.24	26.17		02.28	01.68		03.90
EHS	06.65	01.86			02.21	04.67			01.27	01.10	04.40	04.67		07.06				05.38						03.10		03.12	03.51	01.70	01.59	22.65	12.91		01.32		06.41
AERAF	16.62	01.66			02.14	03.83			01.11	01.01	03.57	03.57		05.64				18.08						01.35		02.54	02.70	01.46	01.13	15.52	09.10	01.45			03.78
Other serivces (except Govt.)	05.81	02.10			02.14	04.97			01.50	01.25	04.83	04.93		11.44				04.08						01.76		03.06	03.53	01.93	01.54	23.48	10.97	02.09	01.17		03.46
Government	03.53	01.58			01.14	08.61			01.82	01.65	08.17	07.26		10.24				02.19						01.58		04.35	03.73	01.34	01.80	21.55	12.47	02.16			

This table documents $\frac{\sigma^2[\gamma_t(\pi_j^{ppi};j')_{h=\infty}]}{\sigma^2[\gamma_t(\pi_j^{ppi})_{h=\infty}]}$, where this value is approximated by $\frac{\sigma^2[\gamma_t(\pi_j^{ppi};j')_{h=\infty}]}{\sum_{j'=1}^{J}\sigma^2[\gamma_t(\pi_j^{ppi};j')_{h=\infty}]}$. Values smaller than 1 are suppressed. Row sums do not add to 100.

Table 16b: Producer prices: Pipeline pressure decomposition (one quarter horizon)

	Agriculture & Forestry	Oil and gas extraction	Mining. except oil and gas	Support activities for mining	Utilities	Construction	Wood products	Nonmetallic mineral products	Primary metals	Fabricated metal products	Machinery	Computer and electronic products	Electrical equipment. and appliances	Motor vehicles. bodies and trailers	Other transportation equipment	Furniture and related products	Miscellaneous manufacturing	Food and beverage and tobacco products	Textile mills and textile product mills	Apparel and leather and allied products	Paper products	Printing and related support activities	Petroleum and coal products	Chemical products	Plastics and rubber products	Wholesale trade	Retail	Transportation and warehousing	Information	FIRE	PROF	EHS	AERAF	Other services. except government	Government
Agriculture & Forestry		07.27	01.03		07.05				01.24		03.19	02.44		06.12				30.44					02.79	07.02	01.49	01.80		07.36		09.19	05.80				
Oil and gas extraction				01.38							01.30			01.46									82.69							04.47	02.66				
Mining, except oil and gas	01.67	13.91		01.75	14.55				07.79	01.18	09.38	03.82		03.53									01.71	02.57	02.57	01.16		09.55		07.96	11.53				
Support activities for mining		68.87							01.16		11.39	01.42		02.94																02.29	05.83				
Utilities	01.47	67.90	02.20									01.81		02.58				01.26										04.23		06.43	05.10				
Construction	04.27	05.39	02.36		01.74		04.48	02.25	02.90	03.50	08.74	05.60	03.48	13.30									02.34	01.21	03.81	01.05	01.60	02.32		19.74	05.95				
Wood products	89.49																													01.06	01.38				
Nonmetallic mineral products	05.54	04.52	25.26		07.08	02.51			02.09	01.92	02.67	05.83		02.79				01.47			01.04			03.31	01.45	01.69	01.04	06.39		07.47	10.92				
Primary metals	01.17	03.44	60.43		06.72					01.28		03.45														01.30		06.45		02.98	05.25				
Fabricated metal products	02.98	02.17	02.26		02.97				55.80		01.20	03.63		01.15				01.28						01.91		01.53		02.04		06.51	08.20				
Machinery		01.80	01.30		02.10				35.29	04.14		11.15	03.84	16.14										01.51	04.04	01.03		01.94		03.61	06.76				
Computer and electronic products	03.96	03.23	01.02		04.83	03.52			10.22	03.47	05.27		02.86	08.54				01.61						02.94	03.13	03.07		03.53	03.96	08.59	20.98				
Electrical equipment, and appliances	01.62	02.77	02.18		02.50				49.05	03.47	02.38	11.04		02.57										01.88	02.18	01.25		02.33		03.71	06.00				
Motor vehicles, bodies and trailers	01.13	01.18	01.25		01.77	01.29			36.77	03.72	10.38	16.11												01.40	09.98	01.36		01.87		02.83	04.39				
Other transportation equipment	02.58	01.91			02.14	01.05			11.95	03.59	04.89	30.09	01.04	11.22				01.50						01.55	02.47	01.25		01.93		05.76	09.43				01.29
Furniture and related products	10.52	01.94			02.76		19.73		10.35	02.16	02.32	05.58		04.98				01.08	01.52					02.97	13.28	01.39		02.75		04.61	06.03				
Miscellaneous manufacturing	08.22	03.15			03.42	01.28			10.27	02.17	02.82	09.70		05.58				03.19	01.17		01.08			05.61	05.60	01.93	01.60	03.22		10.49	11.33	01.11			01.12
Food and beverage and tobacco products	96.06																																		
Textile mills and textile product mills	32.95	02.64			03.20				01.20		01.17	04.48		01.59				01.63						25.12		01.65		02.40		06.31	07.60				
Apparel and leather and allied products	06.21	01.11			02.44							01.80		01.05				02.76	61.48					02.49		01.14		01.90		04.17	08.67				
Paper products	37.48	03.71	01.55		06.43		02.83		01.52	01.33	01.54	05.39		03.08				01.09						05.43	01.11	01.96		03.98		06.65	09.21				
Printing and related support activities	07.17	04.07			02.66	01.37			01.40	01.50	02.92	06.20		04.98				03.10		01.17	19.84		01.14	04.80		02.24	02.36	02.59		12.08	11.31	01.11			01.31
Petroleum and coal products		98.36																																	
Chemical products	05.66	13.47	02.58		07.82				02.45	01.78	02.74	05.39		03.70				03.65					01.58			02.73	01.81	04.85		12.30	19.41				01.35
Plastics and rubber products	08.87	04.88			06.51				03.86	01.99	02.39	05.45		01.27							01.55		01.25	37.40		01.23		03.45		05.05	08.77				
Wholesale trade	08.09	04.27			03.61	01.63			01.69	01.21	02.11	04.36		06.75				03.93						02.01			02.97	04.39	01.65	20.04	20.19	01.47			03.16
Retail	09.92	02.91			03.61	01.60			01.36	01.03	02.32	04.25		11.02				06.73		01.42				01.86		02.15		03.29	01.59	19.59	14.50	01.62	01.09		03.69
Transportation and warehousing	01.73	36.24			02.28						01.48	02.60		12.10				01.03					12.45							09.69	10.16				01.04
Information	08.12	03.78			03.76	01.82			01.74	01.34	02.31	10.07		08.91				04.63						02.02		01.53	01.79	03.05		15.46	18.87	01.41	01.64		01.48
FIRE	07.94	06.59			11.04	03.65			01.99	01.15	02.40	05.10		12.40				06.96		01.30				02.36	01.02	01.61	01.87	02.90	01.65		18.91	01.02	01.19		02.37
PROF	10.10	06.02			05.10	01.99			02.06	01.26	02.39	06.71		09.11				04.76					01.09	02.32		01.74	02.12	04.06	02.75	25.15		01.37	01.97	01.03	02.20
EHS	09.10	02.76			04.19	01.37					01.51	03.33		05.85				07.90						04.94		01.77	02.02	02.43	01.47	22.95	15.55		01.22		04.49
AERAF	26.95	02.01			03.24						01.09	02.06		03.85				29.45						01.06		01.18	01.17	01.63		09.82	07.29				01.69
Other serivces (except Govt.)	06.88	03.30			03.68	01.25			01.55		02.50	04.17		19.11				04.46		01.06				01.84	01.23	01.50	01.91	03.05	01.37	22.42	10.72	01.57			01.57
Government	06.68	03.48			02.14	04.89			01.56	01.41	03.45	05.36		08.69				04.35						02.16		03.25	03.95	02.17	02.06	20.07	14.81	02.80	01.32		

This table documents $\frac{\sigma^2[\gamma_t(\pi_j^{ppi};j')_{h=1}]}{\sigma^2[\gamma_t(\pi_j^{ppi})_{h=1}]}$, where this value is approximated by $\frac{\sigma^2[\gamma_t(\pi_j^{ppi};j')_{h=1}]}{\sum_{j'=1}^{J}\sigma^2[\gamma_t(\pi_j^{ppi};j')_{h=1}]}$. Values smaller than 1 are suppressed. Row sums do not add to 100.

Table 17a: Consumer prices: Pipeline pressure decomposition (infinite quarter horizon)

	Agriculture & Forestry	Oil and gas extraction	Mining. except oil and gas	Support activities for mining	Utilities	Construction	Wood products	Nonmetallic mineral products	Primary metals	Fabricated metal products	Machinery	Computer and electronic products	Electrical equipment. and appliances	Motor vehicles. bodies and trailers	Other transportation equipment	Furniture and related products	Miscellaneous manufacturing	Food and beverage and tobacco products	Textile mills and textile product mills	Apparel and leather and allied products	Paper products	Printing and related support activities	Petroleum and coal products	Chemical products	Plastics and rubber products	Wholesale trade	Retail	Transportation and warehousing	Information	FIRE	PROF	EHS	AERAF	Other services. except government	Government
Motor vehicles and parts														94.76																					
Furnishings and durable hh equipment	03.56	01.22			01.11	02.82			02.19	01.50	03.91	03.36	06.53	04.15		17.30		01.91						01.54	02.18	02.61	14.18	02.91		11.63	06.62	01.07			02.43
Recreational goods and vehicles	02.84	01.03				02.80			01.26	01.01	03.15	33.25		06.94	01.63		01.26	01.88						01.08		02.76	08.41	01.74	04.46	10.55	06.82	01.06			02.10
Other durable goods	03.49	01.11			01.06	03.26			01.12		03.26	06.72		04.74			16.84	02.25		03.20				01.30		03.05	15.50	01.57	01.66	12.20	07.50	02.74			03.39
Food and beverages PFOPC	45.66																	48.54												01.02					
Clothing and footwear																			01.55	91.60							01.40			01.05					
Gasoline and other energy goods		51.35																					40.93							01.37					
Other nondurable goods	19.30	01.43			01.03	02.49					02.65	02.68		03.71				10.64						16.13		02.76	08.29	01.62	01.71	09.66	06.42				02.06
Housing and utilities	01.13	01.32			23.45	01.16								01.65																59.77	02.73				01.83
Health care	02.54					04.99			01.09		04.77	04.35		06.08				01.67						01.19		02.68	02.44		01.09	14.03	07.65	27.44			11.39
Transportation services	01.94	01.78				01.83					01.69	01.77		03.55				01.38								01.34	01.89	32.99		17.48	04.76			19.27	02.46
Recreation services	06.32	01.09			01.04	04.15			01.01		03.84	03.85		05.47				03.46						01.11		02.42	02.60		04.18	15.17	10.16	02.16	15.93		11.06
Food services and accommodations	05.92					01.91					01.78	01.70		02.61				05.82								01.21	01.38			06.87	03.97		57.04		03.43
Financial services and insurance	02.74				01.03	04.79					03.36	03.21		05.41				01.89								02.06	02.20			53.78	06.91	01.21			02.97
Other services	03.47	01.28			01.09	03.64					03.47	03.76		05.37				02.37						01.22		02.34	02.75	03.00	06.78	14.06	13.95	14.46		04.53	07.43
NPISHs	02.97					02.57					02.43	02.47		04.12				02.20								01.85	02.58		01.03	10.74	06.64	27.99	01.41	18.49	05.83
Public sector goods																														01.33					93.85

This table documents $\frac{\sigma^2[\gamma_t(\pi_z^{pce};j')_{h=\infty}]}{\sigma^2[\gamma_t(\pi_z^{pce})_{h=\infty}]}$, where this value is approximated by $\frac{\sigma^2[\gamma_t(\pi_z^{pce};j')_{h=\infty}]}{\sum_{j=1}^{J}\sigma^2[\gamma_t(\pi_z^{pce};j)_{h=\infty}]}$. Values smaller than 1 are suppressed. Row sums do not add to 100.

Table 17b: Consumer prices: Pipeline pressure decomposition (one quarter horizon)

	Agriculture & Forestry	Oil and gas extraction	Mining. except oil and gas	Support activities for mining	Utilities	Construction	Wood products	Nonmetallic mineral products	Primary metals	Fabricated metal products	Machinery	Computer and electronic products	Electrical equipment. and appliances	Motor vehicles. bodies and trailers	Other transportation equipment	Furniture and related products	Miscellaneous manufacturing	Food and beverage and tobacco products	Textile mills and textile product mills	Apparel and leather and allied products	Paper products	Printing and related support activities	Petroleum and coal products	Chemical products	Plastics and rubber products	Wholesale trade	Retail	Transportation and warehousing	Information	FIRE	PROF	EHS	AERAF	Other services. except government	Government
Motor vehicles and parts														96.51																					
Furnishings and durable hh equipment	02.93	01.25			01.11				02.92	01.49	03.61	02.67	11.59	02.17		28.25		01.09	01.09					01.42	03.92	01.52	13.97	04.51		05.38	03.93				
Recreational goods and vehicles	01.69								01.18		01.58	52.96		08.56	02.14		01.67	01.00								01.54	06.94	02.12	04.76	03.55	03.93				
Other durable goods	02.90	01.05			01.04							10.49		02.45			28.09	01.69		07.04				01.09		02.14	17.53	02.12	01.67	05.49	05.03	03.13			01.46
Food and beverages PFOPC	47.92																	49.32																	
Clothing and footwear																			01.27	95.76															
Gasoline and other energy goods		53.99																					42.29												
Other nondurable goods	31.55	01.57										01.28		01.51			01.14	16.07			01.06			19.71		01.71	07.08	01.92	01.56	03.60	03.72				
Housing and utilities		01.57			28.24																									62.87	01.63				
Health care	02.50					01.35					01.11	01.70		02.77				01.74						01.11		01.15	01.42			08.16	05.24	54.56			11.12
Transportation services	01.01	02.16												02.55														46.69		15.45	02.81			21.26	
Recreation services	10.25	01.12			01.20							01.91		03.04				04.35								01.07	01.53		06.38	11.22	10.74	02.33	27.60	01.09	09.46
Food services and accommodations	07.11													01.12				06.93												03.06	02.21		71.32		01.81
Financial services and insurance	02.27				01.22	01.42						01.30		02.92				01.68									01.05			73.85	04.87				01.48
Other services	03.05	01.51			01.18							02.05		03.47				02.07						01.02		01.06	01.67	05.83	10.42	08.54	17.24	22.76		07.41	05.54
NPISHs	02.38											01.03		02.57				01.79									01.71			05.79	05.05	39.53	01.64	27.30	03.69
Public sector goods																																			98.59

This table documents $\frac{\sigma^2[\gamma_t(\pi_z^{pce};j')_{h=1}]}{\sigma^2[\gamma_t(\pi_z^{pce})_{h=1}]}$, where this value is approximated by $\frac{\sigma^2[\gamma_t(\pi_z^{pce};j')_{h=1}]}{\sum_{j=1}^{J}\sigma^2[\gamma_t(\pi_z^{pce};j)_{h=1}]}$. Values smaller than 1 are suppressed. Row sums do not add to 100.

9 Figures

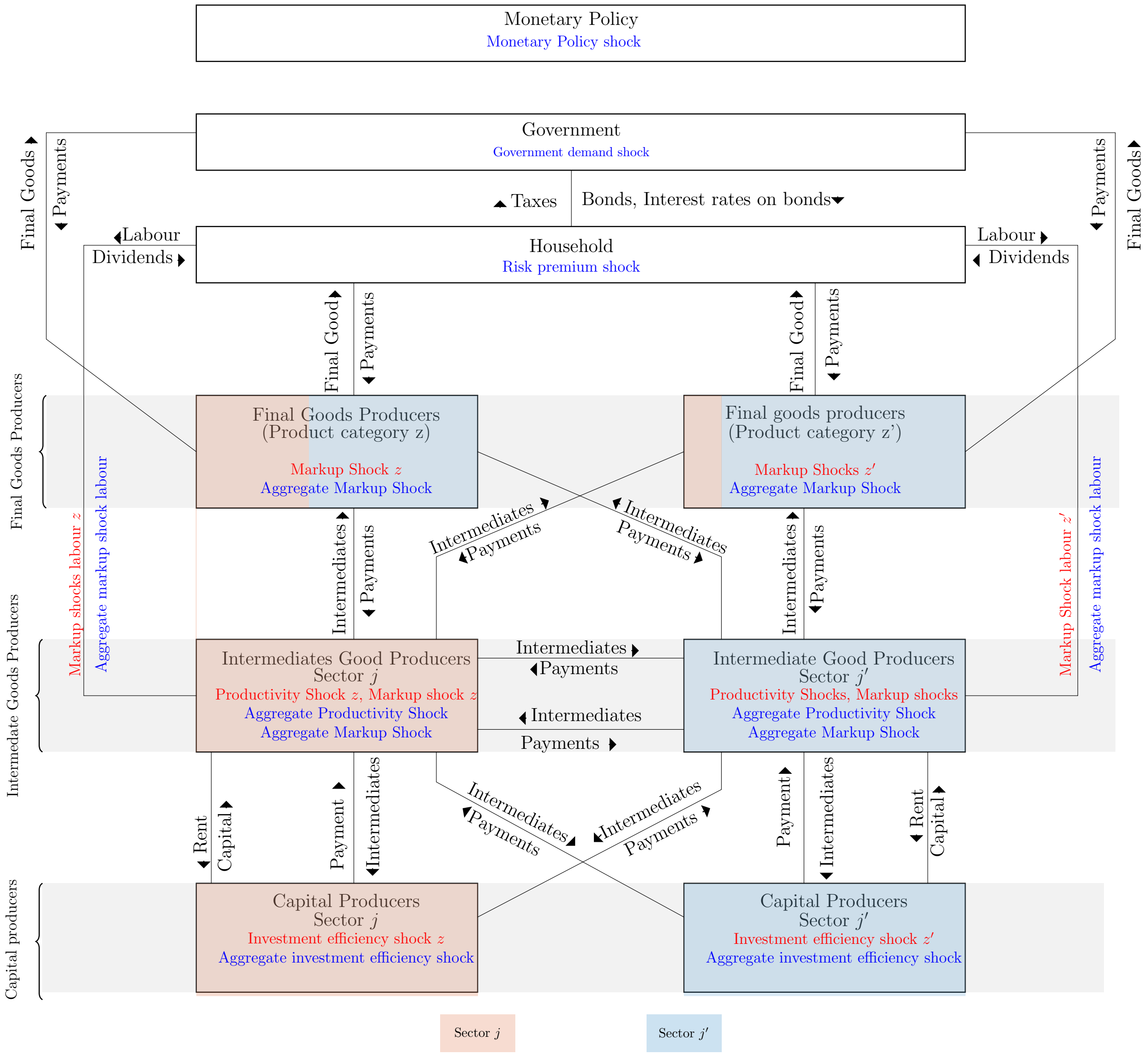


Figure 2: A schematic overview of the model with two sectors j, j' and two product categories z, z'. The aggregate, economywide shocks are depicted in blue. The micro–level shocks are depicted in red.

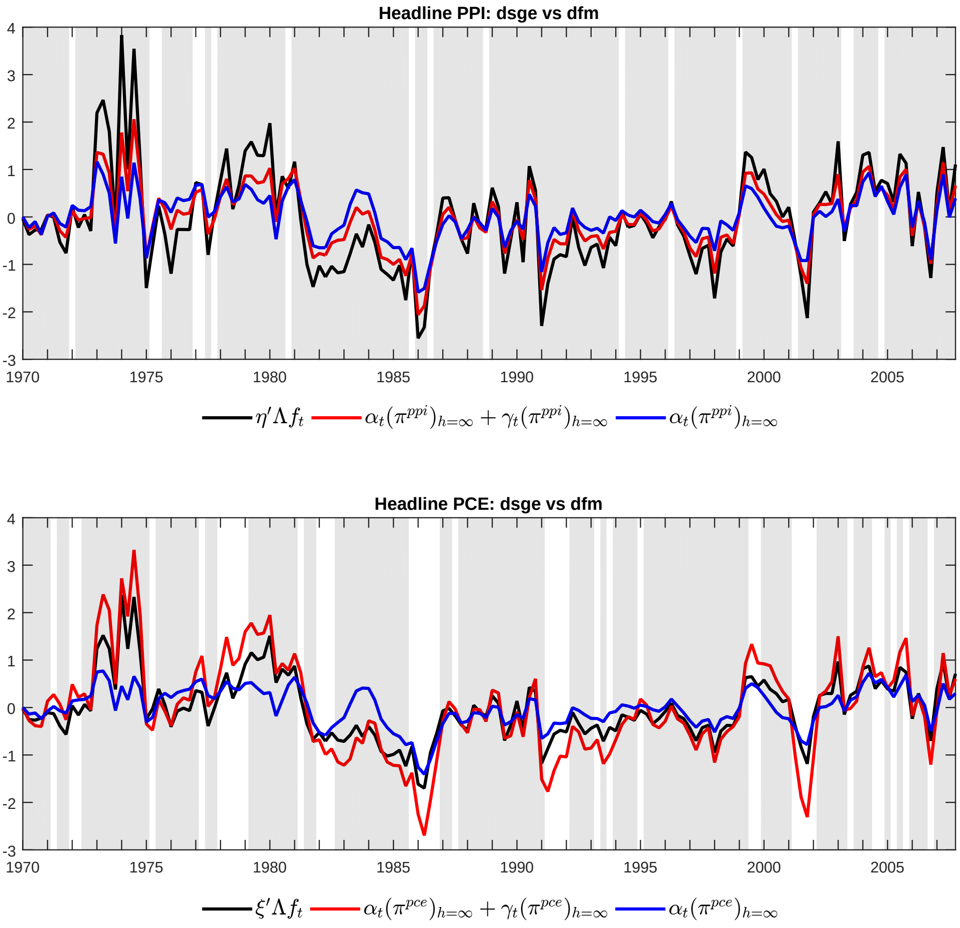


Figure 3: The figure compares the model decomposition with a dynamic factor model decomposition. The shaded areas indicate when pipeline pressures increase comovement with the factors obtained from the dfm.

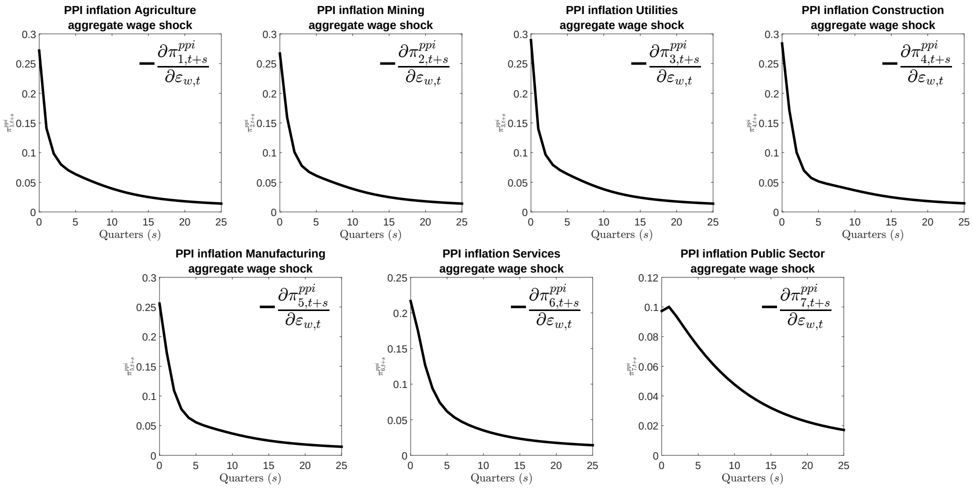


Figure 4: Impulse response functions w.r.t. an aggregate shock.

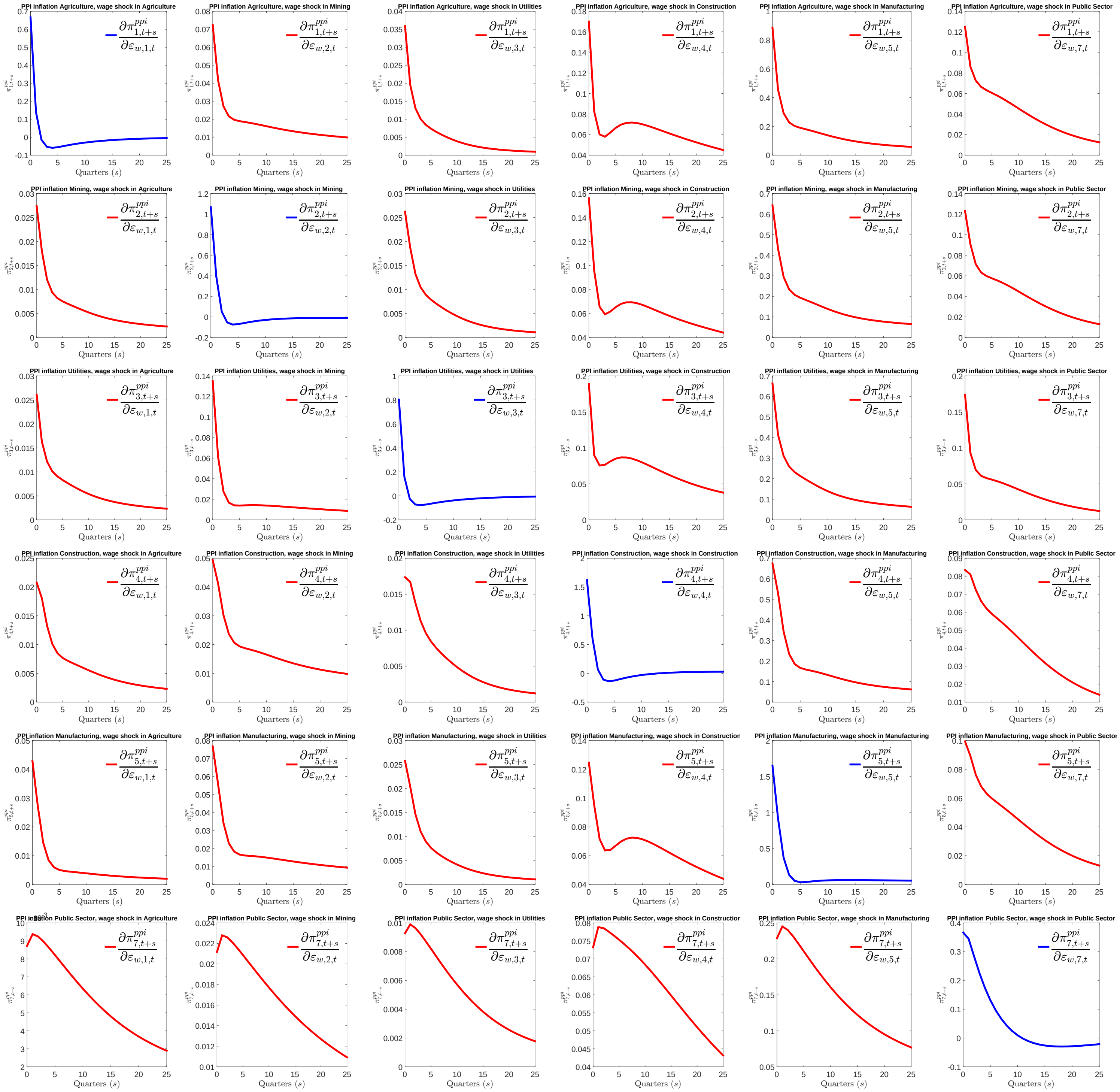


Figure 5: Impulse response functions w.r.t. a sectoral shock.

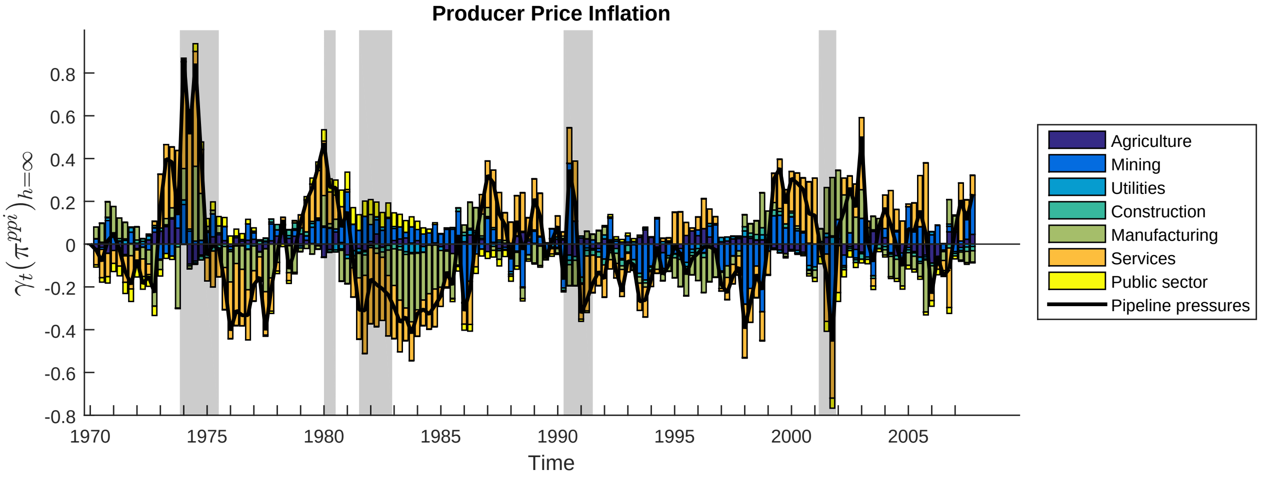
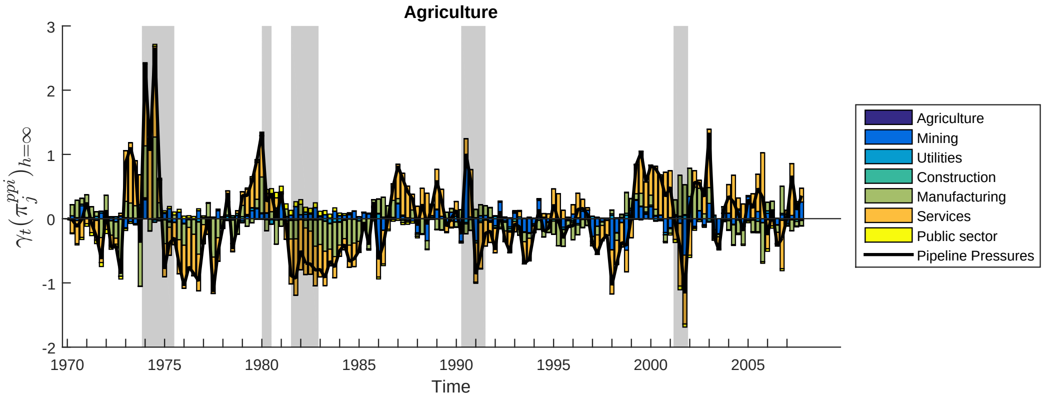
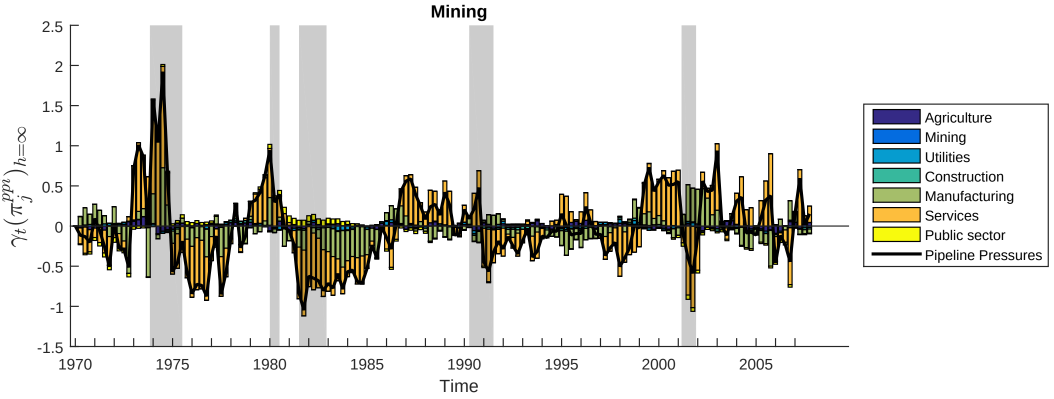
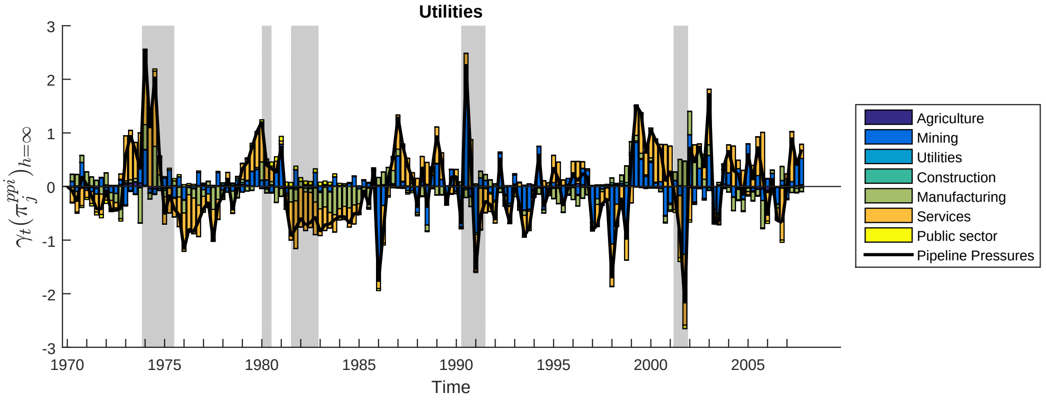
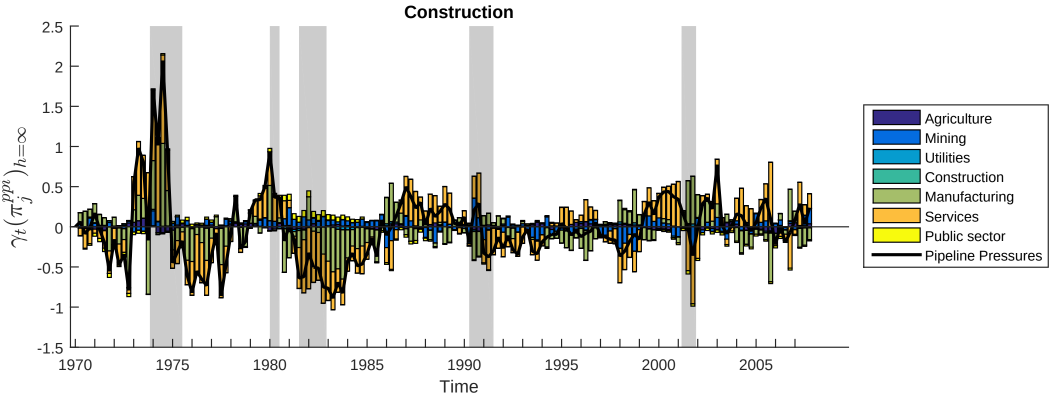


Figure 6: Historical decomposition of pipeline pressures to headline inflation.


Agriculture


Mining


Utilities


Construction

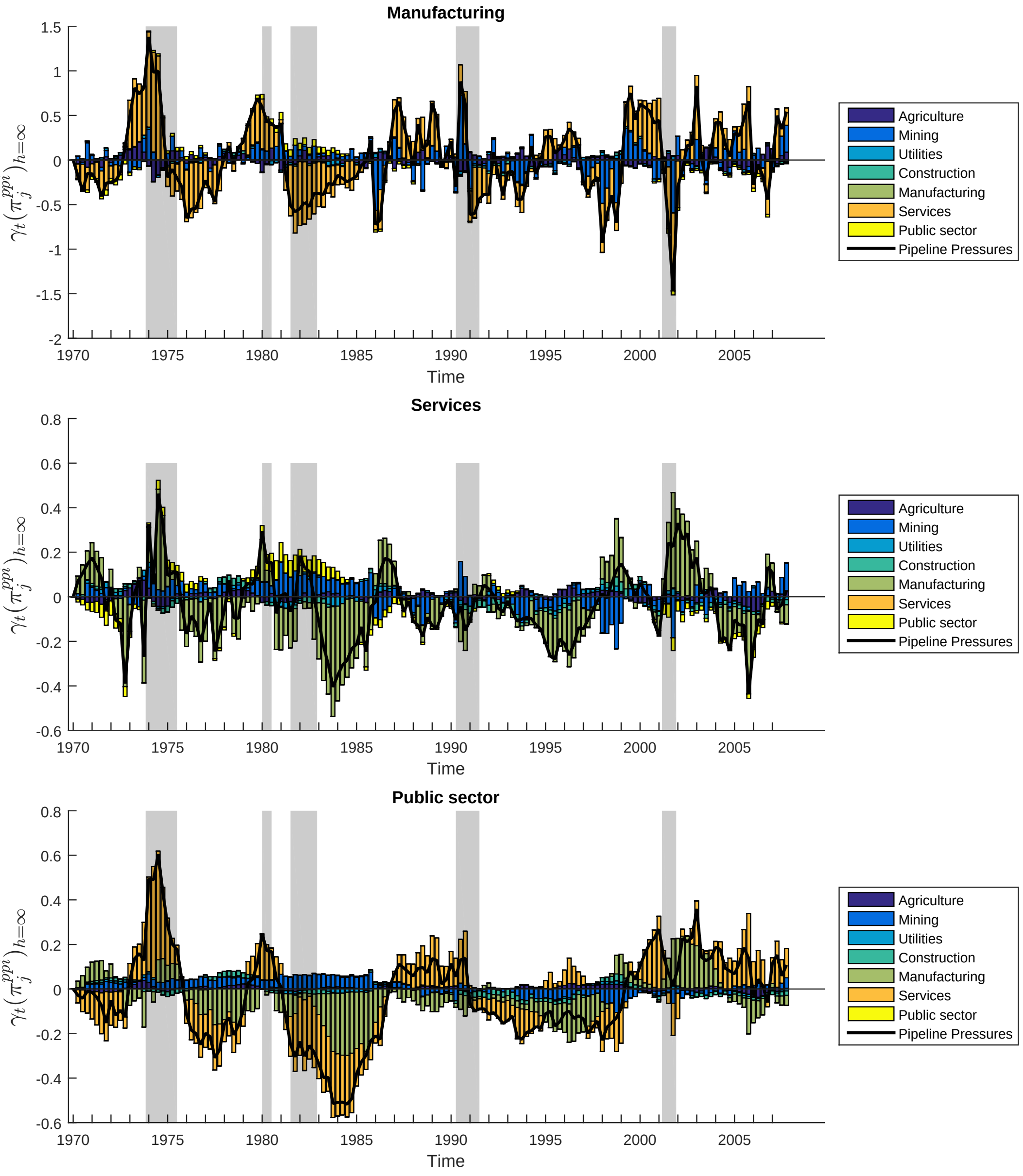


Figure 7: Historical decomposition of pipeline pressures to disaggregate inflation.

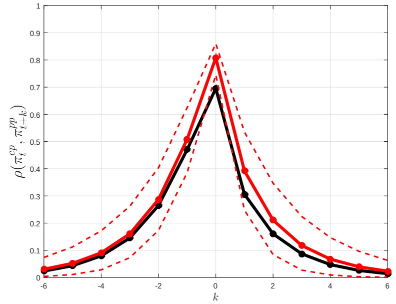


Figure 8: This figure plots the autocorrelation coefficients of headline consumer prices and headline producer prices. The dashed lines represent the 5% and 95% percentiles. Percentiles are based on 100,000 random samples of length 152.

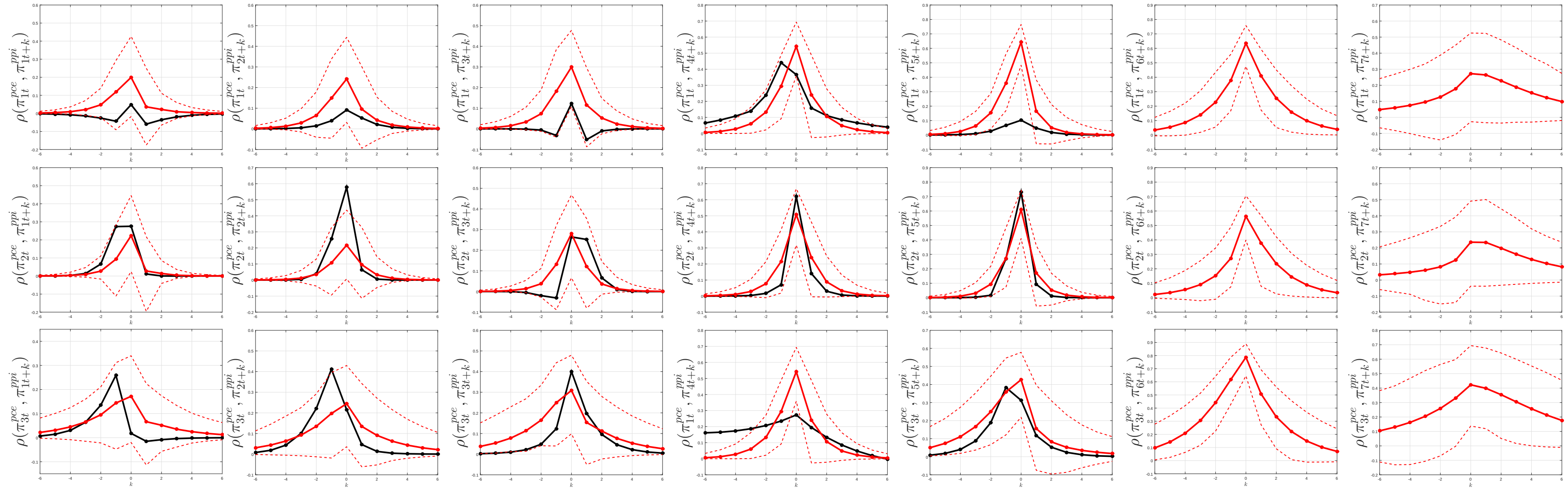


Figure 9: This figure plots the autocorrelation coefficients of disaggregated consumer prices and disaggregated producer prices. The dashed lines represent the 5% and 95% percentiles. Percentiles are based on 100,000 random samples of length 152.

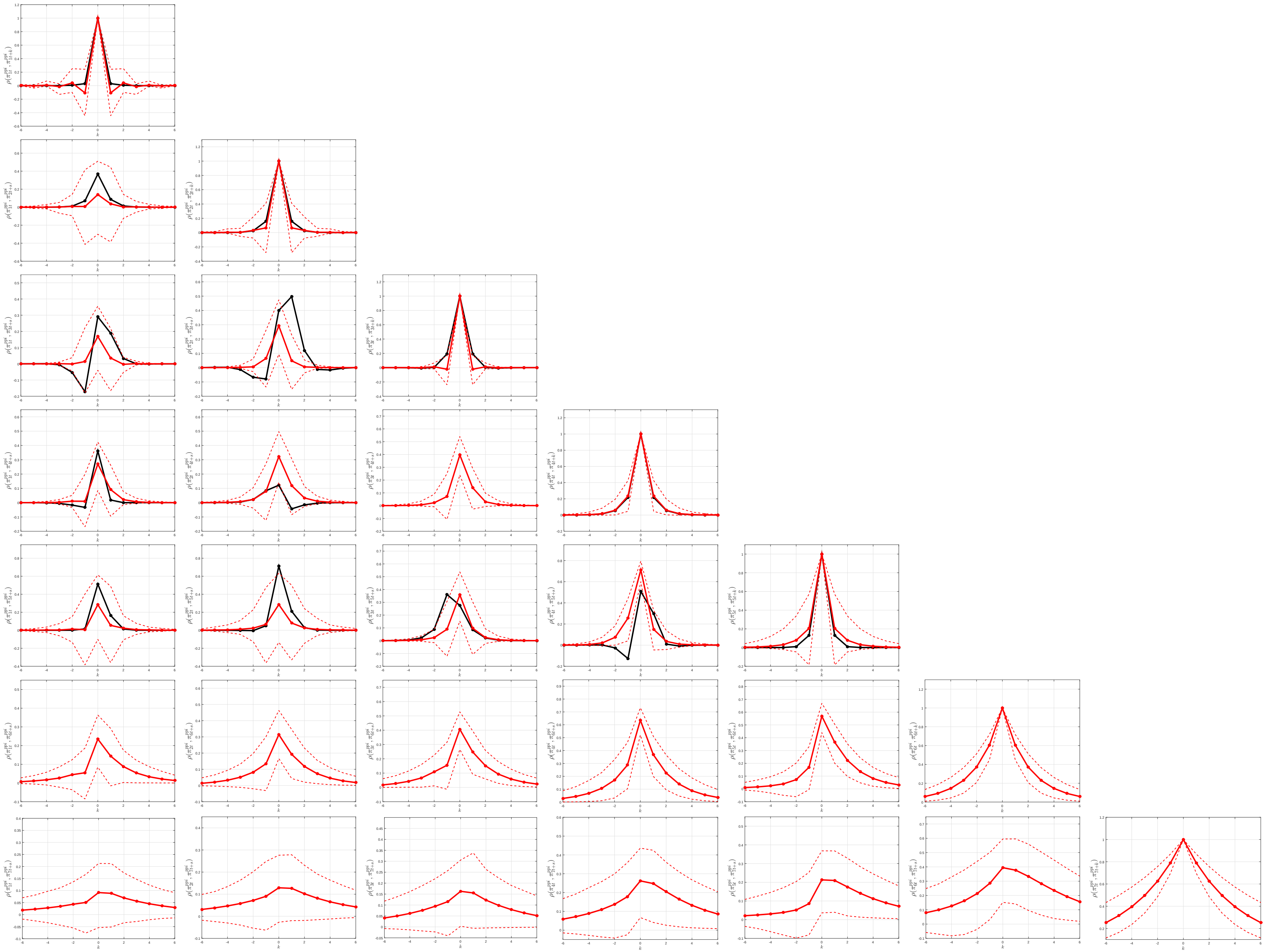


Figure 10: This figure plots the autocorrelation coefficients of headline consumer prices and headline producer prices. The dashed lines represent the 5% and 95% percentiles. Percentiles are based on 100,000 random samples of length 152.

References

D. Acemoglu, V. M. Carvalho, A. Ozdaglar, and A. Tahbaz-Salehi. The Network Origins of Aggregate Fluctuations. *Econometrica*, 80(5):1977–2016, 2012.

D. Acemoglu, U. Akcigit, and W. Kerr. Networks and the macroeconomy: An empirical exploration. Technical report, National Bureau of Economic Research, 2015.

D. Acemoglu, , A. Ozdaglar, and A. Tahbaz-Salehi. Microeconomic Origins of Macroeconomic Tail Risk. *American Economic Review, forthcomming*, 2016.

M. Adolfson, S. Laséen, J. Lindé, and M. Villani. Bayesian Estimation of an Open Economy DSGE Model With Incomplete Pass-Through. *Journal of International Economics*, 72(2):481–511, 2007.

F. Altissimo, L. Bilke, A. Levin, T. Mathä, and B. Mojon. Sectoral and aggregate inflation dynamics in the euro area. *Journal of the European Economic Association*, 4 (2-3):585–593, 2006.

P. Andrade and M. Zachariadis. Global versus local shocks in micro price dynamics. *Journal of International Economics*, 98:78–92, 2016.

E. Atalay. How important are sectoral shocks? *American Economic Journal: Macroeconomics*, 9(4):254–80, 2017.

E. Atalay, T. Drautzburg, and Z. Wang. Accounting for the sources of macroeconomic tail risks. *Economics Letters*, 165:65–69, 2018.

R. A. Auer, A. A. Levchenko, and P. Sauré. International inflation spillovers through input linkages. Technical report, Forthcoming, Review of Economics and Statistics, 2017.

J. Bai and S. Ng. Determining the number of factors in approximate factor models. *Econometrica*, 70(1):191–221, 2002.

D. R. Baqaee and E. Farhi. The macroeconomic impact of microeconomic shocks: beyond hulten's theorem. Technical report, National Bureau of Economic Research, 2017.

J.-N. Barrot and J. Sauvagnat. Input specificity and the propagation of idiosyncratic shocks in production networks. *Quarterly Journal of Economics*, 131:1543–1592, 2016.

S. Basu. Intermediate goods and business cycles: Implications for productivity and welfare. *The American Economic Review*, pages 512–531, 1995.

D. Bergholt. Foreign shocks. *Working paper series*, 15:1–58, 2015.

S. Bigio. Endogenous liquidity and the business cycle. *American Economic Review*, 105 (6):1883–1927, 2015.

M. Bils, Y. Chang, and S.-B. Kim. How sticky wages in existing jobs can affect hiring. Technical report, National Bureau of Economic Research, 2014.

O. J. Blanchard. Price asynchronization and price level inertia, 1982.

C. Boehm, A. Flaaen, and N. Pandalai-Nayar. Input linkages and the transmission of shocks: Firm-level evidence from the 2011 tōhoku earthquake. *US Census Bureau Center for Economic Studies Paper No. CES-WP-15-28*, 2015.

J. Boivin, M. P. Giannoni, and I. Mihov. Sticky prices and monetary policy: Evidence from disaggregated us data. *American economic review*, 99(1):350–84, 2009.

H. Bouakez, E. Cardia, and F. J. Ruge-Murcia. The transmission of monetary policy in a multisector economy. *International Economic Review*, 50(4):1243–1266, 2009.

H. Bouakez, E. Cardia, and F. Ruge-Murcia. Sectoral price rigidity and aggregate dynamics. *European Economic Review*, 65:1–22, 2014.

L. Caliendo, F. Parro, E. Rossi-Hansberg, and P.-D. Sarte. The impact of regional and sectoral productivity changes on the us economy, 2017.

G. A. Calvo. Staggered prices in a utility-maximizing framework. *Journal of monetary Economics*, 12(3):383–398, 1983.

C. Carvalho and J. W. Lee. Sectoral price facts in a sticky-price model. *American Economic Review, R&R*, 2011.

C. Carvalho and F. Nechio. Factor specificity and real rigidities. *Review of Economic Dynamics*, 22:208–222, 2016.

V. M. Carvalho and X. Gabaix. The Great Diversification and its Undoing. *American Economic Review*, 103(5):1697–1727, 2013.

V. M. Carvalho and B. Grassi. Large firm dynamics and the business cycle. *American Economic Review, R&R*, 2016.

V. M. Carvalho, M. Nirei, Y. U. Saito, and A. Tahbaz-Salehi. Supply Chain Disruptions: Evidence from the Great East Japan Earthquake. *Unpublished manuscript*, 2016.

L. J. Christiano, M. Eichenbaum, and C. L. Evans. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of political Economy*, 113(1):1–45, 2005.

L. J. Christiano, M. Trabandt, and K. Walentin. Introducing financial frictions and unemployment into a small open economy model. *Journal of Economic Dynamics and Control*, 35(12):1999–2041, 2011.

T. E. Clark et al. Do producer prices lead consumer prices? *Economic Review-Federal Reserve Bank of Kansas City*, 80:25–25, 1995.

F. De Graeve and K. Walentin. Refining stylized facts from factor models of inflation. *Journal of Applied Econometrics*, 30(7):1192–1209, 2015.

H. Dewachter, J. Tielens, and J. Van Hove. Idiosyncratic Bank Shocks and Aggregate Fluctuations in the Real Economy, 2016.

J. Di Giovanni, A. A. Levchenko, and I. Méjean. Firms, Destinations, and Aggregate Fluctuations. *Econometrica*, 82(4):1303–1340, 2014.

H. D. Dixon, J. Franklin, and S. Millard. Sectoral shocks and monetary policy in the united kingdom. *Bank of England, Working Paper N. 499*, 2014.

C. J. Erceg, D. W. Henderson, and A. T. Levin. Optimal monetary policy with staggered wage and price contracts. *Journal of monetary Economics*, 46(2):281–313, 2000.

European Central Bank. What can recent developments in producer prices tell us about pipeline pressures? *ECB Economic Bulletin, Issue 3*, 2017.

Federal Reserve System. Sustaining full employment and inflation around target. *Speech Governor Lael Brainard*, 2018.

Financial Times. Economists see signs of eurozone price pressure despite soft december inflation, 2018.

A. Foerster and J. Choi. The changing input-output network structure of the us economy. *Economic Review-Federal Reserve Bank of Kansas City*, 102(2):23–49, 2017.

A. T. Foerster, P.-D. G. Sarte, and M. Watson. Sectoral vs. Aggregate Shocks: A Structural Factor Analysis of Industrial Production. *Journal of Political Economy*, 119(1): 1–38, 2011.

M. Forni and L. Gambetti. The dynamic effects of monetary policy: A structural factor model approach. *Journal of Monetary Economics*, 57(2):203–216, 2010.

M. Forni and L. Reichlin. Let's get real: a factor analytical approach to disaggregated business cycle dynamics. *The Review of Economic Studies*, 65(3):453–473, 1998.

J. C. Fuhrer and G. R. Moore. Monetary policy trade-offs and the correlation between nominal interest rates and real output. *The American Economic Review*, pages 219–239, 1995.

X. Gabaix. The Granular Origins of Aggregate Fluctuations. *Econometrica*, 79(3):733–772, 2011.

M. Gertler, L. Sala, and A. Trigari. An estimated monetary dsge model with unemployment and staggered nominal wage bargaining. *Journal of Money, Credit and Banking*, 40(8):1713–1764, 2008.

M. Ghassibe. Monetary policy and production networks: An empirical investigation. *Unpublished working paper*, 2018.

B. Grassi. Io in io: Size, industrial organization, and the input-output network make a firm structurally important, 2017.

J. Greenwood, Z. Hercowitz, and G. W. Huffman. Investment, capacity utilization, and the real business cycle. *The American Economic Review*, pages 402–417, 1988.

M. Horvath. Cyclicality and sectoral linkages: Aggregate fluctuations from independent sectoral shocks. *Review of Economic Dynamics*, 1(4):781–808, 1998.

K. X. Huang. Specific factors meet intermediate inputs: Implications for the persistence problem. *Review of Economic Dynamics*, 9(3):483–507, 2006.

K. X. Huang and Z. Liu. Input–output structure and nominal rigidity: the persistence problem revisited. *Macroeconomic Dynamics*, 8(2):188–206, 2004.

K. X. Huang, Z. Liu, and L. Phaneuf. Why does the cyclical behavior of real wages change over time? *American Economic Review*, 94(4):836–856, 2004.

H. Jensen. Complete financial markets and consumption risk sharing. *Working Paper*, 2011.

R. E. Kass and A. E. Raftery. Bayes factors. *Journal of the american statistical association*, 90(430):773–795, 1995.

D. Kaufmann and S. M. Lein. Sticky prices or rational inattention–what can we learn from sectoral price data? *European Economic Review*, 64:384–394, 2013.

H. Khan and J. Tsoukalas. Investment shocks and the comovement problem. *Journal of Economic Dynamics and Control*, 35(1):115–130, 2011.

J. B. Long and C. I. Plosser. Real Business Cycles. *The Journal of Political Economy*, 91(1):39–69, 1983.

J. B. Long and C. I. Plosser. Sectoral vs. aggregate shocks in the business cycle. *The American Economic Review*, 77(2):333–336, 1987.

B. Maćkowiak, E. Moench, and M. Wiederholt. Sectoral price data and models of price setting. *Journal of Monetary Economics*, 56:S78–S99, 2009.

H. Mumtaz, S. Simonelli, and P. Surico. International comovements, business cycle and inflation: A historical perspective. *Review of Economic Dynamics*, 14(1):176–198, 2011.

E. Nakamura and J. Steinsson. Five facts about prices: A reevaluation of menu cost models. *The Quarterly Journal of Economics*, 123(4):1415–1464, 2008.

E. Nakamura and J. Steinsson. Monetary non-neutrality in a multisector menu cost model. *The Quarterly journal of economics*, 125(3):961–1013, 2010.

A. K. Ozdagli and M. Weber. Monetary policy through production networks: Evidence from the stock market. *Mimeo*, 2016.

E. Pasten, R. Schoenle, and M. Weber. The propagation of monetary policy shocks in a heterogeneous production economy, 2016.

E. Pasten, R. Schoenle, and M. Weber. Price rigidities and the granular origins of aggregate fluctuations. Technical report, National Bureau of Economic Research, 2017.

E. Peneva. Some evidence on factor intensity and price rigidity. *Journal of Economic Dynamics and Control*, 35(10):1652–1658, 2011.

J. Shea. Complementarities and Comovements. *Journal of Money, Credit, and Banking*, 34(2):412–433, 2002.

O. J. Shoemaker. Variance estimates for price changes in the consumer price index: January-december 2006. *Bureau of Labor Statistics, mimeo*, 2007.

F. Smets and R. Wouters. An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European economic association*, 1(5):1123–1175, 2003.

F. Smets and R. Wouters. Shocks and frictions in us business cycles: A bayesian dsge approach. *American Economic Review*, 97(3):586–606, 2007.

A. Stella. Firm dynamics and the origins of aggregate fluctuations. *Journal of Economic Dynamics and Control*, 55:71–88, 2015.

U.S. Department of Labor. Chapter 14: Producer prices, 2011.

Wall Street Journal. Real time economics: Inflation is perking up. will tariffs push consumer prices even higher?, 2018.

M. Woodford. *Interest and prices: Foundations of a theory of monetary policy.* princeton university press, 2011.

T. Yun. Nominal price rigidity, money supply endogeneity, and business cycles. *Journal of monetary Economics*, 37(2):345–370, 1996.

NATIONAL BANK OF BELGIUM - WORKING PAPERS SERIES

The Working Papers are available on the website of the Bank: http://www.nbb.be.

302. “The transmission mechanism of credit support policies in the Euro Area”, by J. Boeckx, M. de Sola Perea and G. Peersman, *Research series*, October 2016.
303. “Bank capital (requirements) and credit supply: Evidence from pillar 2 decisions”, by O. De Jonghe, H. Dewachter and S. Ongena, *Research series*, October 2016.
304. “Monetary and macroprudential policy games in a monetary union”, by R. Dennis and P. Ilbas, *Research series*, October 2016.
305. “Forward guidance, quantitative easing, or both?, by F. De Graeve and K. Theodoridis, *Research series*, October 2016.
306. “The impact of sectoral macroprudential capital requirements on mortgage loan pricing: Evidence from the Belgian risk weight add-on”, by S. Ferrari, M. Pirovano and P. Rovira Kaltwasser, *Research series*, October 2016.
307. “Assessing the role of interbank network structure in business and financial cycle analysis”, by J-Y Gnabo and N.K. Scholtes, *Research series*, October 2016.
308. “The trade-off between monetary policy and bank stability”, by M. Lamers, F. Mergaerts, E. Meuleman and R. Vander Vennet, *Research series,* October 2016.
309. “The response of euro area sovereign spreads to the ECB unconventional monetary policies”, by H. Dewachter, L. Iania and J-C. Wijnandts, *Research series*, October 2016.
310. “The interdependence of monetary and macroprudential policy under the zero lower bound”, by V. Lewis and S. Villa, *Research series*, October 2016.
311. “The impact of exporting on SME capital structure and debt maturity choices”, by E. Maes, N. Dewaelheynes, C. Fuss and C. Van Hulle, *Research series*, October 2016.
312. “Heterogeneous firms and the micro origins of aggregate fluctuations”, by G. Magerman, K. De Bruyne, E. Dhyne and J. Van Hove, *Research series*, October 2016.
313. “A dynamic factor model for forecasting house prices in Belgium”, by M. Emiris, *Research series*, November 2016.
314. “La Belgique et l’Europe dans la tourmente monétaire des années 1970 – Entretiens avec Jacques van Ypersele”, by I. Maes and S. Péters, *Research series*, December 2016.
315. “Creating associations to substitute banks’ direct credit. Evidence from Belgium”, by M. Bedayo, *Research series*, December 2016.
316. “The impact of export promotion on export market entry”, by A. Schminke and J. Van Biesebroeck, *Research series*, December 2016.
317. “An estimated two-country EA-US model with limited exchange rate pass-through”, by G. de Walque, Ph. Jeanfils, T. Lejeune, Y. Rychalovska and R. Wouters, *Research series,* March 2017.
318. Using bank loans as collateral in Europe: The role of liquidity and funding purposes”, by F. Koulischer and P. Van Roy, *Research series*, April 2017.
319. “The impact of service and goods offshoring on employment: Firm-level evidence”, by C. Ornaghi, I. Van Beveren and S. Vanormelingen, *Research series*, May 2017.
320. “On the estimation of panel fiscal reaction functions: Heterogeneity or fiscal fatigue?”, by G. Everaert and S. Jansen, *Research series*, June 2017.
321. “Economic importance of the Belgian ports: Flemish maritime ports, Liège port complex and the port of Brussels - Report 2015”, by C. Mathys, *Document series*, June 2017.
322. “Foreign banks as shock absorbers in the financial crisis?”, by G. Barboni, *Research series*, June 2017.
323. “The IMF and precautionary lending: An empirical evaluation of the selectivity and effectiveness of the flexible credit line”, by D. Essers and S. Ide, *Research series*, June 2017.
324. “Economic importance of air transport and airport activities in Belgium – Report 2015”, by S. Vennix, *Document series*, July 2017.
325. “Economic importance of the logistics sector in Belgium”, by H. De Doncker, *Document series*, July 2017.
326. “Identifying the provisioning policies of Belgian banks”, by E. Arbak, *Research series*, July 2017.
327. “The impact of the mortgage interest and capital deduction scheme on the Belgian mortgage market”, by A. Hoebeeck and K. Inghelbrecht, *Research series,* September 2017.
328. “Firm heterogeneity and aggregate business services exports: Micro evidence from Belgium, France, Germany and Spain”, by A. Ariu, E. Biewen, S. Blank, G. Gaulier, M.J. González, Ph. Meinen, D. Mirza, C. Martín and P. Tello, *Research series*, September 2017.
329. “The interconnections between services and goods trade at the firm-level”, by A. Ariu, H. Breinlichz, G. Corcosx, G. Mion, *Research series,* October 2017.

330. “Why do manufacturing firms produce services? Evidence for the servitization paradox in Belgium”, by P. Blanchard, C. Fuss and C. Mathieu, *Research series,* November 2017.

331. “Nowcasting real economic activity in the euro area: Assessing the impact of qualitative surveys”, by R. Basselier, D. de Antonio Liedo and G. Langenus, *Research series,* December 2017.

332. “Pockets of risk in the Belgian mortgage market: Evidence from the Household Finance and Consumption Survey (HFCS)”, by Ph. Du Caju, *Research series,* December 2017.

333. “The employment consequences of SMEs’ credit constraints in the wake of the great recession” by D. Cornille, F. Rycx and I. Tojerow, *Research series*, December 2017.

334. “Exchange rate movements, firm-level exports and heterogeneity”, by A. Berthou and E. Dhyne, *Research series*, January 2018.

335 “Nonparametric identification of unobserved technological heterogeneity in production”, by L. Cherchye, T. Demuynck, B. De Rock and M. Verschelde, *Research series*, February 2018.

336 “Compositional changes in aggregate productivity in an era of globalisation and financial crisis”, by C. Fuss and A. Theodorakopoulos, *Research series*, February 2018.

337. “Decomposing firm-product appeal: How important is consumer taste?”, by B. Y. Aw, Y. Lee and H. Vandenbussche, *Research series*, March 2018.

338 “Sensitivity of credit risk stress test results: Modelling issues with an application to Belgium”, by P. Van Roy, S. Ferrari and C. Vespro, *Research series*, March 2018.

339. “Paul van Zeeland and the first decade of the US Federal Reserve System: The analysis from a European central banker who was a student of Kemmerer”, by I. Maes and R. Gomez Betancourt, *Research series*, March 2018.

340. “One way to the top: How services boost the demand for goods”, by A. Ariu, F. Mayneris and M. Parenti, *Research series*, March 2018.

341 “Alexandre Lamfalussy and the monetary policy debates among central bankers during the Great Inflation”, by I. Maes and P. Clement, *Research series*, April 2018.

342. “The economic importance of the Belgian ports: Flemish maritime ports, Liège port complex and the port of Brussels – Report 2016”, by F. Coppens, C. Mathys, J.-P. Merckx, P. Ringoot and M. Van Kerckhoven, *Document series*, April 2018.

343. “The unemployment impact of product and labour market regulation: Evidence from European countries”, by C. Piton, *Research series,* June 2018.

344. “Trade and domestic production networks”, by F. Tintelnot, A. Ken Kikkawa, M. Mogstad, E. Dhyne, *Research series*, September 2018.

345. “Review essay: Central banking through the centuries”, by I. Maes, *Research series,* October 2018.

346 “IT and productivity: A firm level analysis”, by E. Dhyne, J. Konings, J. Van den Bosch, S. Vanormelingen, *Research series*, October 2018.

347 “Identifying credit supply shocks with bank-firm data: methods and applications”, by H. Degryse, O. De Jonghe, S. Jakovljević, Klaas Mulier, Glenn Schepens, *Research series*, October 2018.

348 “Can inflation expectations in business or consumer surveys improve inflation forecasts?”, by R. Basselier, D. de Antonio Liedo, J. Jonckheere and G. Langenus, *Research series*, October 2018.

349 “Quantile-based inflation risk models”, by E. Ghysels, L. Iania and J. Striaukas, *Research series*, October 2018.

350 “International food commodity prices and missing (dis)inflation in the euro area”, by G. Peersman, *Research series*, October 2018.

351 “Pipeline pressures and sectoral inflation dynamics”, by F. Smets, J. Tielens and J. Van Hove, *Research series*, October 2018.

National Bank of Belgium
Limited liability company
RLP Brussels – Company's number : 0203.201.340
Registered office : boulevard de Berlaimont 14 – BE-1000 Brussels
www.nbb.be

Editor

Jan Smets
Governor of the National Bank of Belgium

Layout : Analysis and Research Group
Cover : NBB AG – Prepress & Image

Published in October 2018