Pipeline Pressures and Sectoral Inflation Dynamics[1]

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

[1]European Central Bank, UGent and CEPR

[2]National Bank of Belgium

[3]KU Leuven

[4]KBC

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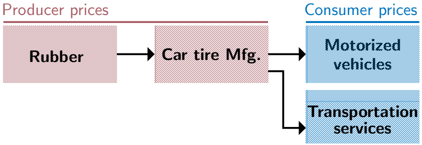
Outline

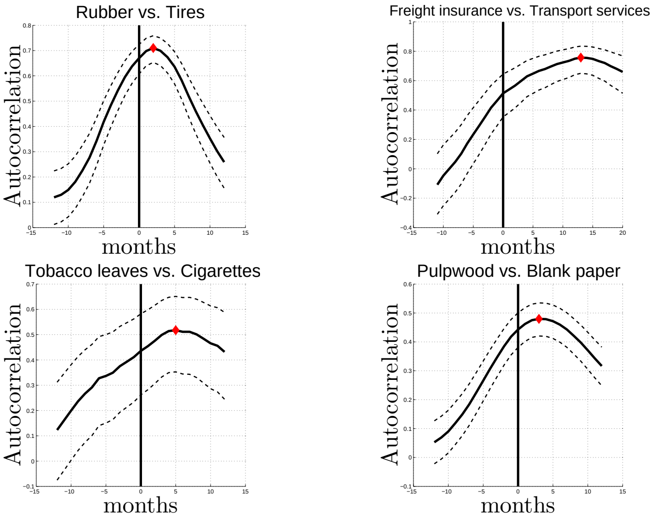
Motivation (i): Pipeline pressures

- Pipeline pressures
  - "*Pipeline pressures have built up in some sectors in early stages of the production and pricing chain.*" (*ECB, 2017*)
  - "*The figures, [...], offer an indication that inflation pressures in the pipeline are slightly weaker in the economy than thought.*" (*Bloomberg, 2019*)
  - "*The figures suggested price pressure at the start of the inflation pipeline may not be building as fast as the BoE feared.*" (*Reuters, 2007*)
- The build–up of ppi inflation in **sector j** at **time t** affects ppi in **sector j'** at **time t'** (and ultimately consumer price inflation).
- Production view on inflation (Means, 1935)



Motivation (ii): Pipeline pressures

– Micro–level PPI's/CPI's often represent sequential input



Motivation (iii): Pipeline pressures

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- Focus on two properties of inflation data:
    1. Persistence
    2. Volatility

Plan

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- Two–way decomposition
  1. Volatility: $\frac{\sigma^2(\boldsymbol{\lambda}_i'\boldsymbol{f}_t)}{\sigma^2(\pi_{it})}$ vs. $\frac{\sigma^2(\epsilon_{it})}{\sigma^2(\pi_{it})}$
  2. Persistence: $\rho(\boldsymbol{\lambda}_i\boldsymbol{f}_t)$ vs. $\rho(\epsilon_{it})$

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- 4 stylized facts

What do we know so far? (ii)

Stylized facts; disaggregate inflation ($\pi_{it} = \boldsymbol{\lambda}_i' \boldsymbol{f}_t + \epsilon_{it}$)

		Consumer prices		Producer prices	
		Mean	Median		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

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- Non–trivial implications on stylized facts
  - $\rho(\boldsymbol{\lambda}_i' \boldsymbol{f}_t)$ reflects aggregate shocks and sectoral shocks
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- This paper: three–way decomposition:

$$\pi_{it} = \underbrace{\boldsymbol{\alpha}_t(\pi_i)}_{\substack{\textit{Aggregate}\\ \textit{shocks}}} + \underbrace{\boldsymbol{\beta}_t(\pi_i)}_{\substack{\textit{Sector i}\\ \textit{shocks}}} + \underbrace{\boldsymbol{\gamma}_t(\pi_i)}_{\substack{\textit{Pipeline}\\ \textit{Pressures}}}$$

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   - Compare model decomposition with dfm decomposition

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3. Verify difficulties of the dfm to correctly disentangle pipeline pressures from aggregate shocks
   - Compare model decomposition with dfm decomposition
4. Assess impact of pipeline pressures on stylized facts

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   - Stylized fact 2 (Disaggregate inflation)
     - 40% for Healthcare (pce index) vs. 0.87% for Agriculture & Forestry (ppi index).
     - Generally larger for consumer prices than for producer prices
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3. Pipeline pressures: Varying size/composition throughout $1970Q1 - 2007Q4$ in U.S. data.

Literature

Crossroads of multiple literatures

1. **Origins inflation persistence:**
   - Basu (AER, 1995); Blanchard (AER, 1982); Huang et al. (AER, 2006); Carvalho (JME, 2006); etc.
2. **Origins inflation volatility:**
   - Bouakez (EER, 2014); Schoenle et al. (2017, 2018); etc.
3. **Dynamic factor model decompositions:**
   - Boivin et al. (AER, 2009); Mackowiak et al. (JME, 2009); Auer et al. (JME, 2018); Kaufmann and Lein (EER, 2013); Andrade and Zachariadis (JIE, 2016); etc.
4. **Propagation mechanisms:**
   - Acemoglu et al. (AER, 2017; EM, 2012); Di Giovanni et al. (EM, 2014); Fahri & Baqaee (EM, 2018); Ozdagli & Weber (EM, 2018); Atalay (AEJ, 2017); etc.
5. **Extend class of multisector dsge models:**
   - Long & Plosser (JPE, 1983; AER, 1987); Bouakez et al. (EER, 2014; IER, 2009); Carvalho (2006, AER); Dixon et al. (BoE, 2007); etc.

Plan

Overview of the model (i)

- Shocks
  - Type: standard set of shocks (workhorse dsge models)
  - Level: aggregate and sectoral

TYPE AND LEVEL OF SHOCKS

	Level of shock	
Type	Aggregate	Sectoral
Monetary policy shock	X	–
Risk shock	X	–
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Productivity shock	X	X
Price markup shock	X	X
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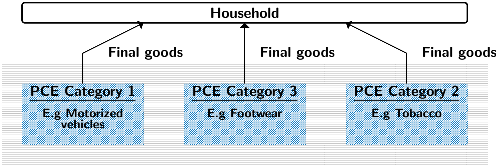

Overview of the model (ii): Household

Maximize utility (household member h in sector j)

$$\mathcal{U}_{j,t}(h) = \sum_{s=t}^{\infty} \beta^{s-t} \left(\frac{(C_t(h) - \chi C_{t-1}(h))^{1-\sigma}}{1-\sigma} - \frac{L_{jt}(h)^{1+\varphi}}{1+\varphi} \right)$$

subject to budget constraint.

Aggregate consumption bundle:

$$C_t = \left(\sum_{z=1}^{Z} \xi_z^{\frac{1}{\nu_c}} C_{zt}^{1-\frac{1}{\nu_c}} \right)^{\frac{\nu_c}{\nu_c - 1}}$$

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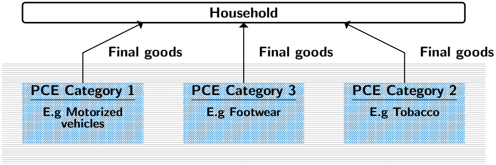

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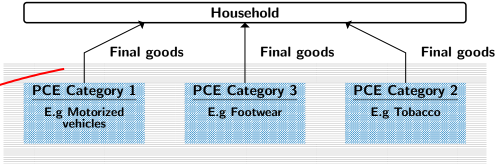

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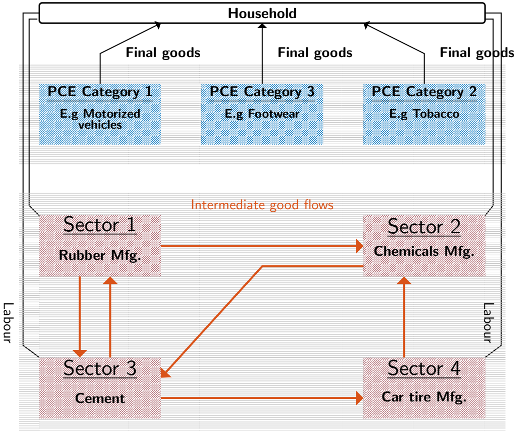

Overview of the model (iii): Intermediate gds producers

Production (of firm f in sector j)

$$Y_{jt}(f) = \underbrace{N_{jt}(f)^{\phi_j^n}}_{\text{Labour}} \underbrace{M_{jt}(f)^{\phi_j^m}}_{\text{Intermediates}} \underbrace{K_{jt}(f)^{\phi_j^k}}_{\text{Capital}} - \Phi_j(f)$$

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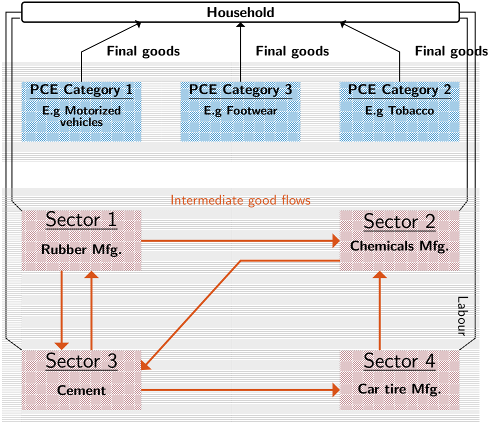

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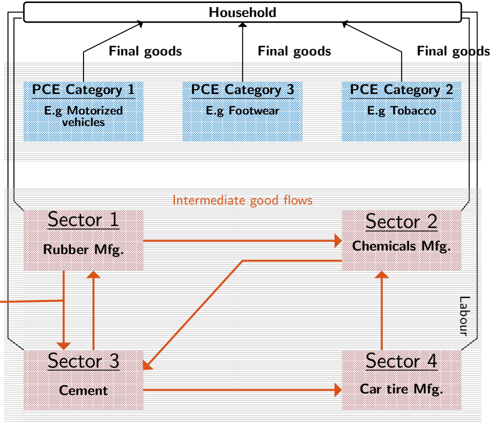

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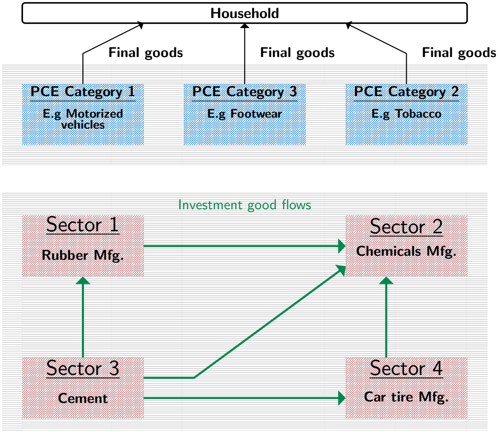

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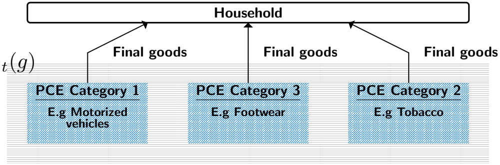

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$$K_{jt+1}(g) = \Big(1-\delta\Big)K_{jt}(g) + \Big(1 - S\big(\tfrac{I_{jt}(g)}{I_{jt-1}(g)}\big)\Big)I_{jt}(g)$$

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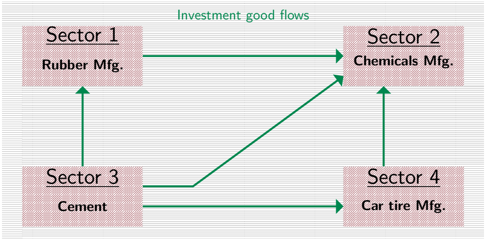
Investment flow structure $\mathbf{\Psi}$ pipeline pressures



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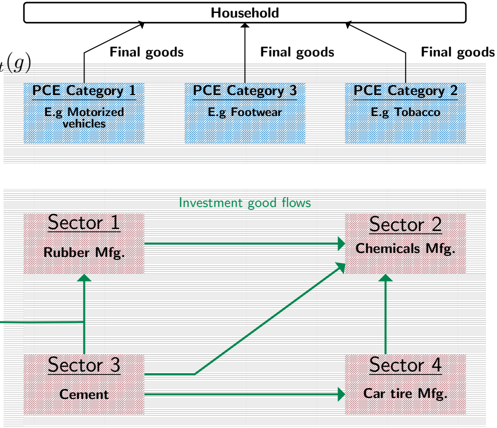
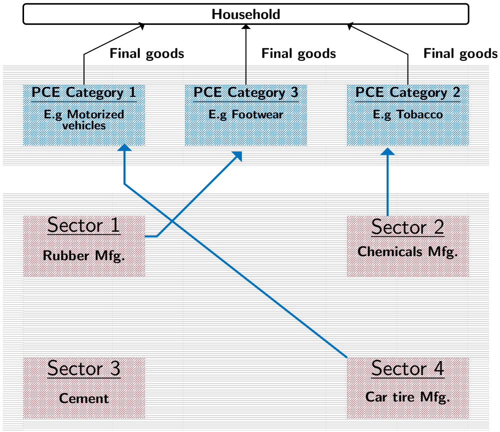


Overview of the model (v)



Overview of the model (v): Final goods producers

Final goods production

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

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

These firms ...

1. set consumer prices (pce's);
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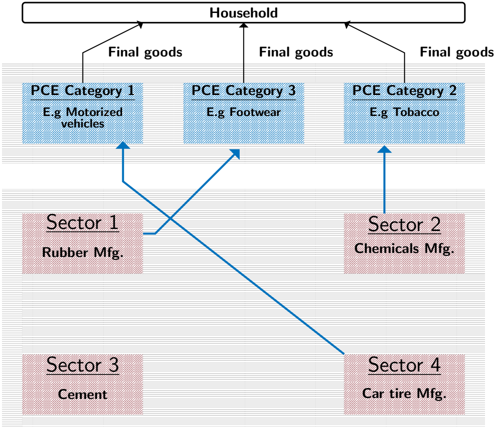

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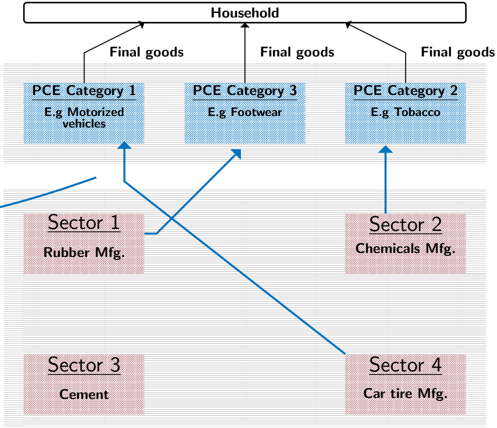

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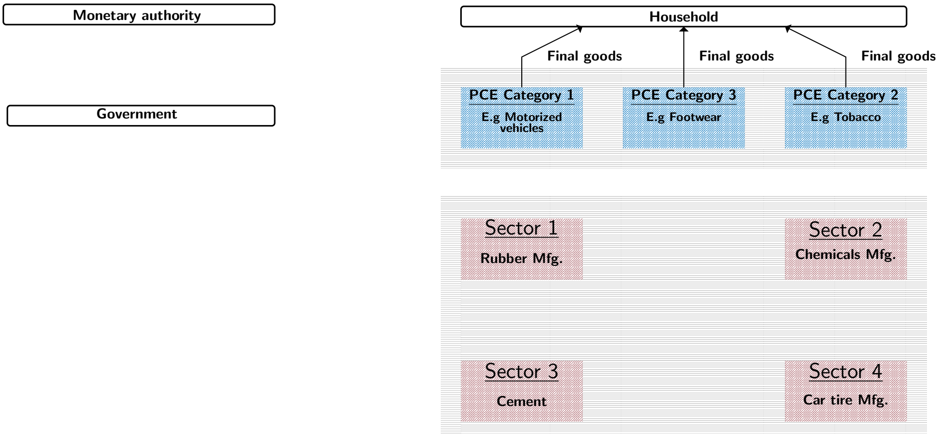

Overview model (vii): Decomposition

Disaggregate ppi inflation

$$\pi_{jt}^{ppi} = \underbrace{\boldsymbol{\alpha}_t(\pi_j^{ppi})}_{\substack{\textit{Aggregate} \\ \textit{shocks}}} + \underbrace{\boldsymbol{\beta}_t(\pi_j^{ppi})}_{\substack{\textit{Sector } j \\ \textit{shocks}}} + \underbrace{\boldsymbol{\gamma}_t(\pi_j^{ppi})}_{\substack{\textit{Pipeline} \\ \textit{Pressures}}}$$

TYPE AND LEVEL OF SHOCKS

Type	**Level of shock**		
	Aggregate	**Micro**	
		ppi j	ppi $-j$
Monetary policy shock	X	–	–
Risk shock	X	–	–
Aggregate demand shock	X	–	–
Productivity shock	X	X	X
Price markup shock	X	X	X
Wage markup shock	X	X	X
Investment shock	X	X	X

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Overview model (vii): Decomposition

Disaggregate pce inflation

$$\pi_{zt}^{pce} = \underbrace{\boldsymbol{\alpha}_t(\pi_z^{pce})}_{\substack{Aggregate \\ shocks}} + \underbrace{\boldsymbol{\beta}_t(\pi_z^{pce})}_{\substack{Sector\ z \\ shocks}} + \underbrace{\boldsymbol{\gamma}_t(\pi_z^{pce})}_{\substack{Pipeline \\ Pressures}}$$

TYPE AND LEVEL OF SHOCKS

Type	Level of shock		
	Aggregate	**Micro**	
		pce z	pce $-z$
Monetary policy shock	X	–	–
Risk shock	X	–	–
Aggregate demand shock	X	–	–
Productivity shock	X	X	X
Price markup shock	X	X	X
Wage markup shock	X	X	X
Investment shock	X	X	X

Estimation details (i)

- What level of estimation?
  - Data limitations
  - Computational limitations
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- Partly calibrated Calibration
  1. Behavioural parameters $\{\beta, \sigma, ...\}$
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- Partly estimated: Bayesian techniques using micro & macro data on the US economy 1970Q1:2007Q4.

Estimation details (ii)

- Identification
  - GE interactions
  - Mapping micro–macro Mapping figures and tables
- Estimation results Estimation results

Plan

Test empirical relevance of pipeline pressures

- Empirical relevance of pipeline pressures?
  - PPI sector j relevant for PPI of sector j'?
  - PPI sector j relevant for PCE of product z?
- Compare 2 models (with/without pipeline pressures)
- Bayes factor to test for relevance pipeline pressures

BAYES FACTOR: PIPELINE PRESSURES

		Agriculture $j=1$	Mining $j=2$	Utilities $j=3$	Construction $j=4$	Manufacturing $j=5$	Services $j=6$	Public Sector $j=7$
$\frac{\mathcal{L}(\mathcal{Y}_T\|\mathcal{M})}{\mathcal{L}(\mathcal{Y}_T\|\mathcal{M}_{\omega_{j'j=0},\psi_{j'j=0}})}$					Panel A			
$j'=1$	Agriculture		1.00	4.13	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	23.42	14.95	7.4		2×10^9	0.00	1.00
$j'=5$	Manufacturing	1×10^4	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	
$\frac{\mathcal{L}(\mathcal{Y}_T\|\mathcal{M})}{\mathcal{L}(\mathcal{Y}_T\|\mathcal{M}_{\kappa_{zj=0}})}$					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

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$\omega_{j'j} = \psi_{j'j} = 0$

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Comparison dfm vs. structural model

- Decompose U.S. inflation
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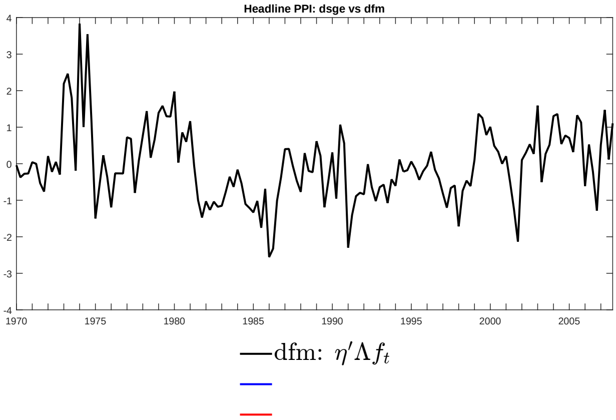

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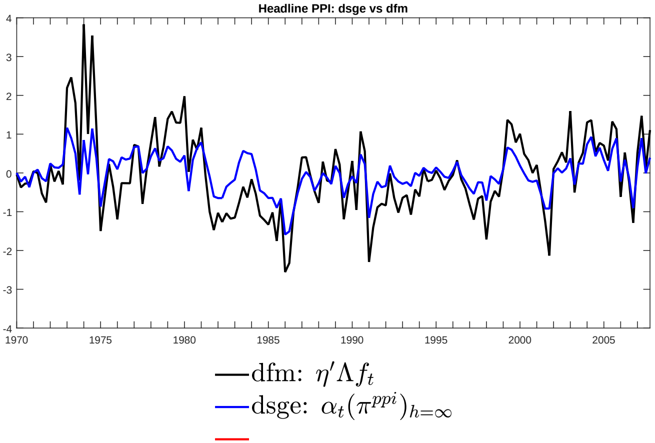

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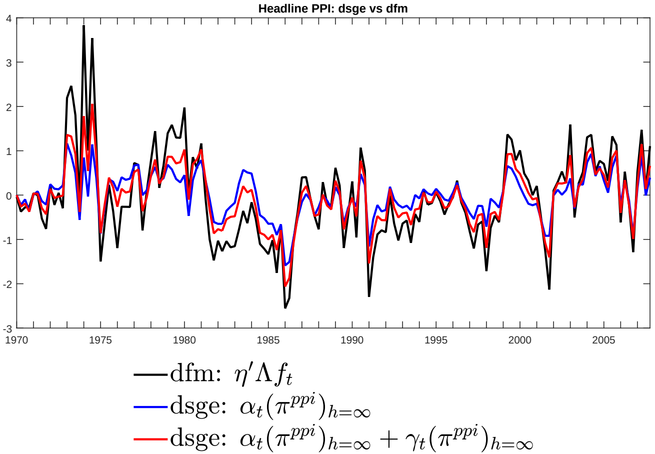

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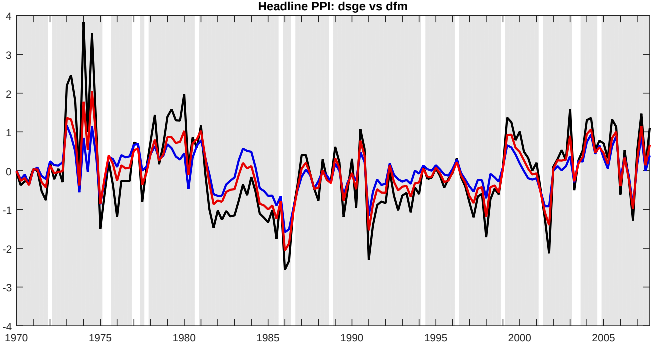

dfm: $\eta' \Lambda f_t$

dsge: $\alpha_t(\pi^{ppi})_{h=\infty}$

dsge: $\alpha_t(\pi^{ppi})_{h=\infty} + \gamma_t(\pi^{ppi})_{h=\infty}$

Volatility & Persistence (i): Volatility

Producer Prices: $\pi_{jt} = \boldsymbol{\alpha}_t(\pi_j) + \boldsymbol{\beta}_t(\pi_j) + \boldsymbol{\gamma}_t(\pi_j)$

	Infinite horizon ($FEVD(\infty)$)			$FEVD(1)$
	Macro	**Micro**		**Micro**
		Direct	Pipeline Pressures	Pipeline Pressures
	(1)	(2)	(3)	(4)
Agriculture & Forestry	5.46	93.68	0.86	0.73
Oil and gas extraction	4.28	92.25	3.47	3.12
Mining, except oil and gas	7.90	90.98	1.12	0.74
Utilities	14.84	81.33	3.83	3.37
Construction	54.90	38.92	6.18	4.03
Computer and electronic products	26.75	70.91	2.34	1.28
Electrical equipment, and appliances	31.07	64.68	4.25	2.98
Motor vehicles, bodies and trailers	28.91	69.46	1.63	1.37
Furniture and related products	30.77	64.51	4.72	2.96
Petroleum and coal products	23.01	36.74	40.25	40.15
Chemical products	26.23	65.32	8.45	4.56
Plastics and rubber products	29.32	67.70	2.97	2.00
Wholesale trade	45.49	30.13	24.38	12.59
Transportation and warehousing	43.20	51.84	4.97	3.44
Information	43.09	41.79	15.11	8.17
FIRE	46.36	41.79	11.85	8.04
PROF	35.53	54.61	9.86	4.59
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Direct sectoral shocks are most important for disaggregate inflation volatility

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Aggregate shocks are less important than common component.

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Pipeline pressures are of second order importance for disaggregate inflation volatility (heterogeneity).

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Information	43.09	41.79	15.11	8.17
FIRE	46.36	41.79	11.85	8.04
PROF	35.53	54.61	9.86	4.59
EHS	34.65	53.79	11.57	5.9
Headline inflation	69.09	9.43	21.47	12.16

Pipeline pressures take time to materialize

Volatility & Persistence (i): Volatility

PRODUCER PRICES: $\pi_{jt} = \boldsymbol{\alpha}_t(\pi_j) + \boldsymbol{\beta}_t(\pi_j) + \boldsymbol{\gamma}_t(\pi_j)$

	Infinite horizon ($FEVD(\infty)$)			$FEVD(1)$
	Macro	**Micro**		**Micro**
		Direct	Pipeline Pressures	Pipeline Pressures
	(1)	(2)	(3)	(4)
Agriculture & Forestry	5.46	93.68	0.86	0.73
Oil and gas extraction	4.28	92.25	3.47	3.12
Mining, except oil and gas	7.90	90.98	1.12	0.74
Utilities	14.84	81.33	3.83	3.37
Construction	54.90	38.92	6.18	4.03
Computer and electronic products	26.75	70.91	2.34	1.28
Electrical equipment, and appliances	31.07	64.68	4.25	2.98
Motor vehicles, bodies and trailers	28.91	69.46	1.63	1.37
Furniture and related products	30.77	64.51	4.72	2.96
Petroleum and coal products	23.01	36.74	40.25	40.15
Chemical products	26.23	65.32	8.45	4.56
Plastics and rubber products	29.32	67.70	2.97	2.00
Wholesale trade	45.49	30.13	24.38	12.59
Transportation and warehousing	43.20	51.84	4.97	3.44
Information	43.09	41.79	15.11	8.17
FIRE	46.36	41.79	11.85	8.04
PROF	35.53	54.61	9.86	4.59
EHS	34.65	53.79	11.57	5.9
Headline inflation	69.09	9.43	21.47	12.16

Direct effect of sectoral shocks average out

Volatility & Persistence (i): Volatility

PRODUCER PRICES: $\pi_{jt} = \boldsymbol{\alpha}_t(\pi_j) + \boldsymbol{\beta}_t(\pi_j) + \boldsymbol{\gamma}_t(\pi_j)$

	Infinite horizon ($FEVD(\infty)$)			$FEVD(1)$
	Macro	**Micro**		**Micro**
		Direct	Pipeline Pressures	Pipeline Pressures
	(1)	(2)	(3)	(4)
Agriculture & Forestry	5.46	93.68	0.86	0.73
Oil and gas extraction	4.28	92.25	3.47	3.12
Mining, except oil and gas	7.90	90.98	1.12	0.74
Utilities	14.84	81.33	3.83	3.37
Construction	54.90	38.92	6.18	4.03
Computer and electronic products	26.75	70.91	2.34	1.28
Electrical equipment, and appliances	31.07	64.68	4.25	2.98
Motor vehicles, bodies and trailers	28.91	69.46	1.63	1.37
Furniture and related products	30.77	64.51	4.72	2.96
Petroleum and coal products	23.01	36.74	40.25	40.15
Chemical products	26.23	65.32	8.45	4.56
Plastics and rubber products	29.32	67.70	2.97	2.00
Wholesale trade	45.49	30.13	24.38	12.59
Transportation and warehousing	43.20	51.84	4.97	3.44
Information	43.09	41.79	15.11	8.17
FIRE	46.36	41.79	11.85	8.04
PROF	35.53	54.61	9.86	4.59
EHS	34.65	53.79	11.57	5.9
Headline inflation	69.09	9.43	21.47	12.16

Stylized fact 4: Pipeline pressures are important due to comovement

Volatility & Persistence (ii): Volatility

Forecast Error Variance Decomposition: Consumer Prices

$$\pi_{zt} = \boldsymbol{\alpha}_t(\pi_z) + \boldsymbol{\beta}_t(\pi_z) + \boldsymbol{\gamma}_t(\pi_z)$$

	Infinite horizon ($FEVD(\infty)$)			$FEVD(1)$
	Macro	**Micro**		**Micro**
		Direct	Pipeline Pressures	Pipeline Pressures
	(1)	(2)	(3)	(4)
Motor vehicles and parts	19.76	42.98	37.26	36.96
Furnishings and durable hh equipment	14.00	76.47	9.53	5.23
Recreational goods and vehicles	15.85	71.19	12.95	8.2
Other durable goods	13.96	74.85	11.19	5.53
Food and beverages PFOPC	12.31	57.48	30.21	28.94
Clothing and footwear	12.12	60.85	27.03	25.65
Gasoline and other energy goods	10.04	68.35	21.61	20.27
Other nondurable goods	10.91	79.1	9.99	6.06
Housing and utilities	20.89	57.63	21.48	18.54
Health care	38.65	18.1	43.25	35.07
Transportation services	21.45	63.2	15.35	10.99
Recreation services	29.57	41.2	29.23	17.87
Food services and accommodations	23.64	43.18	33.18	23.68
Financial services and insurance	32.83	28.2	38.97	30.93
Other services	26.63	50.64	22.72	12.52
NPISHs	20.53	60.92	18.55	10.34
Public Sector	9.33	4.12	86.55	84.05

Volatility & Persistence (i): Persistence

$$\pi_{jt}^{ppi} = \boldsymbol{\alpha}_t(\pi_j^{ppi}) + \boldsymbol{\beta}_t(\pi_j^{ppi}) + \boldsymbol{\gamma}_t(\pi_j^{ppi})$$

		Macro	**Micro**	
			Direct	Pipeline Pressures
		(1)	(2)	(3)
		$\rho(\boldsymbol{\alpha}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi^{ppi}))$
π_t^{ppi}		0.332	0.080	0.793
		$\rho(\boldsymbol{\alpha}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi_j^{ppi}))$
π_{jt}^{ppi}	Average	0.335	0.066	0.635
	Median	0.379	0.115	0.719

Volatility & Persistence (i): Persistence

$$\pi_{jt}^{ppi} = \boldsymbol{\alpha}_t(\pi_j^{ppi}) + \boldsymbol{\beta}_t(\pi_j^{ppi}) + \boldsymbol{\gamma}_t(\pi_j^{ppi})$$

		Macro	**Micro**	
			Direct	Pipeline Pressures
		(1)	(2)	(3)
		$\rho(\boldsymbol{\alpha}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi^{ppi}))$
π_t^{ppi}		0.332	0.080	0.793
		$\rho(\boldsymbol{\alpha}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi_j^{ppi}))$
π_{jt}^{ppi}	Average	0.335	0.066	0.635
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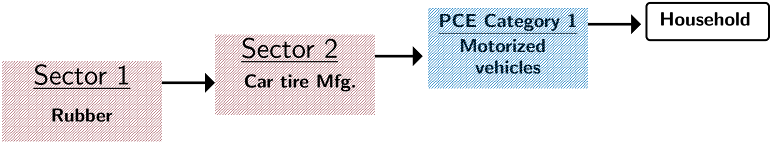
Stylized fact 1 and 3: Aggregate shocks create persistence



Volatility & Persistence (i): Persistence

$$\pi_{jt}^{ppi} = \boldsymbol{\alpha}_t(\pi_j^{ppi}) + \boldsymbol{\beta}_t(\pi_j^{ppi}) + \boldsymbol{\gamma}_t(\pi_j^{ppi})$$

		Macro	**Micro**	
			Direct	Pipeline Pressures
		(1)	(2)	(3)
		$\rho(\boldsymbol{\alpha}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi^{ppi}))$
π_t^{ppi}		0.332	0.080	0.793
		$\rho(\boldsymbol{\alpha}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi_j^{ppi}))$
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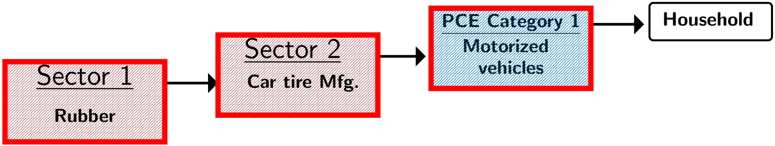

Volatility & Persistence (i): Persistence

$$\pi_{jt}^{ppi} = \boldsymbol{\alpha}_t(\pi_j^{ppi}) + \boldsymbol{\beta}_t(\pi_j^{ppi}) + \boldsymbol{\gamma}_t(\pi_j^{ppi})$$

		Macro	**Micro**	
			Direct	Pipeline Pressures
		(1)	(2)	(3)
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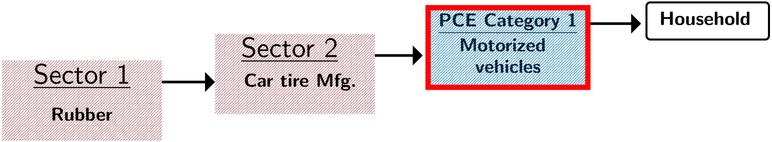
		$\rho(\boldsymbol{\alpha}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi_j^{ppi}))$
π_{jt}^{ppi}	Average	0.335	0.066	0.635
	Median	0.379	0.115	0.719

Stylized fact 1 and 3: Sectoral shocks create no persistence

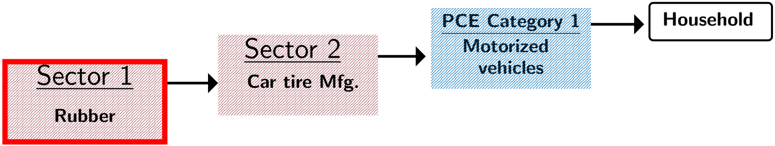


Volatility & Persistence (i): Persistence

$$\pi_{jt}^{ppi} = \boldsymbol{\alpha}_t(\pi_j^{ppi}) + \boldsymbol{\beta}_t(\pi_j^{ppi}) + \boldsymbol{\gamma}_t(\pi_j^{ppi})$$

		Macro	**Micro**	
			Direct	Pipeline Pressures
		(1)	(2)	(3)
		$\rho(\boldsymbol{\alpha}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi^{ppi}))$
π_t^{ppi}		0.332	0.080	0.793
		$\rho(\boldsymbol{\alpha}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\beta}_t(\pi_j^{ppi}))$	$\rho(\boldsymbol{\gamma}_t(\pi_j^{ppi}))$
π_{jt}^{ppi}	Average	0.335	0.066	0.635
	Median	0.379	0.115	0.719

... Sectoral shocks create persistence



Volatility & Persistence (ii): Persistence

Persistence decomposition $\pi_{zt}^{pce} = \boldsymbol{\alpha}_t(\pi_z^{pce}) + \boldsymbol{\beta}_t(\pi_z^{pce}) + \boldsymbol{\gamma}_t(\pi_z^{pce})$

		Macro	**Micro**	
			Direct	Pipeline Pressures
		(1)	(2)	(3)
		$\rho(\boldsymbol{\alpha}_t(\pi^{pce}))$	$\rho(\boldsymbol{\beta}_t(\pi^{pce}))$	$\rho(\boldsymbol{\gamma}_t(\pi^{pce}))$
π_t^{pce}		0.570	0.275	0.901
		$\rho(\boldsymbol{\alpha}_t(\pi_z^{pce}))$	$\rho(\boldsymbol{\beta}_t(\pi_z^{pce}))$	$\rho(\boldsymbol{\gamma}_t(\pi_z^{pce}))$
π_{zt}^{pce}	Average	0.711	0.176	0.865
	Median	0.780	0.151	0.899

Additional results (i): Origins of pipeline pressures

Pipeline pressure decomposition: Infinite Horizon

	Agriculture & Forestry	Oil & gas extraction	Construction	Machinery	Computer & electronics	Motorized vehicles	Wholesale trade	FIRE	PROF
Producer prices									
Utilities	02.37	52.82	02.19		02.02	02.47	01.33	10.88	06.48
Motor vehicles, bodies and trailers	02.30	01.21	02.72	28.05	08.56	12.37	02.46	09.62	06.37
Food and beverage and tobacco products	92.77							01.34	01.10
Petroleum and coal products		97.03							
Wholesale trade	05.15	02.09	05.80	01.61	05.87	05.78		22.31	14.09
Retail	06.11	01.79	06.23	01.53	05.65	05.59	03.58	21.95	12.44
EHS	06.65	01.86	04.67	01.27	04.40	04.67	03.12	22.65	12.91
Consumer prices									
Furnishings and durable hh equipment	03.56	01.22	02.82	02.19	03.91	03.36	02.61	11.63	06.62
Gasoline and other energy goods		51.35						01.37	
Health care	02.54		04.99	01.09	04.77	04.35	02.68	14.03	07.65
Recreation services	06.32	01.09	04.15	01.01	03.84	03.85	02.42	15.17	10.16
Transportation services	01.94	01.78	01.83		01.69	01.77	01.34	17.48	04.76

Additional results (i): Origins of pipeline pressures

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	Agriculture & Forestry	Oil & gas extraction	Construction	Machinery	Computer & electronics	Motorized vehicles	Wholesale trade	FIRE	PROF
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Role of Input–output structure: important

Additional results (i): Origins of pipeline pressures

Pipeline pressure decomposition: Infinite Horizon

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Role of Input–output structure: important

Additional results (i): Origins of pipeline presssures

Pipeline pressure decomposition: Infinite Horizon

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Transportation services	01.94	01.78	01.83		01.69	01.77	01.34	17.48	04.76

Role of service sector: important

Additional results (i): Origins of pipeline pressures

Pipeline pressure decomposition: Infinite Horizon

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Gasoline and other energy goods		51.35						01.37	
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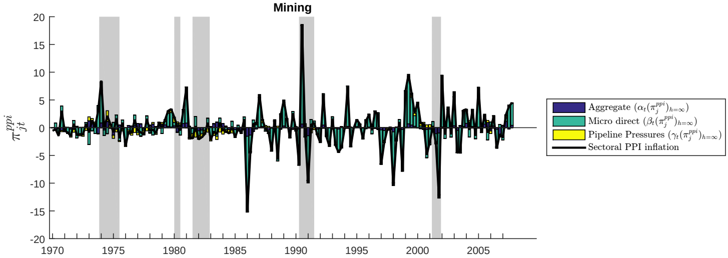
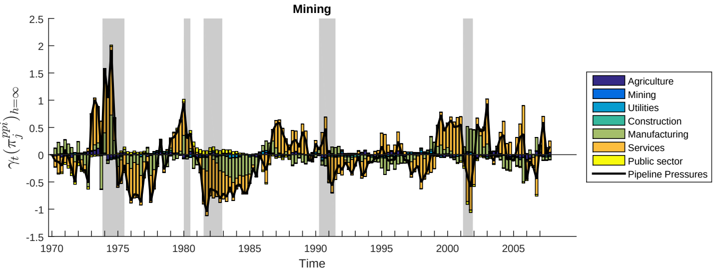
Transportation services	01.94	01.78	01.83		01.69	01.77	01.34	17.48	04.76

Role of investment flows: important

Additional results (ii): Historical decomposition





Plan

Concluding remarks

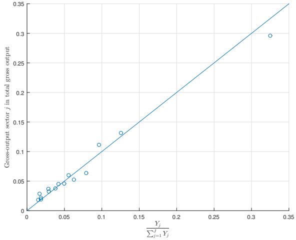
This paper

1. Studied the role of pipeline pressures for inflation volatility and persistence.
2. Benchmarked with traditional dfm framework

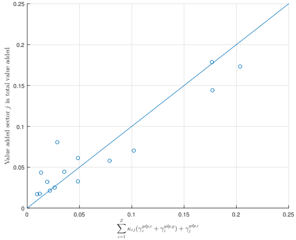
Policy implications & work in progress

1. Improve forecasting: a production view
2. Useful framework to study sector–specific policy interventions.
   - E.g., *Healthcare sector* regulation (e.g. Affordable Care Act, NEJM 2014)
   - E.g., Competition policy *Telecommunications sector* (ECB, 2011)
   - E.g., Liberalisation shale gas in *Mining sector* (Weijermans, 2013)
   - E.g., *Car manufacturing sector*: Dieselgate
   - ...
3. Subdued inflation: missing pipeline inflation?
4. Optimal monetary policy

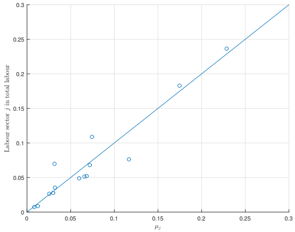
Plan



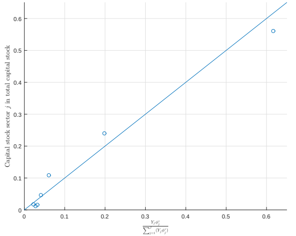
(a) Share gross output. Correlation: 0.99.



(b) Share value added. Correlation: 0.94.



(c) Share employment. Correlation: 0.95.



(d) Share capital stock. Correlation: 0.98.

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Steady state ratios, model vs. data

Aggregate steady states (% GDP)	Model counterpart	Model	Data
Personal consumption expenditures–to–gdp	$\sum_{z=1}^{17} \gamma_z^{gdp,c}$	0.55	0.62
Durables–to–gdp	$\sum_{z=1}^{4} \gamma_z^{gdp,c}$	0.07	0.08
Non-Durables–to–gdp	$\sum_{z=5}^{9} \gamma_z^{gdp,c}$	0.16	0.19
Services–to–gdp	$\sum_{z=9}^{17} \gamma_z^{gdp,c}$	0.32	0.34
Govt. Consumption Expenditures & Govt. Gross Investment–to–gdp	$\sum_{z=1}^{17} \gamma_z^{gdp,g} + \gamma_{35}^{gdp,i}$	0.16	0.20
Govt. Gross investment–to–gdp	$\gamma_{15}^{gdp,i}$	0.02	0.04
Govt. Consumption Expenditures–to–gdp	$\sum_{z=1}^{17} \gamma_z^{gdp,g}$	0.14	0.16
Gross private and Govt. investment–to–gdp	$\sum_{j=1}^{35} \gamma_j^{gdp,i}$	0.31	0.23
Gross output–to–gdp	$\sum_{j=1}^{35} \gamma_j^{gdp,i}$	1.86	1.81

Moments in the data are averages over the post WWII period. Personal consumption expenditures and gross domestic product are obtained from the BEA. Investment data is obtained from the FRED. The model–implied steady states are obtained from the disaggregated version of the model $J = 35, Z = 17$.

Calibration of parameters

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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 in paper
Investment flow matrix	$\boldsymbol{\Psi}$	See table 5 in paper
Labour share	$\boldsymbol{\phi}^n$	See table 6 in paper
Capital share	$\boldsymbol{\phi}^k$	See table 6 in paper
Intermediate goods/services share	$\boldsymbol{\phi}^m$	See table 6 in paper
Wage stickiness	$\boldsymbol{\alpha}^w$	See table 6 in paper
Producer price stickiness	$\boldsymbol{\alpha}^{ppi}$	See table 6 in paper
Consumer price stickiness	$\boldsymbol{\alpha}^{pce}$	See table 7 in paper
Private consumption weights	$\boldsymbol{\xi}$	See table 7 in paper
Government consumption weights	$\boldsymbol{\zeta}$	See table 7 in paper
Intermediate goods producers to final goods producers flow matrix	$\boldsymbol{K}$	See table 8 in paper

This table documents the parameters calibrated throughout the estimation of the model.

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. Go Back

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. Go Back

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. Go Back

Table: 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 et al. (2011) and Bils et al. (2014), respectively. Go Back

Table: 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–Steinsson (2008) price–setting statistics. Go Back

Priors and posteriors of the estimated parameters

Go Back

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]

Priors and posteriors of the estimated parameters

Go Back

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						
$\varsigma_{w,1}, \varsigma_{w,2}, ..., \varsigma_{w,7}$	All sectors	inv-Γ	0.2	2	0.111	[0.087; 0.147]
I. Standard deviation of sectoral investment efficiency shocks						
$\varsigma_{i,1}, \varsigma_{i,2}, ..., \varsigma_{i,7}$	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]

Log–linearised system (i)

Household

$$c_{zt} = -\nu_c p_{zt,r} + c_t$$

$$\lambda_t = -\frac{\sigma}{1-\chi}(c_t - \chi c_{t-1})$$

$$\lambda_t = \mathbb{E}_t(\lambda_{t+1}) + r_t + z_{b,t} - \mathbb{E}_t(\pi^{pce}_{t+1})$$

$$\pi^{pce}_t = \sum_{z=1}^{Z} \xi_z \pi^{pce}_{zt}$$

Monetary policy

$$r_t = \rho_s r_{t-1} + (1-\rho_s)\Big(\rho_\pi \pi^{pce}_t + \rho_{gdp} gdp_t\Big) + z_{r,t}$$

Wage dynamics and labour markets

$$\{\pi^w_{jt} = w_{jt,r} - w_{jt-1,r} + \pi^{pce}_t\}_{j=1}^{J}$$

$$\{\pi^w_{jt} = \beta \mathbb{E}_t(\pi^w_{jt+1}) + \iota_w(\pi^{pce}_{t-1} - \beta\pi^{pce}_t) + \gamma^w_j(mrs_{jt} - w_{jt,r} + (z_{w,j,t} + z_{w,t}))\}_{j=1}^{J}$$

$$\{mrs_{jt} = \varphi n_{jt} - \lambda_t\}_{j=1}^{J}$$

Government

$$p^g_{t,r} = \sum_{z=1}^{Z} \zeta_z p_{zt,r}$$

$$\{g_{zt} = g_t - \nu_g(p_{zt,r} - p^g_{t,r})\}_{z=1}^{Z}$$

Log–linearised system (ii)

Intermediate goods producers

$$\{\pi_{jt}^{ppi} = p_{jt,r} - p_{jt-1,r} + \pi_t^{pce}\}_{j=1}^J$$

$$\{\pi_{jt}^{ppi} = \gamma_{1,j}^{ppi}\mathbb{E}_t\pi_{jt+1}^{ppi} + \gamma_{2,j}^{ppi}\pi_{jt-1}^{ppi} + \gamma_{3,j}^{ppi}(mc_{j,t,r} - p_{jt,r} + (z_{m,t} + z_{m,j,t})\}_{j=1}^J$$

$$\{y_{jt} = (1+\epsilon_m)(z_{p,j,t} + z_{p,t} + \phi_j^n n_{jt} + \phi_j^m m_{jt} + \phi_j^k k_{jt})\}_{j=1}^J$$

$$\{mc_{jt,r} = -(z_{p,j,t} + z_{p,t}) + \phi_j^n w_{jt,r} + \phi_j^m p_{jt,r}^m + \phi_j^k r_{jt,r}\}_{j=1}^J$$

$$\{p_{jt,r}^m = \sum_{j'=1}^J \omega_{jj'} p_{j't,r}\}_{j=1}^J$$

$$\{m_{jt} - n_{jt} = w_{jt,r} - p_{jt,r}^m\}_{j=1}^J$$

$$\{n_{jt} - k_{jt} = r_{jt,r} - w_{jt,r}\}_{j=1}^J$$

$$\{m_{j'jt} = -\nu_m(p_{jt,r} - p_{j't,r}^m) + m_{j't}\}_{j=1}^J$$

$$\{y_{jt} = \sum_{z=1}^Z \gamma_{zj}^{y,m} m_{zjt} + \sum_{j=1}^J \gamma_{j'j}^{y,m} m_{j'jt} + \sum_{j=1}^J \gamma_{j'j}^{y,i} i_{j'jt}\}_{j=1}^J$$

Log–linearised system (iii)

Capital producers

$$\{p^i_{jt,r} = \sum_{j'=1}^{J} \psi_{jj'} p_{j't,r}\}_{j=1}^{J}$$

$$\{i_{j'jt} = -\nu_i(p_{jt,r} - p^i_{j't,r}) + i_{j't}\}_{j=1}^{J}$$

$$\{q_{jt,r} = p^i_{jt,r} + \epsilon_I[(i_{jt} - i_{jt-1}) + \beta\mathbb{E}_t(i_{jt} - i_{jt+1})] - (z_{i,j,t} + z_{i,t})\}_{j=1}^{J}$$

$$\{q_{jt,r} = -(r_t + z_{b,t} - \mathbb{E}_t(\pi^{pce}_{t+1})) + (1-\beta(1-\delta))\mathbb{E}_t r_{jt+1,r} + \beta(1-\delta)q_{jt+1,r}\}_{j=1}^{J}$$

$$\{\widetilde{k}_{jt+1} = (1-\delta)\widetilde{k}_{jt} - \Delta'(1)u_{jt} + \delta i_{jt} + \delta(z_{i,j,t} + z_{i,t})\}_{j=1}^{J}$$

$$\{k_{jt} = \widetilde{k}_{jt} + u_{jt}\}_{j=1}^{J}$$

$$\{r_{jt,r} = q_{jt,r} + \epsilon_U u_{jt}\}_{j=1}^{J}$$

Log–linearised system (iv)

Final goods producers

$$\{\pi_{zt}^{pce} = p_{zt,r} - p_{zt-1,r} + \pi_t^{pce}\}_{z=1}^{Z}$$

$$\{\pi_{zt}^{pce} = \gamma_{1,z}^{pce}\mathbb{E}_t\pi_{zt+1}^{pce} + \gamma_{2,z}^{pce}\pi_{zt-1}^{pce} + \gamma_{3,z}^{pce}(mc_{zt,r} - p_{zt,r} + (z_{c,z,t} + z_{c,t}))\}_{z=1}^{Z}$$

$$\{mc_{zt,r} = p_{zt,r}^{m}\}_{z=1}^{Z}$$

$$\{p_{zt,r}^{m} = \sum_{j=1}^{J}\kappa_{zj}p_{jt,r}\}_{z=1}^{Z}$$

$$\{y_{zt} = (1+\epsilon_c)m_{zt}\}_{z=1}^{Z}$$

$$\{y_{zt} = \gamma_z^{c}c_{zt} + \gamma_z^{g}g_{zt}\}_{z=1}^{Z}$$

$$\{m_{zjt} = -\nu_f(p_{jt,r} - p_{zt,r}^{m}) + m_{zt}\}_{z=1}^{Z}$$

Gross domestic product

$$gdp_t = \sum_{z=1}^{Z}\gamma_z^{gdp,c}(c_{zt} + p_{zt,r}) + \sum_{z=1}^{Z}\gamma_z^{gdp,g}(g_{zt} + p_{zt,r}) + \sum_{j=1}^{J}\gamma_j^{gdp,i}(i_{jt} + p_{jt,r}^{i})$$

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