Investment Networks, Sectoral Comovement, and the Changing U.S. Business Cycle

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Motivation

- Want to understand sources of business cycle fluctuations
- Motivation: change in cyclicality of aggregate labor productivity
  - Pre-1984: highly procyclical
  - Post-1984: roughly acyclical
- Post-1984 period inconsistent with benchmark RBC model driven by aggregate TFP shocks
- Literature has suggested changes in the shock process or in propagation mechanisms

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- Literature has suggested changes in the shock process or in propagation mechanisms
- **Our paper**: sectoral investment network crucial to understand declining cyclicality of labor productivity
  - Changing cyclicality of labor productivity reflects shocks to "investment hubs" become more important

Our Contributions

New empirical facts using sector-level BEA data 1947 - 2017

1. Cyclicality of labor productivity is stable within sectors
2. Entire decline is due to changes in covariances across sectors

$\implies$ must understand changing nature of sectoral comovement

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Multisector business cycle model driven by observed series of sector-level productivity

- Shocks become less correlated post-1984 ("Great Moderation")
- Matches new empirical facts only w/ realistic investment network
- Post-1984: shocks to investment hubs relatively more important and aggregate labor productivity countercyclical in response
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- Post-1984: shocks to investment hubs relatively more important and aggregate labor productivity countercyclical in response
  - Generate large changes in employment across sectors
- Hubs’ value added predicts agg. employment better than GDP and targeting hubs can improve cost-effectiveness of stimulus

Empirical Results

Data Source

BEA industry database, 1947 - 2017 annual

extended to include finer disaggregation of manufacturing ▸ Details

Mining	Utilities
Construction	Wood products
Non-metallic minerals	Primary metals
Fabricated metals	Machinery
Computer and electronic manufacturing	Electrical equipment manufacturing
Motor vehicles manufacturing	Other transportation equipment
Furniture and related manufacturing	Misc. Manufacturing
Food and beverage manufacturing	Textile manufacturing
Apparel manufacturing	Paper manufacturing
Printing products manufacturing	Petroleum and coal manufacturing
Chemical manufacturing	Plastics manufacturing
Wholesale trade	Retail trade
Transportation and warehousing	Information
Finance and insurance	Professional and business services
Management of companies and enterprises	Administrative and waste management services
Educational services	Health care and social assistance
Arts, entertainment, and recreation services	Accommodation and food services
Other services	

Changes in the Aggregate Business Cycle

	Aggregated		**Within-Sector**	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.27%	1.36%		
$\rho(y_t - l_t, y_t)$	0.65	0.26		

- y_t = log of value added
- l_t = log of employment
- All variables have been HP filtered with smoothing = 6.25
- Within-sector averages weighted by value-added shares

Cyclicality of Labor Productivity Implied by Rising Volatility of Employment

$$\mathbb{C}orr(y_t, y_t - l_t) = f\left(\mathbb{C}orr(y_t, l_t), \frac{\sigma(l_t)}{\sigma(y_t)}\right)$$

$$= \frac{1 - \frac{\sigma(l_t)}{\sigma(y_t)}\mathbb{C}orr(y_t, l_t)}{\sqrt{1 + \frac{\sigma(l_t)^2}{\sigma(y_t)^2} - 2\frac{\sigma(l_t)}{\sigma(y_t)}\mathbb{C}orr(y_t, l_t)}}$$

Components of Labor Productivity

	Pre-1984	*Post-1984*
$\mathbb{C}orr(y_t - l_t, y_t)$	0.65	0.26
$\mathbb{C}orr(y_t, l_t)$	0.81	0.83
$\mathbb{C}orr(y_t, l_t)$ only	0.65	0.66
$\sigma(l_t)/\sigma(y_t)$	0.76	1.02
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- Inconsistent with RBC model driven by aggregate TFP shocks because aggregate TFP affects output and employment linearly

Divergence of Aggregate and Within-Sector Cycles

	Aggregated		Within-Sector	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.27%	1.36%	3.58%	3.00%
$\rho(y_t - l_t, y_t)$	0.65	0.26	0.73	0.71
$\sigma(l_t)/\sigma(y_t)$	0.75	1.02	0.65	0.65

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▸ Alt. Weights ▸ First Differences

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How to Reconcile? Changing Comovement

$$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)} \approx \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N}(\omega_{jt}^{l})^2\mathbb{V}ar(l_{jt})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t)\underbrace{\frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{l}\omega_{ot}^{l}\mathbb{C}ov(l_{jt},l_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt},y_{ot})}}_{\text{between-sector}}$$

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	Pre-84	*Post-84*	*Contribution of entire term*
$\frac{\mathbb{V}ar(I_t)}{\mathbb{V}ar(y_t)}$	0.57	0.94	**100%**
Within Sector	0.40	0.39	13%
Between Sector	0.59	1.10	87%
Within Weight	0.11	0.23	
$(\omega_t = \sum_{j=1}^N (\omega_{jt}^y)^2 \mathbb{V}ar(y_{jt}) / \mathbb{V}ar(y_t))$			

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$$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)} \approx \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N}(\omega_{jt}^{l})^2 \mathbb{V}ar(l_{jt})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2 \mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t) \underbrace{\frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{l}\omega_{ot}^{l}\mathbb{C}ov(l_{jt}, l_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt}, y_{ot})}}_{\text{between-sector}}$$

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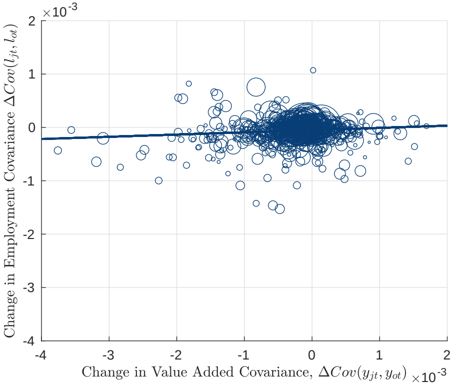
- Comovement of output falls $\Longrightarrow$ aggregate volatility falls
- Comovement of employment stable $\Longrightarrow$ agg. volatility stable

Derivation | Accuracy | Fixed Weights | First Diffs | Correlations | Distribution

Changes in Covariances, Pre vs. Post 1984



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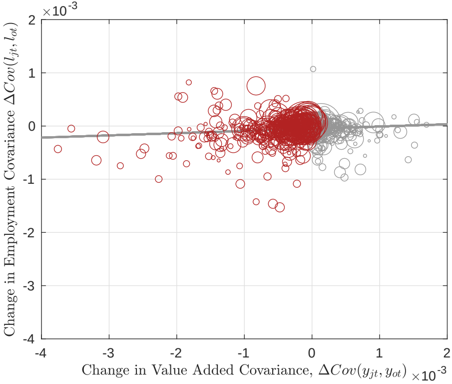
Value Added Covariances Fall Substantially



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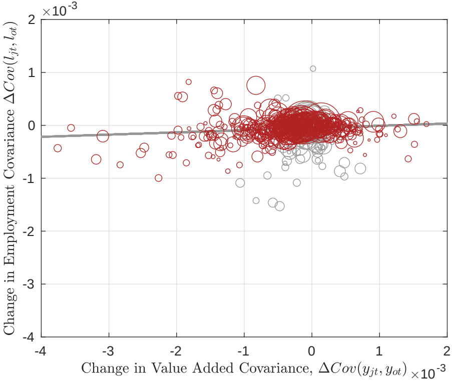
82% of $|\Delta\mathbb{C}ov(l_{jt}, l_{ot})|$ are less than $|\Delta\mathbb{C}ov(y_{jt}, y_{ot})|$



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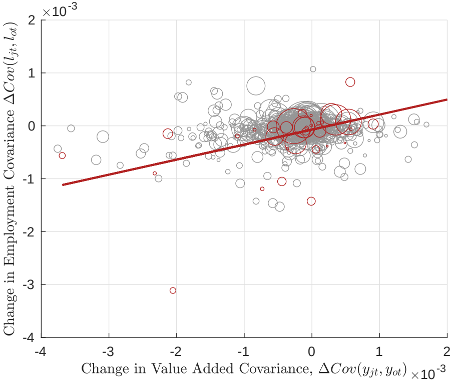
Within-Sector Variances Move Together (Coeff $\approx$ .3)



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Additional Results on the Decomposition

1. Results hold at finer disaggregation (450 manufacturing sectors), but not for goods vs. services ▸ Details

2. Aggregate factor becomes less important for output, but not for employment ▸ Details

3. Changes in investment volatility and comovement similar to that of employment ▸ Details

Existing Explanations for Changing Business Cycles

1. **Changing shock process**:
   - Aggregate demand shocks: Gali and Gambetti (2009); Barnichon (2010); Sarte, Schwartzman, and Lubik (2015)
   - Reallocation shocks become more important: Garin, Pries, and Sims (2018)
2. **More flexible labor markets**: Barnichon (2010), Gali-van Rens (2013)
3. **Selective hiring/firing**:
   - Streamline in recessions: Koenders-Rogerson (2005); Berger (2018)
   - Labor hoarding: Gali-Gambetti (2009); Bachmann (2012)
4. **Mismeasurement of inputs or outputs**:
   - Utilization less procyclical: Fernald- Wang (2016)
   - Non-measured intangible investment is procyclical: McGrattan-Prescott (2007, 2012); McGrattan (2017)

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Existing mechanisms abstract from sectoral heterogeneity,
$\Longrightarrow$ need new explanation for falling cyclicality of labor productivity

Model

Production

- Fixed number of sectors $j \in \{1, ..., N\}$
- Gross output Q_{jt} produced according to

$$Q_{jt} = A_{jt} \left(K_{jt}^{\alpha_j} L_{jt}^{1-\alpha_j} \right)^{\theta_j} X_{jt}^{1-\theta_j}$$

- Intermediates input-output network

$$X_{jt} = \Pi_{i=1}^{N} M_{ijt}^{\gamma_{ij}}, \quad \text{where } \sum_{i=1}^{N} \gamma_{ij} = 1$$

- TFP shocks

$$\log A_{jt+1} = \rho_j \log A_{jt} + \varepsilon_{jt+1}, \quad \text{where } (\varepsilon_{1t}, ..., \varepsilon_{Nt})' \sim N(0, \Sigma_t)$$

Investment

- Capital accumulation technology

$$K_{jt+1} = (1 - \delta_j)K_{jt} + I_{jt}$$

- Investment input-output network

$$I_{jt} = \Pi_{i=1}^{N} I_{ijt}^{\lambda_{ij}}, \quad \text{where} \sum_{i=1}^{N} \lambda_{ij} = 1$$

Household and Equilibrium

- Representative household with preferences

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t - L_t\right), \quad \text{where } C_t = \Pi_{j=1}^{N} C_{jt}^{\xi_j} \text{ and } \sum_{j=1}^{N} \xi_j = 1$$

- Output market clearing

$$C_{jt} + \sum_{i=1}^{N} M_{jit} + \sum_{i=1}^{N} I_{jit} = Q_{jt}$$

- Labor market clearing

$$\sum_{j=1}^{N} L_{jt} = L_t$$

Calibration

Calibration Overview

- **Thought experiment**: feed in changing shock process, holding structure of the economy fixed
  - TFP shocks become less correlated across sectors
  - Main challenge: generate stable comovement of employment

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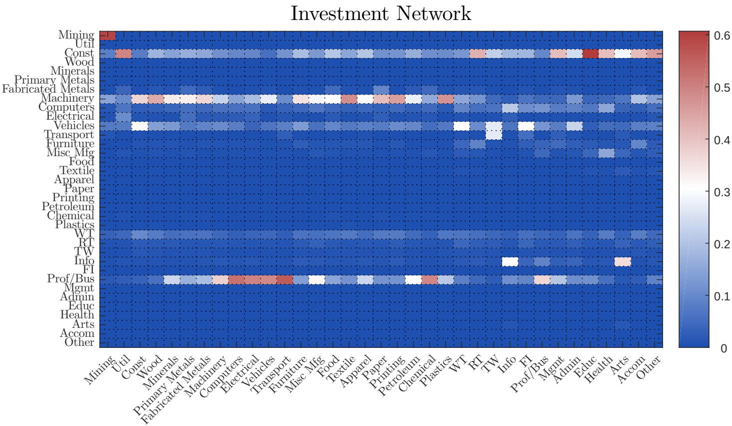
  - TFP shocks become less correlated across sectors
  - Main challenge: generate stable comovement of employment

- Calibrate model in two steps:
  1. All parameters other than shocks constant over time ▸ Details
  2. Feed in measured TFP shocks observed in sectoral data

- Results robust to allowing structure of economy to change
  $\implies$ shock process key change over this period

Empirical Investment Network



- Four investment hubs: construction, machinery, motor vehicles, professional/business services (mostly intellectual property)
- Supply approximately 2/3 of aggregate investment

Measurement of Shock Process

$$\log A_{jt+1} = \rho_j \log A_{jt} + \varepsilon_{jt+1}, \text{ where } (\varepsilon_{1t}, ..., \varepsilon_{Nt})' \sim N(0, \Sigma_t)$$

- Measure sector-level TFP A_{jt} as Solow residual, log-polynomially detrended ▸ Details
- **Persistence parameters** ρ_j: persistence over whole sample ▸ Details
- We linearize the model, so Σ_t does not affect decision rules $\implies$ **feed in measured shocks** and simulate

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- We linearize the model, so Σ_t does not affect decision rules $\Longrightarrow$ **feed in measured shocks** and simulate
- Robustness: estimate covariance matrix separately for pre vs. post subsamples and compute population moments
  - Empirical estimates not full rank since $N = 35 > T$, so collapse number of sectors to $N = 28 < T$ ▸ Details

Measured Shock Process

$$\mathbb{V}ar(x_t) = \underbrace{\sum_{j=1}^{N} (\omega_{jt}^{y})^2 \mathbb{V}ar(x_{jt})}_{\text{within-sector}} + \underbrace{\sum_{j=1}^{N} \sum_{o \neq j} \omega_{jt}^{y} \omega_{ot}^{y} \mathbb{C}ov(x_{jt}, x_{ot})}_{\text{between-sector}}$$

	Measured TFP		**HP-Filtered Value Added**	
	Pre-84	*Post-84*	*Pre-84*	*Post-84*
$100\mathbb{V}ar(x_t)$	0.19	0.10	0.52	0.19
Within Sector	0.03	0.04	0.06	0.05
Between Sector	0.16	0.06	0.46	0.14

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Helpful special case for interpretation: $\log A_t + \log \widehat{A}_{jt}$

- Declining covariances $\implies$ aggregate shock less volatile
- Consistent with principal components analysis ▸ Details

Quantitative Results

Model Matches Aggregate Business Cycle Changes

Data	*Aggregated*		*Within-Sector*	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.27%	1.36%	3.58%	3.00%
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$\sigma(l_t)/\sigma(y_t)$	0.76	1.02	0.65	0.65
Model				
$\sigma(y_t)$	2.60%	2.24%	4.03%	4.18%
$\rho(y_t - l_t, y_t)$	0.90	0.45	0.82	0.80
$\sigma(l_t)/\sigma(y_t)$	0.74	0.92	0.48	0.51

- Model generates decline in cyclicality of labor productivity and rise in relative employment volatility
- Model also generates 40% of decline in aggregate GDP volatility ("Great Moderation")

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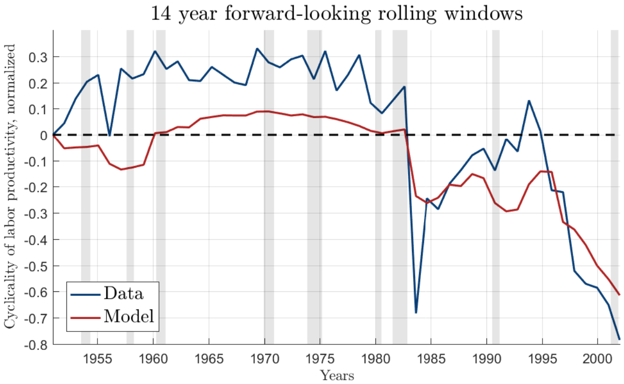

- Model matches timing of change in labor productivity cyclicality (measured using 14-year forward-looking rolling windows)

Model Consistent with Sectoral Decomposition

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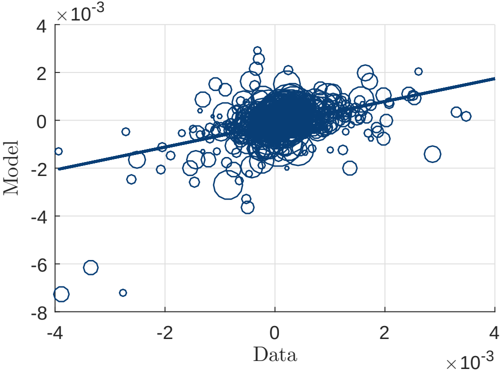
$$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)} = \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N} (\omega^{l}_{jt})^2 \mathbb{V}ar(l_{jt})}{\sum_{j=1}^{N} (\omega^{y}_{jt})^2 \mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t) \underbrace{\frac{\sum_{j=1}^{N} \sum_{o \neq i} \omega^{l}_{jt}\omega^{l}_{ot}\mathbb{C}ov(l_{jt}, l_{ot})}{\sum_{j=1}^{N} \sum_{o \neq i} \omega^{y}_{jt}\omega^{y}_{ot}\mathbb{C}ov(y_{jt}, y_{ot})}}_{\text{between-sector}}$$

	Data			**Model**		
	Pre-84	*Post-84*	*Cont.*	*Pre-84*	*Post-84*	*Cont.*
$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)}$	0.57	0.94	**100%**	0.55	0.84	**100%**
Within Sector	0.40	0.39	13%	0.47	0.47	11%
Between Sector	0.59	1.10	87%	0.56	0.92	89%
Within Weight	0.11	0.23		0.11	0.18	
$(\omega_t = \sum_{j=1}^{N} (\omega^{y}_{jt})^2 \mathbb{V}ar(y_{jt}) / \mathbb{V}ar(y_t))$						

▸ Pop moments ▸ Changing parms ▸ GHH ▸ Frisch ▸ Maintenance ▸ Capital ACs

Model Consistent with Sectoral Decomposition



- Plot *sector-pair level* "diff-in-diff" $\Delta\mathbb{C}ov(n_{jt}, n_{ot}) - \Delta\mathbb{C}ov(y_{jt}, y_{ot})$
- Model's $R^2 = 27\%$!

Main Challenge: Changing Comovement Patterns

$$\rho_\tau^x \equiv \frac{\sum_{i=1}^N \sum_{j=i+1}^N \omega_i^x \omega_j^x \mathbb{C}orr(x_{jt}, x_{jt} | t \in \tau)}{\sum_{i=1}^N \sum_{j=i+1}^N \omega_i^x \omega_j^x}$$

- x_{jt} is HP-filtered + logged variable of interest
- $\omega_{i\tau}^x = \mathbb{E}[\frac{x_{jt}}{x_s}]$ are sectoral weights
- $\tau \in$ {pre 1984, post 1984} is time period

	Data		**Model**	
	Employment	*Value added*	*Employment*	*Value added*
1951-1983	0.55	0.36	0.88	0.35
1984-2012	0.51	0.17	0.84	0.19
Difference	-0.04	-0.19	-0.04	-0.17

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- $\tau \in \{\text{pre 1984, post 1984}\}$ is time period

	Model		**Model, no investment net.**	
	Employment	*Value added*	*Employment*	*Value added*
1951-1983	0.88	0.35	0.39	0.28
1984-2012	0.84	0.19	0.20	0.10
Difference	-0.04	-0.17	-0.19	-0.18

Without investment network, model does not match comovement and produces no change in labor productivity cyclicality (0.87 to 0.91)

Mechanism

Special Case to Explain the Mechanism

- $N = 2$ sectors, $j \in \{1, 2\}$
- Sector j productivity: $\log A_{jt} = \log A_t + \log \widehat{A}_{jt}$
  - Aggregate shock follows: $\log A_t = \rho \log A_{t-1} + \varepsilon_t$
  - Sector-specific shock follows: $\log \widehat{A}_{jt} = \rho \log \widehat{A}_{jt-1} + \varepsilon_{jt}$

  $\implies \mathbb{C}ov(\log A_{1t}, \log A_{2t}) = \mathbb{V}ar(\log A_t)$
- Changing shock process: aggregate vs. sectoral components
  - *Pre-1984*: $\sigma(\varepsilon_t) = 0.01$ and $\sigma(\varepsilon_{jt}) = 0.00$
  - *Post-1984*: $\sigma(\varepsilon_t) = 0.00$ and $\sigma(\varepsilon_{jt}) = 0.01$
- Network structure mimics calibrated model
  - Sector 1 is investment hub: $\lambda_{11} = \lambda_{12} = 1$
  - Uniform intermediates network: $1 - \theta_j = 0.4$
- Less important paramaters set to standard values:

  $\beta = 0.96, \xi = 0.5, \delta = 0.10, \rho = 0.7$

Pre-1984 Period: Effect of Aggregate Shock

Value added: generates correlated increase in both sectors

$$Y_{jt} = \frac{1}{\theta_j} \log A_t + \alpha_j \log K_{jt} + (1 - \alpha_j) \log N_{jt}$$

Employment: generates correlated increase in both sectors

- Quantitatively depends on strength of two effects
  - Direct effect: increases $\Delta MPN_{jt} > 0$, holding N_{jt} fixed
  - Indirect effect: increases consumption $\Delta C_{jt} > 0$

$$\frac{MPN_{1t}}{C_{1t}} = \chi \left(N_{1t} + N_{2t}\right)^{\frac{1}{\eta}} = \frac{MPN_{2t}}{C_{2t}}$$

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- Larger investment response $\implies$ larger employment response (weaker indirect effect ΔC_{jt})

Post-1984 Period: Effect of Idiosyncratic Shocks

Value added: uncorrelated shocks $\implies$ responses less correlated

- Small spillovers through intermediates network, e.g.

$$\frac{1}{C_{1t}} = MPX_{2t}\frac{1}{C_{2t}}$$

Post-1984 Period: Effect of Idiosyncratic Shocks

Value added: uncorrelated shocks $\implies$ responses less correlated

Employment: primarily response to sector 1-specific shock

- Sector 1-specific shock $\approx$ "investment supply shock"

$$\underbrace{\frac{1}{C_{1t}}}_{\text{marginal cost of capital}} = \beta\left(\frac{1}{C_{jt+1}} MPK_{jt+1} + (1-\delta)\frac{1}{C_{1t+1}}\right)$$

- Increased consumption $\Delta C_{1t} > 0$ lowers cost of capital for both sectors $\implies$ raises investment ($\Delta MPK_{jt+1} < 0$)

Post-1984 Period: Effect of Idiosyncratic Shocks

Value added: uncorrelated shocks $\implies$ responses less correlated

Employment: primarily response to sector 1-specific shock

- Sector 1-specific shock ≈ "investment supply shock"

$$\frac{MPN_{1t}}{C_{1t}} = \chi \left(N_{1t} + N_{2t}\right)^{\frac{1}{\eta}} = \frac{MPN_{2t}}{C_{2t}}$$

  - Sector 1 employment increases to supply investment goods
  - Sector 2 employment increases to supply intermediates to sector 1

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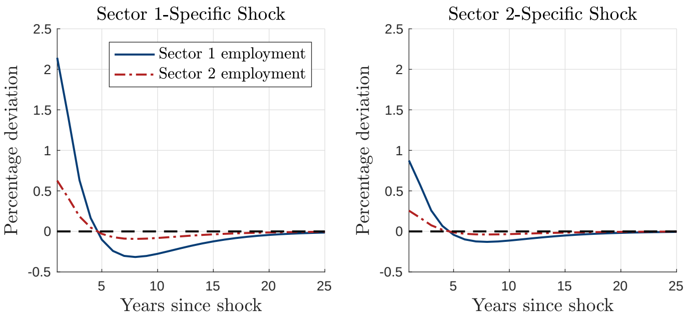
  - Sector 2 employment increases to supply intermediates to sector 1

- Sector-2 specific shock ≈ idiosyncratic "investment demand shock" $\implies$ small effect on aggregate investment/employment

Post-1984 Period: Effect of Idiosyncratic Shocks

Value added: uncorrelated shocks $\implies$ responses less correlated

Employment: primarily response to sector 1-specific shock



▸ Also true in full model

Changing Business Cycles

	Aggregate shocks (≈ pre-1984)	**Sectoral shocks** (≈ post-1984)
$\text{Corr}(y_{1t}, y_{2t})$	0.99	0.23
$\sigma(y_t)$	1.48%	1.25%
$\text{Corr}(n_{1t}, n_{2t})$	1.00	1.00
$\sigma(n_t)$	0.91%	1.04%
$\sigma(n_t)/\sigma(y_t)$	0.62	0.83
$\text{Corr}(y_t - n_t, y_t)$	0.96	0.57

- Value added primarily driven by sector-specific shocks
  - Sector-level value added becomes less correlated
  - Aggregate value added becomes less volatile

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- Employment primarily driven by investment hub shocks
  - Sector-level employment correlations are stable
  - Aggregate employment volatility is stable

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- Employment primarily driven by investment hub shocks
  - Sector-level employment correlations are stable
  - Aggregate employment volatility is stable
- Therefore, relative volatility of employment increases
  $\implies$ aggregate labor productivity becomes less cyclical

Supporting Evidence of Mechanism

1. Volatility of aggregate investment rises relative to output in the post-1984 period ▸ Details

2. Investment comovement is stable post-1984 and accounts for rise in relative volatility of investment ▸ Details

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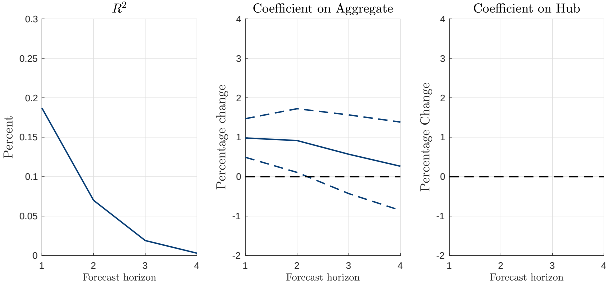
3. Investment hub shocks become more volatile and more correlated post-1984 ▸ Details

4. Spillovers from investment hubs onto aggregate employment stronger than spillovers for non-hubs ▸ Details

More Aggregate Implications Of Investment Network

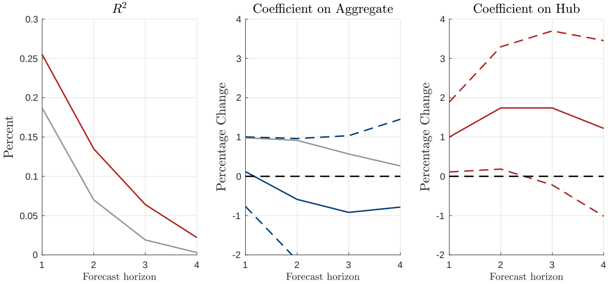
Forecasting Aggregate Employment



$$\log N_{t+h} - \log N_t = \alpha + \gamma(\log Y_t - \log Y_{t-1}) + \varepsilon_{t+h}$$

GDP growth rate is standardized

Forecasting Aggregate Employment

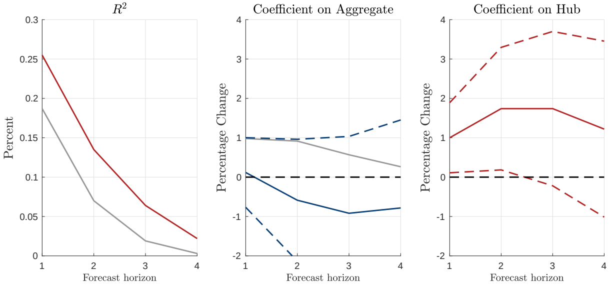


$$\log N_{t+h} - \log N_t = \alpha + \gamma(\log Y_t - \log Y_{t-1}) + \beta(\log y_{st} - \log y_{st-1}) + \varepsilon_{t+h}$$

$\log y_{st} - \log y_{st-1}$ = growth rate of hubs' value added

(y_{st} = aggregated across hubs, RHS variables standardized)

Forecasting Aggregate Employment



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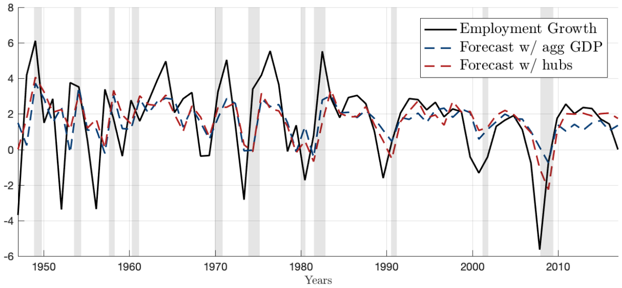
$\log y_{st} - \log y_{st-1} =$ growth rate of hubs' value added

($y_{st} =$ aggregated across hubs, RHS variables standardized)

- Despite the fact that hubs are 10% of aggregate GDP!

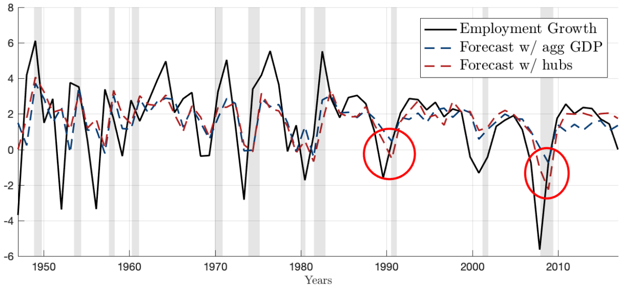
Fitted Values From Forecasting Regression



$$\log N_{t+1} - \log N_t = \alpha + \beta(\log y_{hubs,t} - \log y_{hubs,t-1}) + \varepsilon_{t+h} \text{ vs.}$$

$$\log N_{t+1} - \log N_t = \alpha + \beta(\log Y_t - \log Y_{t-1}) + \varepsilon_{t+h}$$

Fitted Values From Forecasting Regression



$$\log N_{t+1} - \log N_t = \alpha + \beta(\log y_{hubs,t} - \log y_{hubs,t-1}) + \varepsilon_{t+h} \text{ vs.}$$

$$\log N_{t+1} - \log N_t = \alpha + \beta(\log Y_t - \log Y_{t-1}) + \varepsilon_{t+h}$$

- Hubs especially improve forecasts in post-1984 recessions (and subsequent "jobless recoveries")

Improving Cost-Effectiveness of Stimulus Policies

- Goal of many countercyclical stimulus policies is to generate broad-based increase in aggregate employment
- Often work by increasing aggregate demand for goods
- **Our model**: resources spent on hubs have larger bang-for-the-buck than resources spent at non-hubs
- **Back of the envelope** (in two-sector model for now): production subsidy τ_t financed lump-sum from own-sector output

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- **Back of the envelope** (in two-sector model for now): production subsidy τ_t financed lump-sum from own-sector output

	$\%\Delta N_t$	$\%\Delta Y_t$
Blanket 1% subsidy	1.8	1.1
Cost-equivalent hub subsidy	3.5	0.8

$\Longrightarrow$ targeting hubs doubles bang-for-the-buck

Conclusion

Our contributions

1. Decline in cyclicality of aggregate labor productivity driven by changes in sectoral comovement, not changes within sectors

2. Rising importance of investment hubs accounts for declining cyclicality and changing comovement

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Investment network important for aggregate dynamics

1. Investment hubs' value added predicts agg. employment better than aggregate GDP
2. Stimulus directed toward hubs more cost-efficient

Appendix

Construction of the Data Set ▸ Back

1. **Value added** from BEA industry database, 1947 - 2017 (35 NAICS sector level)

2. **Investment** and capital stocks from BEA fixed asset tables, aggregated to sector level using shares of capital types, 1947 - 2017 (35 NAICS sector level)

3. **Employment** from two sources, harmonized using Fort-Klimek (2016) crosswalk
    - BEA industry database, 1977 - 2017 (35 NAICS sector level)
    - Historical supplements, 1948 - 1977 (SIC codes)

Average Within-Sector Cycles Using Different Weights

	Time-Varying (Baseline)		**Fixed Weights**	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	3.58%	3.00%	3.32%	3.23%
$\sigma(l_t)/\sigma(y_t)$	0.65	0.64	0.65	0.65
$\rho(y_t - l_t, y_t)$	0.73	0.71	0.72	0.73

- y_t = log of value added
- l_t = log of employment
- All variables have been HP filtered with smoothing = 6.25

Back

Divergence of Aggregate and Within-Sector Cycles in First Differences

	Aggregated		Within-Sector	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	3.39%	2.30%	5.71%	5.01%
$\rho(y_t - l_t, y_t)$	0.68	0.40	0.77	0.74
$\sigma(l_t)/\sigma(y_t)$	0.74	0.93	0.62	0.63

- y_t = log of value added
- l_t = log of employment
- All variables have been first-differenced
- Within-sector averages weighted by value-added shares

Back

Decomposition on Role of Comovement ▸ Back

$$\mathbb{V}ar(x_t) = \underbrace{\sum_{j=1}^{N} (\omega_{jt}^{x})^2 \mathbb{V}ar(x_{jt})}_{\text{within-sector}} + \underbrace{\sum_{j=1}^{N} \sum_{o \neq j} \omega_{jt}^{x} \omega_{ot}^{x} \mathbb{C}ov(x_{jt}, x_{ot})}_{\text{between-sector}}$$

Decomposition on Role of Comovement ▸ Back

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$$\mathbb{V}ar(y_t) = \sum_{j=1}^{N} (\omega_{jt}^{y})^2 \mathbb{V}ar(y_{jt}) + \sum_{j=1}^{N} \sum_{o \neq j} \omega_{jt}^{y} \omega_{ot}^{y} \mathbb{C}ov(y_{jt}, y_{ot})$$

Decomposition on Role of Comovement ▸ Back

$$\frac{\mathbb{V}ar(x_t)}{\mathbb{V}ar(y_t)} = \frac{\sum_{j=1}^{N}(\omega_{jt}^{x})^2\mathbb{V}ar(x_{jt})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt}) + \sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt}, y_{ot})}$$

$$+ \frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{x}\omega_{ot}^{x}\mathbb{C}ov(x_{jt}, x_{ot})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt}) + \sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt}, y_{ot})}$$

Decomposition on Role of Comovement ▸ Back

$$\frac{\mathbb{V}ar(x_t)}{\mathbb{V}ar(y_t)} = \frac{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt})}{\mathbb{V}ar(y_t)} \frac{\sum_{j=1}^{N}(\omega_{jt}^{x})^2\mathbb{V}ar(x_{jt})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt})}$$

$$+ \frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{x}\omega_{ot}^{x}\mathbb{C}ov(x_{jt},x_{ot})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt}) + \sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt},y_{ot})}$$

Decomposition on Role of Comovement ▸ Back

$$\frac{\mathbb{V}ar(x_t)}{\mathbb{V}ar(y_t)} = \frac{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt})}{\mathbb{V}ar(y_t)} \frac{\sum_{j=1}^{N}(\omega_{jt}^{x})^2\mathbb{V}ar(x_{jt})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt})}$$

$$+ \frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt}, y_{ot})}{\mathbb{V}ar(y_t)} \frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{x}\omega_{ot}^{x}\mathbb{C}ov(x_{jt}, x_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt}, y_{ot})}$$

Accuracy of Decomposition ▸ Back

$$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)} \approx \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N}(\omega_j^l)^2\mathbb{V}ar(l_{jt})}{\sum_{j=1}^{N}(\omega_j^y)^2\mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t)\underbrace{\frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_j^l\omega_o^l\mathbb{C}ov(l_{jt}, l_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega_j^y\omega_o^y\mathbb{C}ov(y_{jt}, y_{ot})}}_{\text{between-sector}}$$

	Pre-84	*Post-84*
Actual, variance	0.58	1.04
Approximation, variance	0.57	0.94
Actual, standard deviation	0.76	1.02
Approximation, standard deviation	0.75	0.97

Decomposition with Fixed Weights ▸ Back

$$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)} \approx \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N}(\omega_j^l)^2 \mathbb{V}ar(l_{jt})}{\sum_{j=1}^{N}(\omega_j^y)^2 \mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t) \underbrace{\frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_j^l \omega_o^l \mathbb{C}ov(l_{jt}, l_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega_j^y \omega_o^y \mathbb{C}ov(y_{jt}, y_{ot})}}_{\text{between-sector}}$$

	Pre-84	*Post-84*	*Contribution of entire term*
$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)}$	0.60	0.81	**100%**
Within Sector	0.44	0.32	8%
Between Sector	0.62	0.93	92%
Within Weight	0.11	0.20	
$(\omega_t = \sum_{j=1}^{N}(\omega_{jt}^y)^2 \mathbb{V}ar(y_{jt}) / \mathbb{V}ar(y_t))$			

Decomposition of First Differences ▸ Back

$$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)} \approx \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N}(\omega_j^l)^2 \mathbb{V}ar(l_{jt})}{\sum_{j=1}^{N}(\omega_j^y)^2 \mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t) \underbrace{\frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_j^l \omega_o^l \mathbb{C}ov(l_{jt}, l_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega_j^y \omega_o^y \mathbb{C}ov(y_{jt}, y_{ot})}}_{\text{between-sector}}$$

	Pre-84	*Post-84*	*Contribution of entire term*
$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)}$	0.55	0.87	**100%**
Within Sector	0.35	0.39	15%
Between Sector	0.58	1.01	85%
Within Weight	0.12	0.23	
$(\omega_t = \sum_{j=1}^{N}(\omega_{jt}^y)^2 \mathbb{V}ar(y_{jt}) / \mathbb{V}ar(y_t))$			

Measuring Comovement with Correlations ▸ Back

$$\rho_\tau^X \equiv \frac{\sum_{i=1}^N \sum_{j=i+1}^N \omega_i^X \omega_j^X \mathbb{C}orr(x_{it}, x_{jt} | t \in \tau)}{\sum_{i=1}^N \sum_{j=i+1}^N \omega_i^X \omega_j^X}$$

- x_{jt} is logged + HP-filtered variable of interest
- $\tau \in \{\text{pre } 1984, \text{post } 1984\}$ is time period
- $\omega_{i\tau}^X$ are sectoral shares

	Employment	**Value added**
1951 - 1983	0.55	0.36
1984 - 2014	0.51	0.17
Difference	-0.04	-0.18

▸ Distribution of Changes ▸ First Diffs ▸ Time-Varying Weights

Correlations of First Differences ▸ Back

$$\rho_\tau^X \equiv \frac{\sum_{i=1}^{N}\sum_{j=i+1}^{N}\omega_i^X\omega_j^X \mathbb{C}orr(x_{it}, x_{jt}|t \in \tau)}{\sum_{i=1}^{N}\sum_{j=i+1}^{N}\omega_i^X\omega_j^X}$$

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- $\omega_{i\tau}^X$ are sectoral shares

	Employment	**Value added**
1951 - 1983	0.49	0.31
1984 - 2014	0.52	0.18
Difference	0.03	-0.13

Correlations with Time-Varying Weights ▸ Back

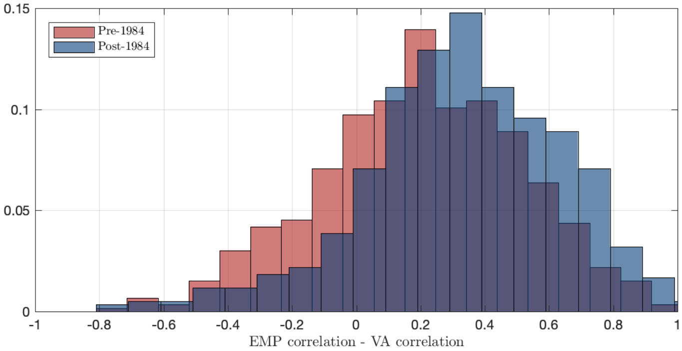
$$\rho_\tau^x \equiv \frac{\sum_{i=1}^N \sum_{j=i+1}^N \omega_{i\tau}^x \omega_{j\tau}^x \mathbb{C}orr(x_{it}, x_{jt} | t \in \tau)}{\sum_{i=1}^N \sum_{j=i+1}^N \omega_{i\tau}^x \omega_{j\tau}^x}$$

- x_{jt} is logged + HP-filtered variable of interest
- $\tau \in \{\text{pre 1984, post 1984}\}$ is time period
- ω_i^x are fixed sectoral shares

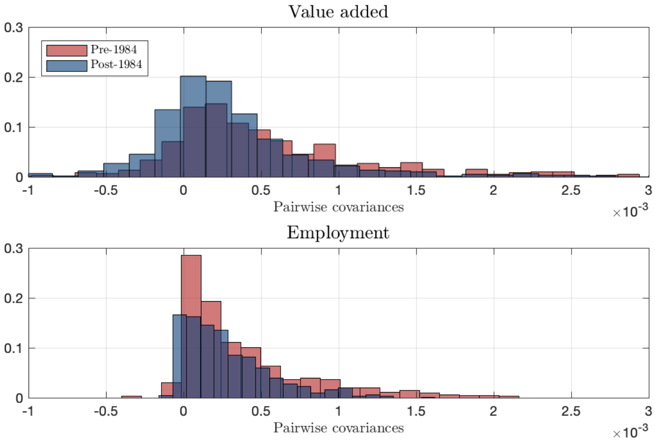
	Employment	**Value added**
1951 - 1983	0.56	0.37
1984 - 2014	0.47	0.14
Difference	-0.09	-0.23

Distribution of Changes in Correlations ▸ Back

$$\rho_\tau^X \equiv \frac{\sum_{i=1}^{N}\sum_{j=i+1}^{N}\omega_i^X\omega_j^X \mathbb{C}orr(x_{it}, x_{jt} | t \in \tau)}{\sum_{i=1}^{N}\sum_{j=i+1}^{N}\omega_i^X\omega_j^X}$$



Change in Covariances is Broad-Based ▸ Back



Decomposition at 450 Sector Level (NBER-CES Manufacturing Data)

Back

$$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)} \approx \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N}(\omega_{jt}^{l})^2\mathbb{V}ar(l_{jt})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t)\underbrace{\frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{l}\omega_{ot}^{l}\mathbb{C}ov(l_{jt},l_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt},y_{ot})}}_{\text{between-sector}}$$

	Pre-84	*Post-84*	*Contribution of entire term*
$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)}$	0.40	0.57	**100%**
Within Sector	0.34	0.20	1.4%
Between Sector	0.37	0.60	92.6%
Within Weight	0.03	0.06	
$(\omega_t = \sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt})/\mathbb{V}ar(y_t))$			

Decomposition At Goods vs. Services Level

Back

$$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)} \approx \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N}(\omega_{jt}^{l})^2\mathbb{V}ar(l_{jt})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t)\underbrace{\frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{l}\omega_{ot}^{l}\mathbb{C}ov(l_{jt},l_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt},y_{ot})}}_{\text{between-sector}}$$

	Pre-84	*Post-84*	*Contribution of entire term*
$\frac{\mathbb{V}ar(l_t)}{\mathbb{V}ar(y_t)}$	0.58	1.05	**100%**
Within Sector	0.56	0.96	51%
Between Sector	0.61	1.17	49%
Within Weight	0.57	0.58	
$(\omega_t = \sum_{j=1}^{N}(\omega_{jt}^{y})^2\mathbb{V}ar(y_{jt})/\mathbb{V}ar(y_t))$			

Factor Analysis of Sectoral Comovement ▸ Back

- Study changes in aggregate shock process using **factor analysis** (e.g. Garin-Pries-Sims 2011)
  - Let $X_t = (\Delta \log x_{1t}, ..., \Delta \log x_{nt})'$ be a vector of sector-level value added or employment
  - Denote $V =$ variance/covariance matrix of X_t
  - Decompose as $V = \Gamma \Lambda \Gamma'$ where Λ is matrix of eigenvalues
  - "Aggregate" factor is first principle component: $F_t = X_t \Gamma_1$
- Investigate how much variation F_t explains pre vs. post 1984
- Interpret F_t as combination of
  1. Aggregate shocks which affect all sectors
  2. Sectoral shocks propagated across sectors through linkages

Factor Analysis of Sectoral Comovement ▸ Back

Sample period	$1000\mathbb{V}ar(\Delta \log X_t)$	Due to 1st component	Residual
Value added			
1951-2014	0.80	0.63 (79%)	0.17 (21%)
1951-1983	1.12	0.97 (86%)	0.15 (14%)
1984-2014	0.46	0.26 (57%)	0.20 (43%)
Employment			
1951-2014	0.51	0.47 (93%)	0.03 (7%)
1951-1983	0.61	0.57 (93%)	0.04 (7%)
1984-2014	0.40	0.38 (94%)	0.02 (6%)

- Our model's interpretation:
  1. Aggregate shocks became less volatile post 1984
  2. But sectoral shock spillovers still strong for employment

Divergence of Aggregate and Within-Sector Cycles Including Investment

Back

	Aggregated		**Within-Sector**	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.27%	1.36%	3.58%	3.00%
$\rho(y_t - l_t, y_t)$	0.65	0.26	0.73	0.71
$\sigma(l_t)/\sigma(y_t)$	0.75	1.02	0.65	0.64
$\sigma(i_t)/\sigma(y_t)$	1.94	2.91	2.76	2.84

- y_t = log of value added
- l_t = log of employment
- i_t = log of investment
- All variables have been HP filtered with smoothing = 6.25
- Within-sector averages weighted by value-added shares

Decomposition of Investment Volatility Back

$$\frac{\mathbb{V}ar(i_t)}{\mathbb{V}ar(y_t)} \approx \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N}(\omega^i_{jt})^2 \mathbb{V}ar(i_{jt})}{\sum_{j=1}^{N}(\omega^y_{jt})^2 \mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t) \underbrace{\frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega^i_{jt}\omega^i_{ot}\mathbb{C}ov(i_{jt}, i_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega^y_{jt}\omega^y_{ot}\mathbb{C}ov(y_{jt}, y_{ot})}}_{\text{between-sector}}$$

	Pre-84	*Post-84*	*Contribution of entire term*
$\frac{\mathbb{V}ar(I_t)}{\mathbb{V}ar(y_t)}$	3.77	8.49	**100%**
Within Sector	4.89	6.14	19%
Between Sector	3.64	9.18	81%
Within Weight	0.11	0.23	
$(\omega_t = \sum_{j=1}^{N}(\omega^y_{jt})^2 \mathbb{V}ar(y_{jt})/\mathbb{V}ar(y_t))$			

Calibration of Production Parameters ▸ Back

$$Q_{jt} = A_{jt}(K_{jt}^{\alpha_j} L_{jt}^{1-\alpha_j})^{\theta_j} X_{jt}^{1-\theta_j} \quad \text{where } X_{jt} = \Pi_{i=1}^{N} M_{ijt}^{\gamma_{ij}}$$

1. **Value added shares** θ: average value added as share of gross output (BEA I-O database 1947 - 2017) ▸ Details

Calibration of Production Parameters ▸ Back

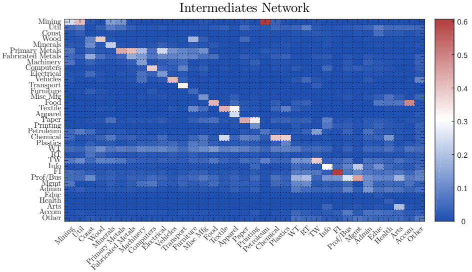
$$Q_{jt} = A_{jt}(K_{jt}^{\alpha_j} L_{jt}^{1-\alpha_j})^{\theta_j} X_{jt}^{1-\theta_j} \quad \text{where } X_{jt} = \Pi_{i=1}^{N} M_{ijt}^{\gamma_{ij}}$$

1. **Value added shares** θ
2. **Labor shares** α: average labor compensation as share of total costs adjusted for taxes and self-employment (BEA I-O database extended back to 1947 - 2017) ▸ Details

Calibration of Production Parameters ▸ Back

$$Q_{jt} = A_{jt}(K_{jt}^{\alpha_j} L_{jt}^{1-\alpha_j})^{\theta_j} X_{jt}^{1-\theta_j} \quad \text{where } X_{jt} = \Pi_{i=1}^{N} M_{ijt}^{\gamma_{ij}}$$

1. **Value added shares** θ
2. **Labor shares** α
3. **Intermediates input-output network** Γ: average intermediates cost as share of total costs (BEA I-O database 1947-2017)



Calibration of Investment Parameters ▸ Back

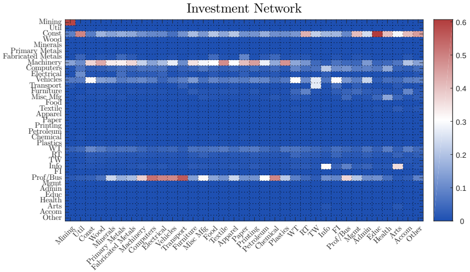
$$K_{jt+1} = (1 - \delta_j)K_{jt} + I_{jt} \quad \text{where } I_{jt} = \Pi_{i=1}^{N} I_{ijt}^{\lambda_{ij}}$$

1. **Depreciation rate** δ_j: average annual depreciation (BEA fixed assets 1947 - 2017) ▸ Details

Calibration of Investment Parameters ▸ Back

$$K_{jt+1} = (1-\delta_j)K_{jt} + I_{jt} \quad \text{where } I_{jt} = \Pi_{i=1}^{N} I_{ijt}^{\lambda_{ij}}$$

1. **Depreciation rate** δ_j
2. **Investment input-output network** Λ: average investment cost from j as share of total investment cost (constructed from BEA capital flows + fixed assets 1947 - 2017)



Calibration of Preference Parameters ▸ Back

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t - L_t\right), \quad \text{where } C_t = \Pi_{j=1}^{N} C_{jt}^{\xi_j} \text{ and } \sum_{j=1}^{N} \xi_j = 1$$

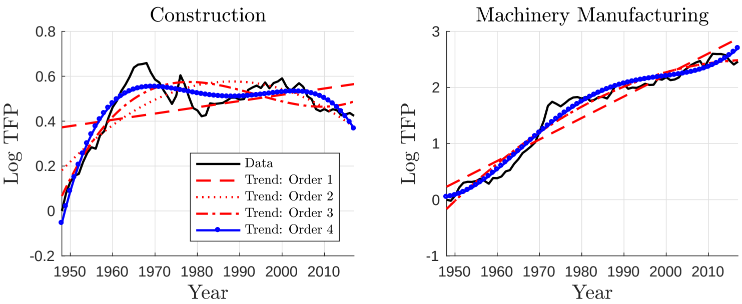
1. **Discount factor** $\beta = 0.96$ (annual)

Calibration of Preference Parameters ▸ Back

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t - L_t\right), \quad \text{where } C_t = \Pi_{j=1}^{N} C_{jt}^{\xi_j} \text{ and } \sum_{j=1}^{N} \xi_j = 1$$

1. **Discount factor** $\beta = 0.96$ (annual)
2. **Consumption shares** ξ_j: average consumption expenditure on j as share of total consumption expenditure (BEA I-O database 1947 - 2017) ▸ Details

Detrending Sector-Level Data ‣ Back



- Sector-level data is not well-described by linear trend
- Choose log-polynomial trend with order = 4 in order to balance:
  1. Flexibility of the trend ($\Longrightarrow$ higher order)
  2. Overfitting of the data ($\Longrightarrow$ lower order)

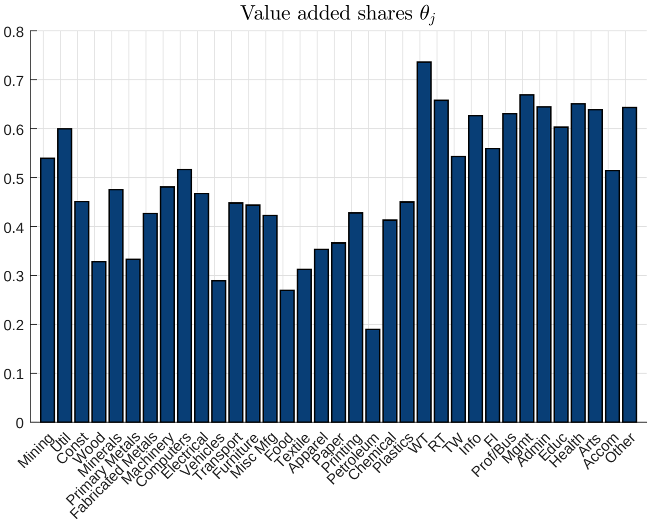
Collapsing Sectors ▸ Back

- Need $N = 30$ to estimate full-rank covariance matrix
- Collapse all of non-durable manufacturing together because:
  1. Not investment hubs, so not central to our main results
  2. More similar to each other than other sectors (e.g. services)
  3. Readily available from BEA

Mining	Utilities
Construction	Wood products
Non-metallic minerals	Primary metals
Fabricated metals	Machinery
Computer and electronic manufacturing	Electrical equipment manufacturing
Motor vehicles manufacturing	Other transportation equipment
Furniture and related manufacturing	Misc. Manufacturing
Wholesale trade	Retail trade
Transportation and warehousing	Information
Finance and insurance	Professional and business services
Management of companies and enterprises	Administrative and waste management services
Educational services	Health care and social assistance
Arts, entertainment, and recreation services	Accommodation and food services
Other services	**Non-durable manufacturing**

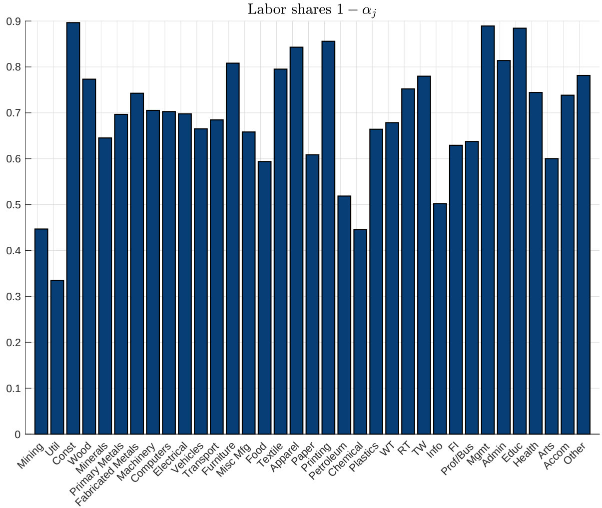
Measured Value Added Shares

Back



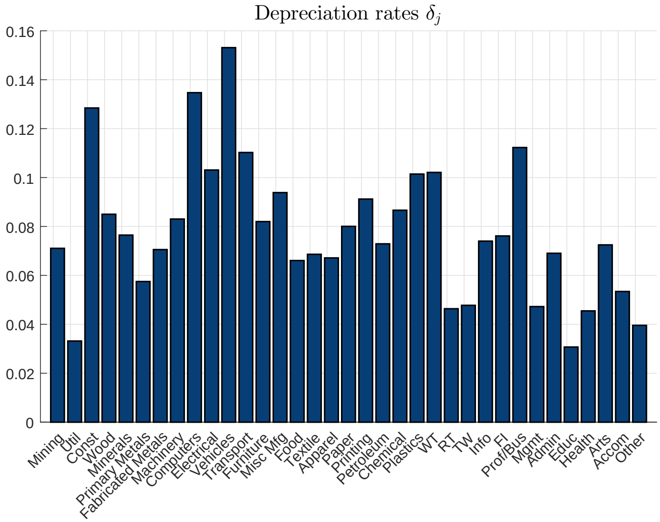
Measured Labor Shares

Back



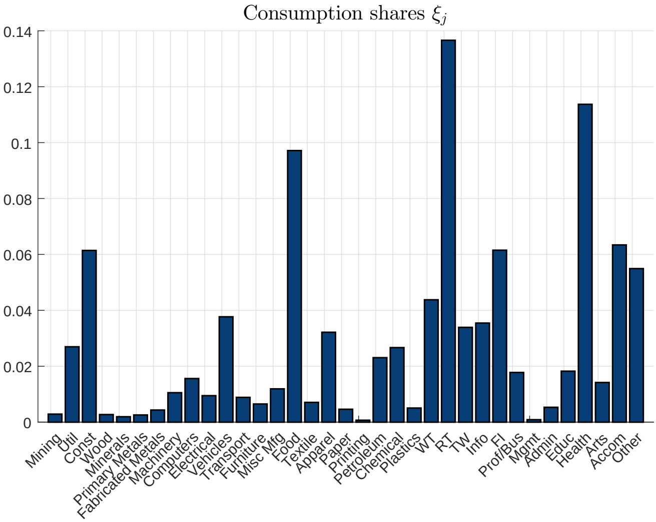
Measured Depreciation Rates

Back



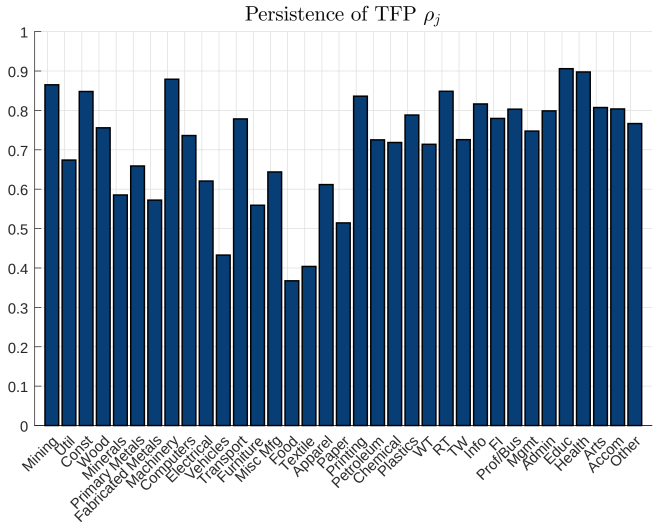
Measured Consumption Shares

Back



Measured TFP Persistence

▸ Back



Interpretation of Change in Shock Process ▸ Back

- Helpful special case to interpret change in shock process:

$$\log A_{jt} = \underbrace{\log A_t}_{\text{aggregate shock}} + \underbrace{\log \widehat{A}_{jt}}_{\text{sector-specific shock}}$$

- Characterize using principal components analysis:
  (on collapsed $N = 28$ sector data)

Sample period	$1000\mathbb{V}ar(\Delta \log A_t)$	Due to 1st component	Residual
1949-1983	0.40	0.32 (81%)	0.08 (19%)
1984-2017	0.27	0.15 (56%)	0.12 (44%)

- Volatility of aggregate factor falls in half,
  but volatility of idiosyncratic factor stable

Robustness of Main Results ▸ Back

	Population Moments		Changing Structure	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.68%	2.12%	3.13%	1.85%
$\rho(y_t - l_t, y_t)$	0.85	0.47	0.85	0.54
$\sigma(l_t)/\sigma(y_t)$	0.77	0.91	0.79	0.88
Within contribution to change		15%		38%
Between contribution to change		85%		62%

- Population moments is long simulation for $N = 28 < T$ partition
- Changing structure computes population moments and allows following parameters to differ pre vs. post 1984: ▸ Measurement Details
  - Value added shares θ_j, labor shares α_j, intermediates network Γ_{ij}
  - Depreciation rates δ_j, investment network Λ_{ij}
  - Consumption shares ξ_j
  - Persistence of TFP ρ_j

GHH Preferences ▸ Back

	Baseline Results		Changing Structure	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.60%	2.24%	X%	X%
$\rho(y_t - l_t, y_t)$	0.90	0.45	X	X
$\sigma(l_t)/\sigma(y_t)$	0.74	0.92	X	X
Within contribution to change		11%		X%
Between contribution to change		89%		X%

- Description

Frisch Elasticity of Labor Supply = 4 ▸ Back

	Baseline Results		Changing Structure	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.60%	2.24%	2.21%	1.84%
$\rho(y_t - l_t, y_t)$	0.90	0.45	0.96	0.8
$\sigma(l_t)/\sigma(y_t)$	0.74	0.92	0.61	0.77
Within contribution to change		11%		21%
Between contribution to change		89%		79%

25% Maintenance Investment ▸ Back

	Baseline Results		Changing Structure	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.60%	2.24%	2.58%	2.06%
$\rho(y_t - l_t, y_t)$	0.90	0.45	0.93	0.6
$\sigma(l_t)/\sigma(y_t)$	0.74	0.92	0.73	0.88
Within contribution to change		11%		10%
Between contribution to change		89%		90%

Capital Adjustment Costs ▸ Back

	Baseline Results		Changing Structure	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.60%	2.24%	2.43%	2.05%
$\rho(y_t - l_t, y_t)$	0.90	0.45	0.92	0.65
$\sigma(l_t)/\sigma(y_t)$	0.74	0.92	0.68	0.85
Within contribution to change		11%		7%
Between contribution to change		89%		93%

- Each sector faces quadratic capital adjustment cost φ
- Choose large adjustment cost parameter $\varphi = 4$

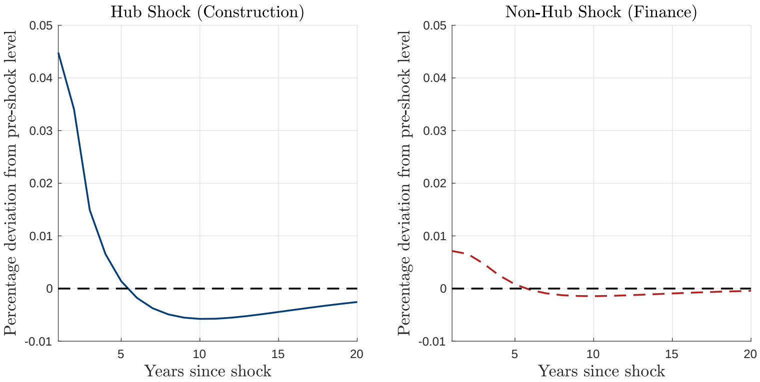
Measurement of Parameter Changes over Time ▸ Back

- Most parameters based on moments that are available year-by-year: **value added shares, intermediates network, depreciation rates, consumption shares**
- **Persistence of TFP** estimated via MLE on two subsamples
- **Labor shares** combines two data sources (harmonized using Fort-Klimek crosswalk):
  1. BEA industry database 1987 - 2017 on payroll, value added, indirect taxes, and self-employment (NAICS)
  2. Historical data on payroll, value added, and indirect taxes 1948 - 1987 (SIC)
  3. Self-employment back-casted using average ratio from NAICS data

Measurement of Parameter Changes over Time ‣ Back

- See sector's total investment expenditure year-by-year, but need to allocate across sectors using **bridge file**
- All structures produced by construction, except for mining (following BEA practice)
- Intellectual property also follows BEA practice:
  - Pre-packed software and most artistic originals from info
  - Other software and R&D investment from prof/technical
  - Misc. other small allocations
- Equipment production combines three BEA datasets:
  - 1997 - 2017 census year: BEA provides bridge file
  - 1987 and 1992: BEA provides SIC bridge file, harmonized using Fort-Klimek
  - 1948 - 1987: interpolate based on observed bridge files

Effects of Sectoral Shocks on Aggregate Employment in Full Model ▸ Back



Divergence of Aggregate and Within-Sector Cycles Including Investment

▸ Back

	Aggregated		**Within-Sector**	
	Pre-1984	*Post-1984*	*Pre-1984*	*Post-1984*
$\sigma(y_t)$	2.27%	1.36%	3.58%	3.00%
$\rho(y_t - l_t, y_t)$	0.65	0.26	0.73	0.71
$\sigma(l_t)/\sigma(y_t)$	0.75	1.02	0.65	0.64
$\sigma(i_t)/\sigma(y_t)$	1.94	2.91	2.76	2.84
$\sigma(i_t)/\sigma(y_t)$ model	X	X	X	X

- y_t = log of value added
- l_t = log of employment
- i_t = log of investment
- All variables have been HP filtered with smoothing = 6.25
- Within-sector averages weighted by value-added shares
- Model = model with capital adjustment costs

Decomposition of Investment Volatility ▸ Back

$$\frac{\mathbb{V}ar(i_t)}{\mathbb{V}ar(y_t)} \approx \underbrace{\omega_t}_{\text{within weight}} \underbrace{\frac{\sum_{j=1}^{N}(\omega_{jt}^{i})^2 \mathbb{V}ar(i_{jt})}{\sum_{j=1}^{N}(\omega_{jt}^{y})^2 \mathbb{V}ar(y_{jt})}}_{\text{within-sector}} + (1-\omega_t) \underbrace{\frac{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{i}\omega_{ot}^{i}\mathbb{C}ov(i_{jt}, i_{ot})}{\sum_{j=1}^{N}\sum_{o\neq j}\omega_{jt}^{y}\omega_{ot}^{y}\mathbb{C}ov(y_{jt}, y_{ot})}}_{\text{between-sector}}$$

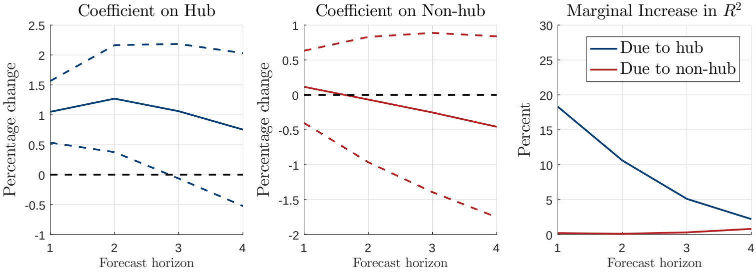
	Data			**Model**		
	Pre-84	*Post-84*	*Cont.*	*Pre-84*	*Post-84*	*Cont.*
$\frac{\mathbb{V}ar(I_t)}{\mathbb{V}ar(y_t)}$	3.77	8.49	**100%**	X	X	100%
Within Sector	4.89	6.14	19%	X	X	42%
Between Sector	3.64	9.18	81%	X	X	58%
Within Weight	0.11	0.23		X	X	
$(\omega_t = \sum_{j=1}^{N}(\omega_{jt}^{y})^2 \mathbb{V}ar(y_{jt})/\mathbb{V}ar(y_t))$						

Rising Importance of Investment Hub Shocks (Unweighted Averages) ▸ Back

	Pre-84	*Post-84*	*Percentage Change*
$\frac{\mathbb{E}[\sigma(A_{jt})\|\text{hubs}]}{\mathbb{E}[\sigma(A_{jt})\|\text{non-hubs}]}$	1.13	1.27	12%
$\mathbb{E}[\mathbb{C}orr(A_{jt}, A_{ot})\|\text{hubs}]$	0.25	0.27	8%
$\mathbb{E}[\mathbb{C}orr(A_{jt}, A_{ot})\|\text{non-hubs}]$	0.17	0.06	-65%

Spillovers from Sector-Level Shocks Onto Aggregate Employment

▸ Back



$$\log N_{t+h} - \log N_t = \alpha + \gamma(\log y_{hub,t} - \log y_{hub,t-1}) + \beta(\log y_{non,t} - \log y_{non,t-1}) + \varepsilon_{t+h}$$

y_{st} = aggregated across $s \in \{\text{hub, non-hub}\}$ in year t

$\log y_{s,t} - \log y_{s,t-1}$ = is standardized