Financial Frictions across the Production Network and the Transmission of Monetary Policy

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Motivation

- **Production networks** important in shaping transmission of common and idiosyncratic shocks.
- **Financial frictions** acting as amplifier/accelerator of monetary policy shocks

Research Question

How do financial frictions across the production network affect monetary policy transmission?

Paper Summary

- Use detailed production sector data + firm-level balance sheet data to build new measures of network leverage exposures.
- **Main results:**
  - ⇒ Leverage amplifies the effects of monetary tightening.
  - ⇒ Indirect (network) leverage exposure is especially important.
  - ⇒ Customers' leverage reinforces, suppliers' leverage mitigates effect of the shock.
- Rationalized in a multisector model.

Literature

1. Theoretical studies on **production networks**:
   Acemoglu et al. (2012); La'O and Tahbaz-Salehi (2022); Rubbo (2023); Bigio and La'O (2020)
2. Empirical studies on **sectoral monetary policy transmission**
   Ghassibe (2021); Durante et al. (2022); Borağan Aruoba and Drechsel (2024)
3. **Financial frictions and monetary policy transmission:**
   Bernanke and Gertler (1995); Bernanke et al. (1999); Ottonello and Winberry (2020); Jeenas (2018); Gilchrist et al. (2017); Adelino et al. (2023)
4. **Monetary policy shocks in local projections:**
   Borağan Aruoba and Drechsel (2024); Jordà and Taylor (2024); Ramey (2016); Ramey and Zubairy (2018); BarthIII and Ramey (2002)

Data

- **Country-sector panel** (monthly) for 20 euro area countries
- Dataset composed of **five building blocks**:
  1. **Macroeconomic indicators** at country level
  2. **Monetary policy shocks** via high-frequency identification (Altavilla et al., 2019; Jarociński and Karadi, 2020)
  3. **Sector-specific PPI and activity measures** at NACE-2 level granularity (64 sectors for each country)
  4. Data on **input-output linkages** by sector/country
  5. **Firm-level balance sheet** data from Orbis
- Final dataset spanning **2002m1 to 2024m12** (approx 250.000 observations)

Appendix

Indirect leverage measures

Combine the information from balance sheet with data on intersectoral flows to construct sectoral exposures to suppliers' and customers' leverage

$$\Phi_{ic,t_{12}} = (1 - a_{ic,t_{12}}) \sum_{j,d} 1(j \neq i, d \neq c) \nu_{ic,jd,t_{12}} \times \varphi_{jd,t_{12}}$$

$$\tilde{\Phi}_{ic,t_{12}} = (1 - \tilde{a}_{ic,t_{12}}) \sum_{j,d} 1(j \neq i, d \neq c) \tilde{\nu}_{ic,jd,t_{12}} \times \varphi_{jd,t_{12}}$$

Appendix

Empirical specification

- MP shock interaction w/ **sector *i*'s leverage ($\varphi_{ic,t}$)**
- MP shock interaction w/ sector *i*'s exposure to **leverage position of suppliers ($\Phi_{ic,t}$) and customers ($\tilde{\Phi}_{ic,t}$)**

$$\Delta_h y_{ic,t+h} = \underbrace{\beta_1^h \varphi_{ic,t_{12}-1} \times s_t}_{\text{Direct leverage effect}} + \underbrace{\overbrace{\beta_2^h \Phi_{ic,t_{12}-1} \times s_t}^{\text{Upstream effect}} + \overbrace{\beta_3^h \tilde{\Phi}_{ic,t_{12}-1} \times s_t}^{\text{Downstream effect}}}_{\text{Indirect leverage effect}} + \tag{1}$$

$$+ \beta_4^h s_t + \cdots + \epsilon_{ic,t+h}$$

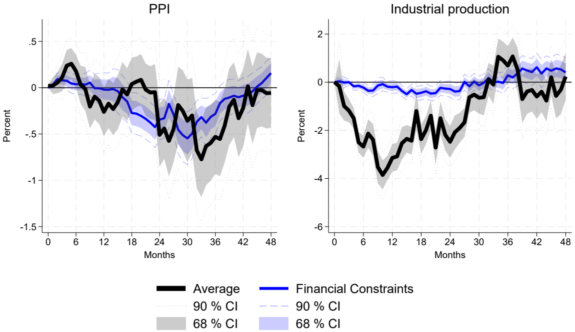
Appendix: Full model

Results

1. Overall response

- Prices and production fall in first 3 years after the MP shock
- Higher leverage (↑10% from sample average) across the network implies additional dampening in prices and activity

Figure: Impulse responses to 25bp tightening shock



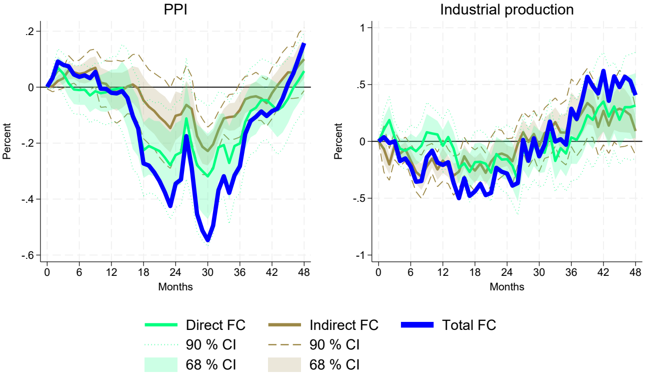
Working capital results

Results

2. Direct vs. indirect network leverage effects

- Exposure to leverage in the network as important as own leverage for transmission to prices.
- Effects broadly similar for industrial production.

Figure: Impulse responses to 25bp tightening shock

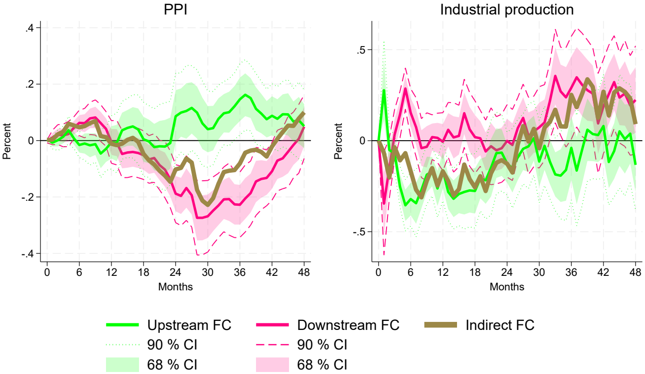


Results

3. Up- and downstream network leverage effects

- Exposure to suppliers' (customers') leverage mitigates (reinforces) transmission to prices.
- Mixed evidence on industrial production

Figure: Impulse responses to 25bp tightening shock



Model Structure

- Multi-sector static model with production networks and sector-specific working capital constraint.
- Builds on Bigio and La'O (2020), extended to:
  - ⇒ Capture heterogeneity in how monetary policy (i) affects each sector.
  - ⇒ Link transmission strength to sectoral financial positions via φ_i.
- Profit equation

$$\pi_i = p_i y_i - (1 + i\varphi_i)(L_i + \sum_{j \in K} p_j x_{i,j})$$

Key equations

Sector optimality conditions

$$p_i = (1 + i\varphi_i)mc_i,$$

$$mc_i = \frac{1}{z_i}\frac{(1-\alpha_i)^{\alpha_i - 1}}{\alpha_i^{\alpha_i}}\left(\prod_{i \in K} p_i^{\nu_{i,j}}\right)^{1-\alpha_i}.$$

HH consumption and market clearing

$$y_i = c_i + \sum_{j \in K} x_{j,i} \quad \forall\ i$$

$$c_i = \frac{P^c}{p_i}\nu_{ci}C \tag{2}$$

Empirical Mapping

- Model-implied derivative of sectoral prices:

$$\frac{d}{di}\log(p_i) \approx \varphi_i + \sum_{j \neq i} \nu_{i,j}\varphi_j \quad \text{(direct + upstream)}$$

- Model-implied interest-rate sensitivity of sectoral nominal output:

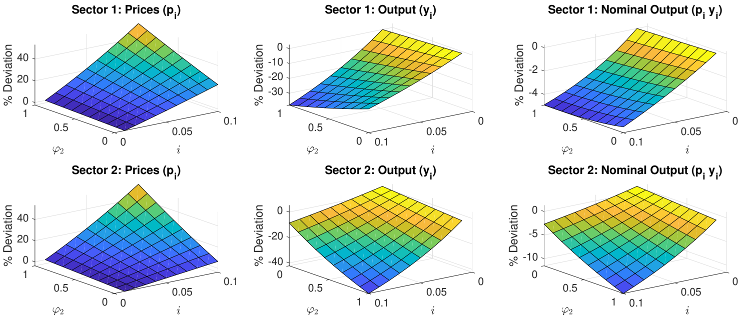
$$p_i y_i = P^c \nu_{ci} C + \sum_{j \neq i} \frac{\nu_{j,i}(1-\alpha_j)}{(1+\varphi_j i)} P^c \nu_{cj} C \quad \text{(downstream)}$$

General equations

Two-sector comparative statics

- Calibrated two-sector version ⇒ industry vs. services
- **Exercise**: Vary **policy rate** and sector 2's **financial position**
- **Results:**
  - ⇒ Higher i increases prices and reduces output across sectors
  - ⇒ Increasing φ_2 increases prices and reduces output in both sectors ⇒ **network transmission**

Figure: Policy rate and sectoral financial position



Conclusion

Key results

- Network leverage exposure important amplifier of disinflationary impact
- Up- and downstream leverage exposure affect prices in opposite directions
- Real/financial network amplifies effect of interest rate changes in a multisector model with working capital constraint.

Way forward

- Model a direct link between downstream leverage and prices (easy solution: segmented labor markets)
- Incorporate the mechanism in a 2-period NK model to disentangle conventional MP and network-financial effect.

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Appendix
Data - overview

Country-sector euro area panel

- 2-digit NACE info on producer price index, industrial production, turnover and employment, by country. From STS Eurostat dataset

Input-output data

- FIGARO tables at 2-digit NACE level (from 2010 to 2022).

Firm-level financial constraints measures

- Information on firm level balance sheet data from ORBIS (using the cleaning method from Kalemli-Ozcan et al. (2015))

Data

Input-output linkages

- Annual input-output (IO) linkages from Eurostat's FIGARO database (2010-2023)

Table: Simplified Multi-Country Input-Output Table

		Intermediate use				
		1A	**2A**	**1B**	**2B**	**Final use**
Intermed. input	**1A**	$z_{11}^{A,A}$	$z_{12}^{A,A}$	$z_{11}^{A,B}$	$z_{12}^{A,B}$	y_1^A
	2A	$z_{21}^{A,A}$	$z_{22}^{A,A}$	$z_{21}^{A,B}$	$z_{22}^{A,B}$	y_2^A
	1B	$z_{11}^{B,A}$	$z_{12}^{B,A}$	$z_{11}^{B,B}$	$z_{12}^{B,B}$	y_1^B
	2B	$z_{21}^{B,A}$	$z_{22}^{B,A}$	$z_{21}^{B,B}$	$z_{22}^{B,B}$	y_2^B
	VA+Labor	VA_1^A	VA_2^A	VA_1^B	VA_2^B	
	Taxes	T_1^A	T_2^A	T_1^B	T_2^B	

Appendix
Data - Input-output linkages

$$a_{1A} = \frac{y_1^A}{z_{11}^{A,A} + z_{12}^{A,A} + z_{11}^{A,B} + z_{12}^{A,B} + y_1^A} \tag{3}$$

$$\tilde{a}_{1A} = \frac{VA_1^A + T_1^A}{z_{11}^{A,A} + z_{21}^{A,A} + z_{11}^{B,A} + z_{21}^{B,A} + VA_1^A + T_1^A} \tag{4}$$

- Square IO matrix:

$$\boldsymbol{A} = \begin{bmatrix} z_{11}^{A,A} & z_{12}^{A,A} & z_{11}^{A,B} & z_{12}^{A,B} \\ z_{21}^{A,A} & z_{22}^{A,A} & z_{21}^{A,B} & z_{22}^{A,B} \\ z_{11}^{B,A} & z_{12}^{B,A} & z_{11}^{B,B} & z_{12}^{B,B} \\ z_{21}^{B,A} & z_{22}^{B,A} & z_{21}^{B,B} & z_{22}^{B,B} \end{bmatrix} \tag{5}$$

Data

Appendix

Data - Input-output linkages

- Matrix of technical coefficients $\boldsymbol{B}$: divide each element of $\boldsymbol{A}$ by total of respective column:

$$\boldsymbol{B} = \begin{bmatrix} \nu_{11}^{A,A} & \nu_{12}^{A,A} & \nu_{11}^{A,B} & \nu_{12}^{A,B} \\ \nu_{21}^{A,A} & \nu_{22}^{A,A} & \nu_{21}^{A,B} & \nu_{22}^{A,B} \\ \nu_{11}^{B,A} & \nu_{12}^{B,A} & \nu_{11}^{B,B} & \nu_{12}^{B,B} \\ \nu_{21}^{B,A} & \nu_{22}^{B,A} & \nu_{21}^{B,B} & \nu_{22}^{B,B} \end{bmatrix} \quad (6)$$

- Matrix of allocation coefficients $\boldsymbol{C}$: divide each element of $\boldsymbol{A}$ by the total of the rows:

$$\boldsymbol{C} = \begin{bmatrix} \tilde{\nu}_{11}^{A,A} & \tilde{\nu}_{12}^{A,A} & \tilde{\nu}_{11}^{A,B} & \tilde{\nu}_{12}^{A,B} \\ \tilde{\nu}_{21}^{A,A} & \tilde{\nu}_{22}^{A,A} & \tilde{\nu}_{21}^{A,B} & \tilde{\nu}_{22}^{A,B} \\ \tilde{\nu}_{11}^{B,A} & \tilde{\nu}_{12}^{B,A} & \tilde{\nu}_{11}^{B,B} & \tilde{\nu}_{12}^{B,B} \\ \tilde{\nu}_{21}^{B,A} & \tilde{\nu}_{22}^{B,A} & \tilde{\nu}_{21}^{B,B} & \tilde{\nu}_{22}^{B,B} \end{bmatrix} \quad (7)$$

- Account for higher-order effects by deriving Leontief and Gosh inverses (Acemoglu et al., 2016)

$$\boldsymbol{L} \equiv (\boldsymbol{I} - \boldsymbol{B})^{-1} = \begin{bmatrix} \omega_{11}^{A,A} & \omega_{12}^{A,A} & \omega_{11}^{A,B} & \omega_{12}^{A,B} \\ \omega_{21}^{A,A} & \omega_{22}^{A,A} & \omega_{21}^{A,B} & \omega_{22}^{A,B} \\ \omega_{11}^{B,A} & \omega_{12}^{B,A} & \omega_{11}^{B,B} & \omega_{12}^{B,B} \\ \omega_{21}^{B,A} & \omega_{22}^{B,A} & \omega_{21}^{B,B} & \omega_{22}^{B,B} \end{bmatrix} \tag{8}$$

$$\boldsymbol{G} \equiv (\boldsymbol{I} - \boldsymbol{C})^{-1} = \begin{bmatrix} \tilde{\omega}_{11}^{A,A} & \tilde{\omega}_{12}^{A,A} & \tilde{\omega}_{11}^{A,B} & \tilde{\omega}_{12}^{A,B} \\ \tilde{\omega}_{21}^{A,A} & \tilde{\omega}_{22}^{A,A} & \tilde{\omega}_{21}^{A,B} & \tilde{\omega}_{22}^{A,B} \\ \tilde{\omega}_{11}^{B,A} & \tilde{\omega}_{12}^{B,A} & \tilde{\omega}_{11}^{B,B} & \tilde{\omega}_{12}^{B,B} \\ \tilde{\omega}_{21}^{B,A} & \tilde{\omega}_{22}^{B,A} & \tilde{\omega}_{21}^{B,B} & \tilde{\omega}_{22}^{B,B} \end{bmatrix} \tag{9}$$

Data

$$
\begin{aligned}
y_{ic,t+h} = {} & \underbrace{\beta_1^h \varphi_{ic,t_{12}-1} \times s_t}_{\substack{\text{Direct financial}\\ \text{constraints effect}}} + \underbrace{\overbrace{\beta_2^h \Phi_{ic,t_{12}-1} \times s_t}^{\text{Upstream effect}} + \overbrace{\beta_3^h \tilde{\Phi}_{ic,t_{12}-1} \times s_t}^{\text{Downstream effect}}}_{\substack{\text{Indirect financial constraints}\\ \text{effect}}} + \\
& \underbrace{\beta_4^h a_{ic,t_{12}-1} \times s_t + \beta_5^h \tilde{a}_{ic,t_{12}-1} \times s_t + \beta_6^h s_t}_{\text{Non-network effect}} + \sum_{l=0}^{L} \boldsymbol{\gamma^h H_{t-l}} \\
& + \sum_{l=1}^{L} \boldsymbol{\delta^h K_{t-l}} + \sum_{l=0}^{L} \boldsymbol{\eta^h X_{t-l}} + \theta_{t_{12}} + \kappa_{t+h} + \epsilon_{ic,t+h} \qquad (10)
\end{aligned}
$$

Main

Appendix
Empirical specification

- **Matrix** H_t contains sector-level variables unrelated to the monetary shock. **Matrix** K_t collects lags of the dependent variable and shock variables:

$$H_t = \begin{bmatrix} a_{ic,t_{12}-1} \\ \tilde{a}_{ic,t_{12}-1} \\ \varphi_{ic,t_{12}-1} \\ \Phi_{ic,t_{12}-1} \\ \tilde{\Phi}_{ic,t_{12}-1} \end{bmatrix}, \quad K_t = \begin{bmatrix} \Delta y_{ic,t} \\ \varphi_{ic,t_{12}-1} \times s_t \\ a_{ic,t_{12}-1} \times s_t \\ \tilde{a}_{ic,t_{12}-1} \times s_t \\ \Phi_{ic,t_{12}-1} \times s_t \\ \tilde{\Phi}_{ic,t_{12}-1} \times s_t \\ s_t \end{bmatrix}$$

- **Matrix** X_t contains a set of macro-financial controls

Main

Appendix

Empirical specification - details

Estimation Method:

- Model estimated in long-differences: $\Delta x_t = x_t - x_{t-1}$.
- Results are robust to levels estimation.
- Coefficients capture sector-level responses to monetary policy shocks via direct, indirect, and non-network channels.

Controls:

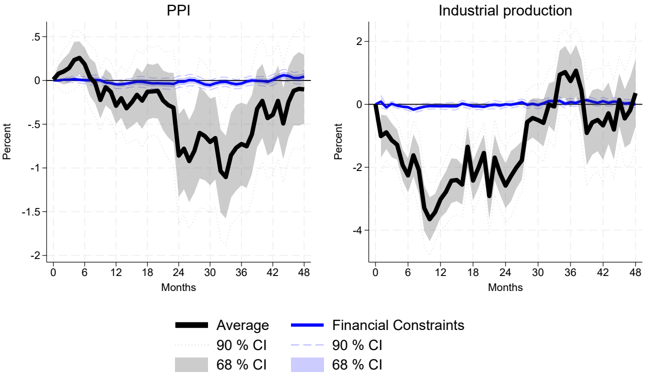
- Sectoral lags (dependent variable and shock variables).
- Macroeconomic controls: OIS rates, sovereign yields, FX rates, CISS, HICP, unemployment.
- Fixed effects: month-level fixed effects (θ_t) and Covid-19 dummy (κ_{t+h}).

Main

Appendix

1. Overall financial constraints effect - Working Capital

Figure: Impulse responses to 25bp tightening shock - working capital



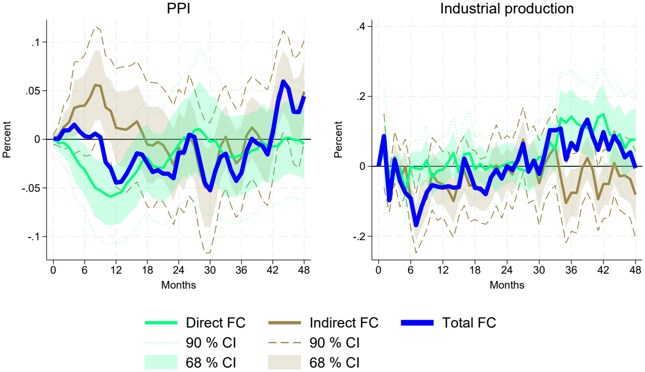
Back to main results

Appendix

2. Direct vs. indirect network financial constraints effects - Working Capital

- Heterogeneous direct and indirect working capital effects
- Indirect effects particularly important for prices

Figure: Impulse responses to 25bp tightening shock - working capital



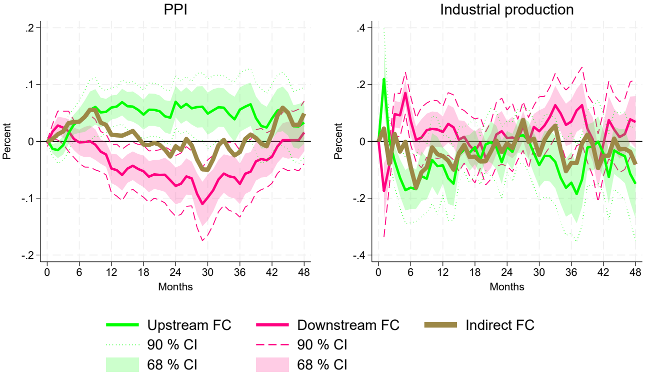
Back to main results

Appendix

3. Up- and downstream network financial constraints effects - WC

- Downstream working capital constraints reinforce drop in prices and output
- Upstream constraints dampen drop in prices and output

Figure: Impulse responses to 25bp tightening shock - working capital



General expressions

$$\frac{d}{di}\log(p_i) \approx [1+\nu_{i,i}(1-\alpha_i)]\varphi_i + \nu_{i,i}(1-\alpha_i)\frac{mc_i'(i)}{mc_i(i)} + (1-\alpha_i)\sum_{j\neq i}\nu_{i,j}\left(\varphi_j + \frac{mc_j'(i)}{mc_j(i)}\right)$$

$$p_i y_i = \nu_{ci}P^c C + \frac{\nu_{i,i}(1-\alpha_i)}{(1+\varphi_i i)}(\nu_{ci}P^c C + \sum_{s\in K} P^s \nu_{s,i} x_s) + \sum_{j\neq i}\frac{\nu_{j,i}(1-\alpha_j)}{(1+\varphi_j i)}(\nu_{cj}P^c C + \sum_{s\in K} P^s \nu_{s,j} x_s)$$

Model Setup and Calibration

- Two-sector model calibrated to match European **industry** (sector 1) and **services** (sector 2).
- Input-output shares ($\nu_{i,j}$) calibrated to Eurostat FIGARO data:
  - ⇒ Industry: 60% industry, 40% services inputs
  - ⇒ Services: 20% industry, 80% services inputs
- Final consumption shares (ν_{ci}): 55% goods, 45% services (COICOP).
- Other parameters (e.g. φ_i, α_i) set uniformly across sectors.

Real Input Linkages and Financial Exposure

- We vary ν_{12} to capture sector 1's reliance on sector 2.
- Key takeaways:
  - ⇒ Higher ν_{12} raises sector 2 output, lowers sector 1 output.
  - ⇒ Prices remain unchanged—confirming price sensitivity is tied to financing frictions.

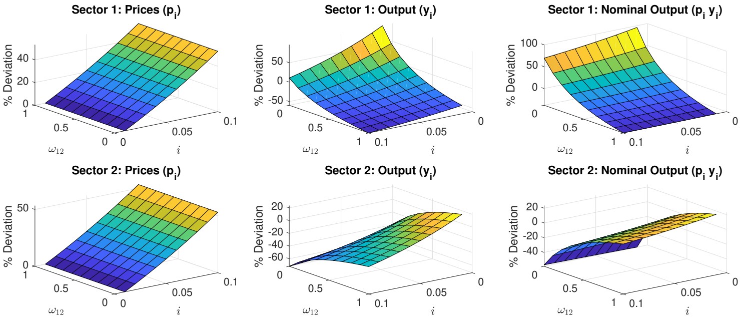


Fig: Impact of input share ν_{12} and i on sectoral output.

Interaction: Financial Frictions & Input Linkages

- We now vary both: Sector 2's **financial friction** φ_2 and Sector 1's reliance on services via **input share** ν_{12}
- As φ_2 tightens, higher ν_{12} amplifies the contraction in sector 1 output. Clear non-linearities: network exposure intensifies effects of financial shocks.

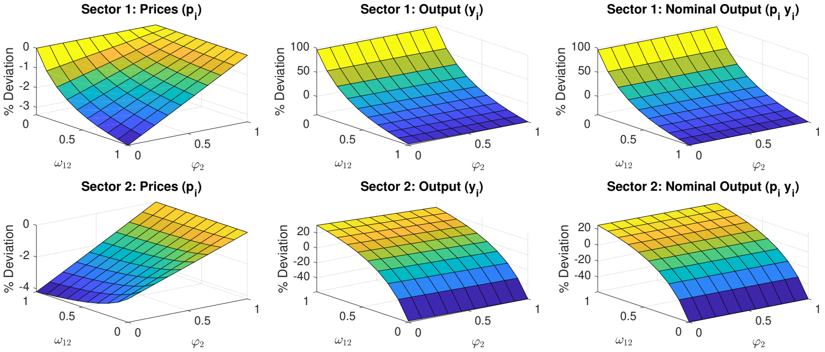


Fig: Joint variation of φ_2 and ν_{12}—sectoral output and price responses.

Network Amplification Effects

- We compare the full model to an **isolationist economy** (no input linkages, $\alpha_i = 1$).
- **Amplification evidence:**
  - $\Rightarrow$ Without network effects, sector 1's price rise is up to 44 pp lower.
  - $\Rightarrow$ Output drop is 34 pp smaller in the isolationist model.
- Rationalizes empirical result: interest rate changes transmit via production networks.