Sectoral vs. Aggregate Shocks: A Structural Factor Analysis of Industrial Production

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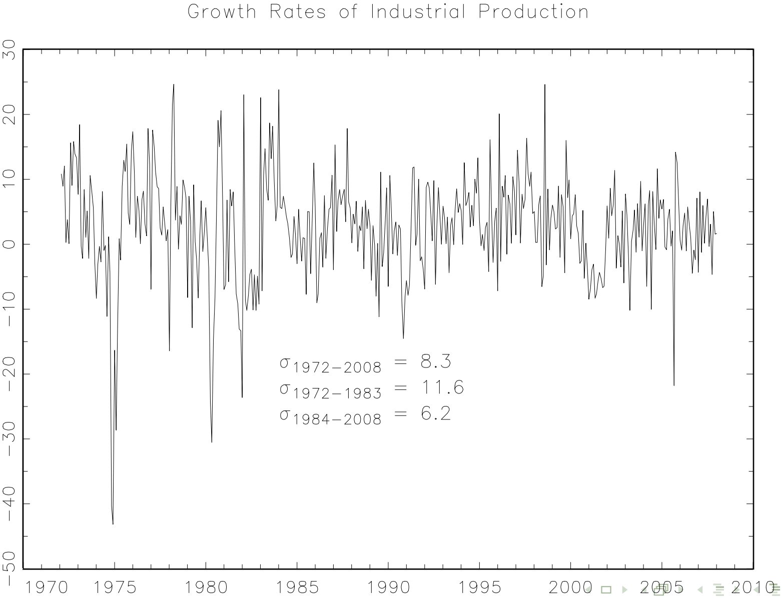
Observations and Motivating Questions

- Month-to-month and quarter-to-quarter variations in Industrial Production (IP) are large
  - std. dev. of monthly growth rates is 8 percent
  - std. dev. of quarterly growth rates is 6 percent
  - noticeably large fall in the volatility of IP after 1984

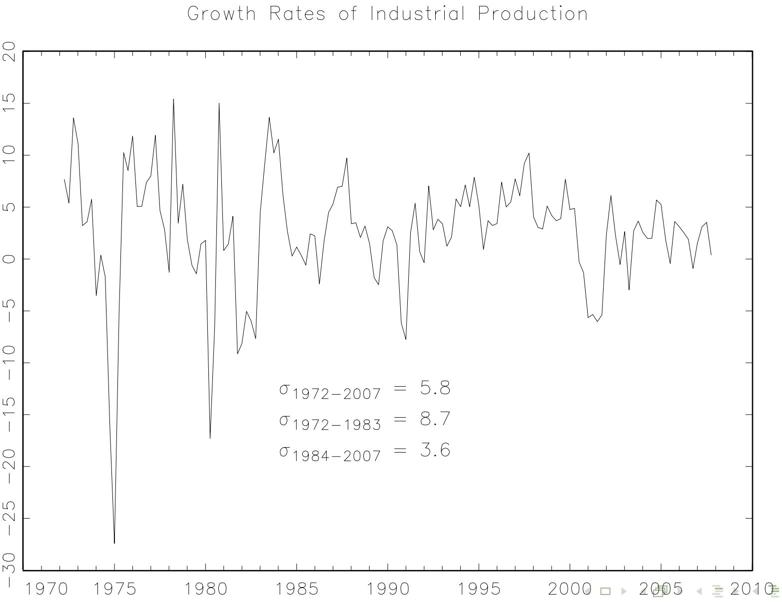
- IP index is constructed as a weighted average of production indices across a large number of sectors...

- ... apparently, much of the variability in individual sectors does not "average out"

An Initial Look at IP Data



An Initial Look at IP Data



Observations and Motivating Questions

- Aggregate Shocks that affect all industrial sectors
- Some sectors have very large weights in the aggregate index, Gabaix (2005)
- Complementarities in production amplify and propagate sector-specific shocks
  - input-output (IO) linkages
  - aggregate activity spillovers
  - local activity spillovers

Approaches to analyzing sources of variations in the business cycle

- Factor Analytic Methods - Long and Plosser (1987), Forni and Reichlin (1998), Shea (2002)
  - broad identifying restrictions
  - Non-trivial contribution of sector-specific shocks to aggregate variability (approximately 50 percent)
- Structural (calibrated) Models - Long and Plosser (1983), Horvath (1998), Dupor (1999), Horvath (1998, 2000)
  - contribution of idiosyncratic shocks to aggregate variability depends on exact structure of IO matrix
- Other: Conley and Dupor (2003), Gabaix (2005), Comin and Philippon (2005)

Overview for this paper

- Bridge factor-analytic and structural approaches to the analysis of idiosyncratic and aggregate shocks
  - Highlight conditions under which multisector growth models (Long and Plosser 1983, Horvath 1998) produce factor models as reduced forms
  - Factors are associated with aggregate productivity shocks
  - “Uniquenesses” are associated with (linear combinations of) sector-specific productivity shocks

- Sort through leading explanations underlying:
  - both aggregate and sectoral IP volatility
  - the decline in aggregate IP volatility after 1984

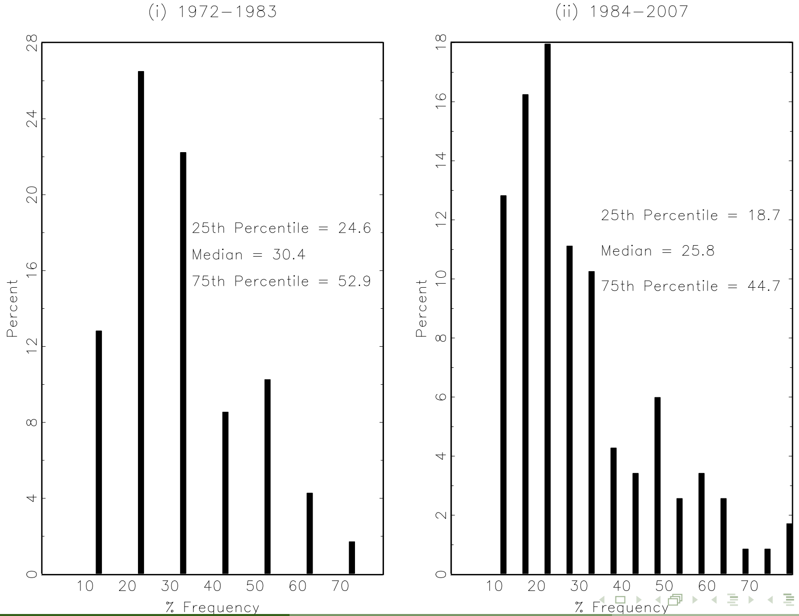
Overview for this paper

- Aggregate variability is driven mainly by covariability across sectors, Quah and Sargent (1993), Forni and Reichlin (1998), Shea (2002)
- This covariability resides in a small number of factors
  - factors capture mostly aggregate productivity shocks
- Sectoral productivity shocks play a relatively modest role in explaining aggregate IP variability
  - but importance doubles after 1984 (from explaining 12 percent to 30 percent of aggregate IP)
  - changes in U.S. IO matrix did not lead to greater propagation of idiosyncratic shocks after 1984
  - increase in relative importance of idiosyncratic productivity shocks stems from decrease in contribution of aggregate productivity shocks

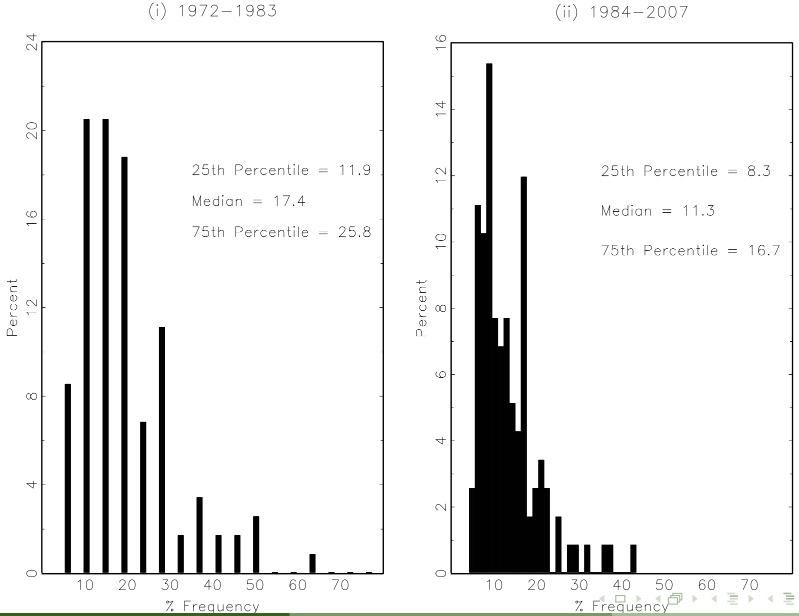
Data

- Sectoral Industrial Production, 1972-2007 from Board of Governors
- Benchmark Input-Output tables from Bureau of Economic Analysis
- Disaggregated according to NAICS
- Consider two benchmark years, 1977 and 1998
  - NAICS cannot be matched to IO tables prior to 1997
  - make use of vintage IP data, 1967-2002, disaggregated according to SIC codes
  - discontinued after 2002

Std. Dev. of Sectoral IP Growth Rates



Std. Dev. of Sectoral IP Growth Rates



Average Pairwise Correlation of Sectoral IP Growth Rates

Monthly Growth Rates			Quarterly Growth Rates		
72-07	72-83	84-07	72-07	72-83	84-07
0.08	0.13	0.05	0.19	0.27	0.11

Standard Deviation of IP Growth Rates

(Percentage points at annual rate)

Share Weights Used to Aggregate Sectoral IP	Monthly Growth Rates 1972-2007	Monthly Growth Rates 1972-1983	Monthly Growth Rates 1984-2007	Quarterly Growth Rates 1972-2007	Quarterly Growth Rates 1972-1983	Quarterly Growth Rates 1984-2007
a. Full Covariance Matrix of Sectoral Growth Rates						
Time Varying (w_{it})	8.3	11.6	6.2	5.8	8.7	3.6
Constant (μ_w)	8.4	11.7	6.2	5.8	8.9	3.6
Equal ($1/N$)	10.4	14.4	7.6	6.9	10.5	4.2
b. Diagonal Covariance Matrix of Sectoral Growth Rates						
Time Varying (w_{it})	4.3	4.9	4.1	1.9	2.6	1.6
Constant (μ_w)	4.2	4.6	4.0	1.9	2.4	1.5
Equal ($1/N$)	4.6	5.6	4.0	1.8	2.5	1.4

Statistical Factor Analysis

- $$X_t = \Lambda F_t + u_t$$
- X_t is an N-dimensional vector of sectoral output growth rates, F_t is a set of r common factors, and u_t is an Nx1 vector of idiosyncratic disturbances that satisfy weak dependence
- Principle components of X_t are consistent estimators of F_t, Stock and Watson (2002)
- $$\Sigma_{XX} = \Lambda \Sigma_{FF} \Lambda' + \Sigma_{uu}$$
- Note: Λ and F_t are not separably identified (because $\Lambda F_t = \widetilde{\Lambda} \widetilde{F}_t$ where $\widetilde{\Lambda} = \Lambda R$ and $\widetilde{F}_t = R^{-1} F_t$ for arbitrary kxk matrices R)

A Digression: Principle Components

- The PC problem represents a way to capture the comovement across these N categories of interest rate changes in a convenient way

- The PC problem transforms the X 's into a new set of variables that...

    - are pairwise uncorrelated,

    - of which the first such variable has the maximum possible variance, the second the maximum possible variance among those uncorrelated with the first, etc...

A Digression: Principle Components

- Let
$$F_1' = X'\lambda_1$$
denote the first variable, where Λ_1 is $Nx1$ and F_1' is $Tx1$

- The sum of squares is
$$F_1 F_1' = \lambda_1{}'\Sigma_{XX}\lambda_1$$
where Σ_{XX} is the variance-covariance (when divided by T) of interest rate changes

- We wish to choose the weights λ_1 to maximize $F_1 F_1'$, but some constraint must evidently be imposed on λ_1

A Digression: Principle Components

- The PC problem is,

$$\max_{\lambda_1} \lambda_1' \Sigma_{XX} \lambda_1 + \mu_1 (1 - \lambda_1' \lambda_1)$$

- The corresponding firs-order condition is,

$$2\Sigma_{xx}\lambda_1 - 2\mu_1\lambda_1 = 0.$$

- or

$$\Sigma_{xx}\lambda_1 = \mu_1\lambda_1.$$

- Note that $\lambda_1' \Sigma_{XX} \lambda_1 = \lambda_1' \mu_1 \lambda_1 = \mu_1$. So choose the eigenvector associated with the largest eigenvalue of Σ_{xx}.

A Digression: Principle Components

- Define the next principle component of X as $F_2' = X'\lambda_2$
- The PC problem is

$$\max_{\lambda_2} \lambda_2' \Sigma_{XX} \lambda_2 + \mu_2(1 - \lambda_2'\lambda_2) + \phi\lambda_2'\lambda_1.$$

- The weights λ_2 satisfy

$$\Sigma_{xx}\lambda_2 = \mu_2\lambda_2,$$

- and, in particular, should be chosen as the eigenvector associated with the second largest eigenvalue of Σ_{XX}.

A Digression: Principle Components

- Proceeding in this way, suppose we find the first k principle components of X. We can arrange the weights λ_1, λ_2,...,λ_k in an $N \times k$ orthogonal matrix

$$\Lambda_k = [\lambda_1, \lambda_2, ..., \lambda_k].$$

- Furthermore, the general PC problem may then be described as finding the $T \times k$ matrix of components, $F' = X'\Lambda_k$, such that Λ_k solves

$$\max_{\Lambda_k} \Lambda_k' \Sigma_{XX} \Lambda_k \text{ subject to } \Lambda_k' \Lambda_k = I_k.$$

A Digression: Principle Components

- Solving the general PC problem is equivalent to solving

$$\min_{\{F_1\}_{t=1}^{T},\ldots,\{F_k\}_{t=1}^{T},\Lambda_k} T^{-1}\sum_{t=1}^{T}(X_t-\Lambda_k F_t)'(X_t-\Lambda_k F_t) \text{ s. t. } \Lambda_k'\Lambda_k = I_k$$

- To see this, suppose Λ_k is known. Then,

$$F_t(\Lambda_k) = (\Lambda_k'\Lambda_k)^{-1}\Lambda_k X_t$$

- Now concentrate out F_t to get

$$\min_{\Lambda_k} T^{-1}\sum_{t=1}^{T} X_t'[I_k - \Lambda_k(\Lambda_k'\Lambda_k)\Lambda_k]X_t \text{ s. t. } \Lambda_k'\Lambda_k = I_k$$

Statistical Factor Analysis

- Bai and Ng (2002) ICP1 and ICP2 yield 2 factors in full and first sample,(1972-2007) and (1972-1983), and 1 factor in second sample (1984-2007)

- $$g_t = \mathbf{w}' X_t = \mathbf{w}' \Lambda F_t + \mathbf{w}' u_t$$

- $$R^2(F) = \mathbf{w}' \Lambda \Sigma_{FF} \Lambda' \mathbf{w} / \sigma_g^2$$

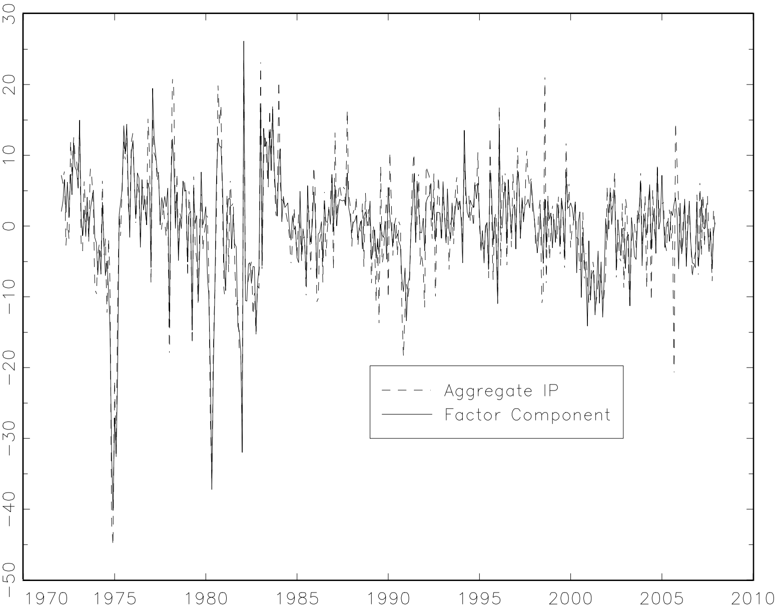
- Distribution of $R_i^2(F)$

Statistical Factor Analysis

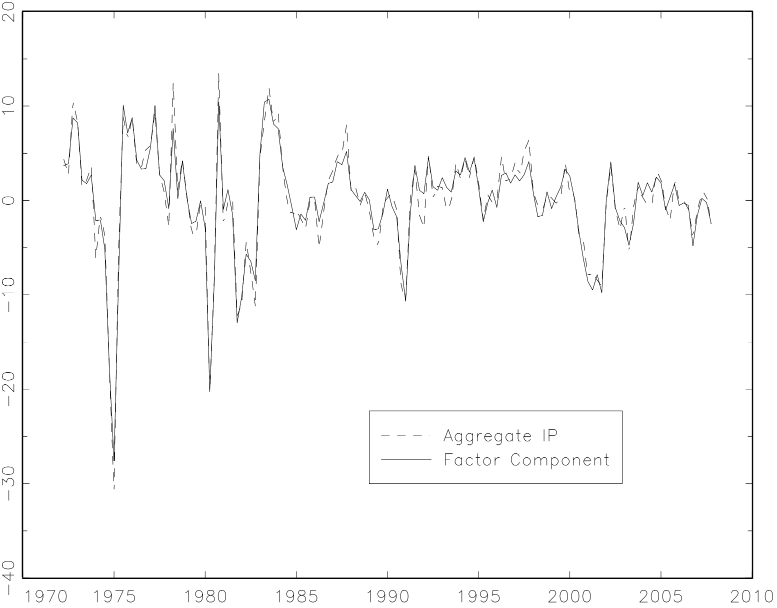
Decomposition of Variance from Statistical 2-Factor Model

	Monthly Rates		Quarterly Rates	
	72-83	84-07	72-83	84-07
Std. Deviation of IP Growth Rates Implied by Factor Model (with Constant Share Weights)	11.7	6.2	8.9	3.6
$R^2(F)$	0.86	0.49	0.89	0.87

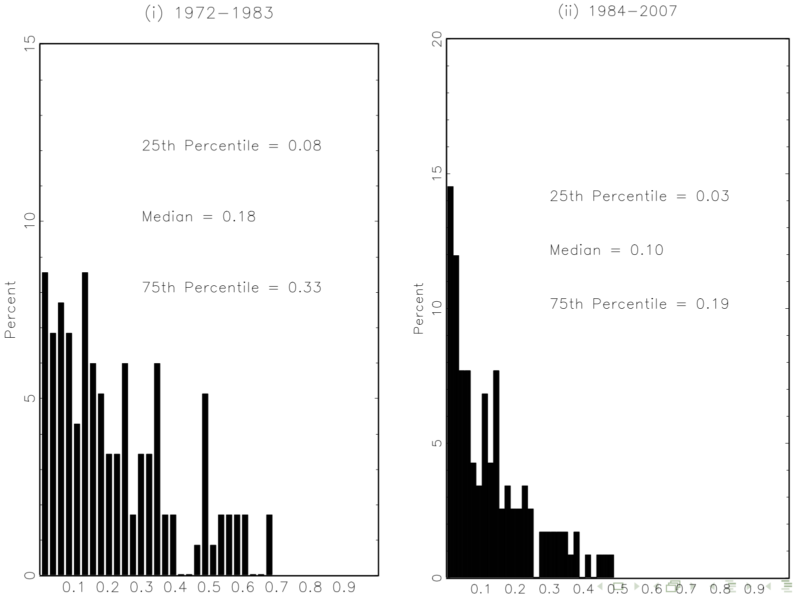
Factor Decomposition of Industrial Production (Monthly)



Factor Decomposition of Industrial Production (Quarterly)



Distribution of $R_i^2(F)$ of Sectoral Growth Rates



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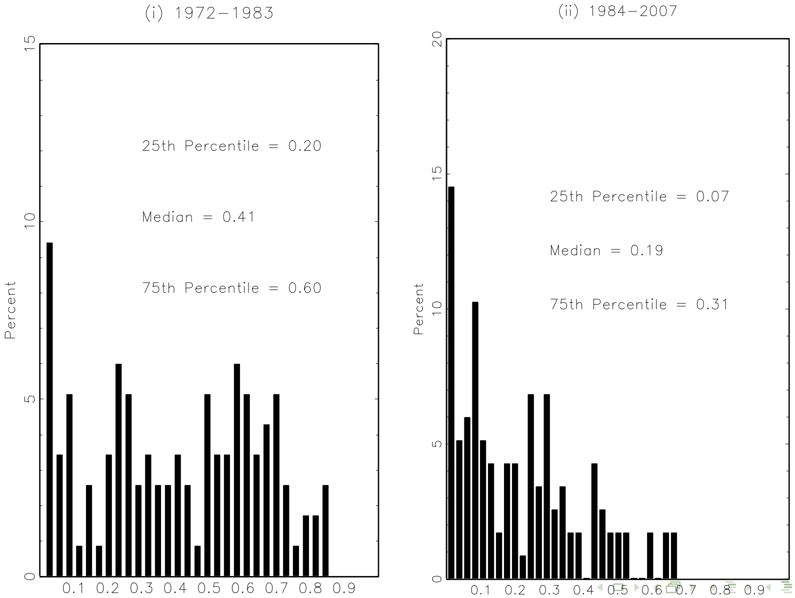

Fraction of Variability in Sectoral Growth Rates Explained by Common Factors (Quarterly Data Growth Rates)

1972-1983	
Sector	$R_i^2(F)$
Other Fabricated Metal Products	0.86
Fabricated Metals: Forging and Stamping	0.85
Machine Shops: Turned Products and Screws	0.83
Commercial and Service Industry Machinery/Other General Purpose	0.83
Foundries	0.80
Other Electrical Equipment	0.79
Metal Working Machinery	0.78
Fabricated Metals: Cutlery and Handtools	0.76
Electrical Equipment	0.73
Architectural and Structural Metal Products	0.72

Fraction of Variability in Sectoral Growth Rates Explained by Common Factors (Quarterly Data Growth Rates)

	1984-2007
Sector	$R_i^2(F)$
Coating, Engraving, Heat Treating, and Allied Activities	0.68
Plastic Products	0.67
Commercial and Service Industry Machinery/Other General Purpose	0.65
Fabricated Metals: Forging and Stamping	0.65
Household and Institutional Furniture and Kitchen Cabinets	0.59
Veneer, Plywood, and Engineered Wood Products	0.59
Metal Working Machinery	0.52
Foundries	0.52
Millwork	0.51
Other Fabricated Metal Products	0.50

Statistical Factor Analysis

- Tracking real time movements in IP using only a subset *M* of the IP sectors
- $\widetilde{X}_t = \mathbf{s}X_t$, where **s** is an *M* x *N* selection matrix
- Weights, ψ, determined by projection of g_t onto $\widetilde{X}_t$

$$\psi = (\mathbf{s}\Sigma_{XX}\mathbf{s}')^{-1}\mathbf{s}\Sigma_{XX}\mathbf{w}$$

- Bulk of variation in IP explained by a small number of sectors

Information Content of IP Contained in Individual Sectors

Selected Sectors Ranked by $R_i^2(F)$	1972-1983 Fraction of Explained IP	1984-2000 Fraction of Explained IP
Top 5 Sectors	85.0	75.4
Top 10 Sectors	90.3	80.4
Top 20 Sectors	97.9	86.4
Top 30 Sectors	98.8	90.3

Structural Factor Analysis

- Consistent estimation of factors relies on weak cross-sectional dependence of "uniquenesses", u_t ...
- ... but IO linkages can transform sector-specific shocks into common shocks
- Require a model that incorporates linkages across sectors - Long and Plosser (1983), Horvath (1998)
- Key feature is that production in each sector uses materials produced in other sectors
- Statistical Factor Model can be interpreted as the reduced form of the Structural Model. We can filter out the effects of IO linkages.

Structural Factor Analysis

- N distinct sectors, indexed $j = 1, ..., N$
- Technology:

$$Y_{jt} = A_{jt} K_{jt}^{\alpha_j} \prod_{i=1}^{N} M_{ij}^{\gamma_{ij}} L_{jt}^{1-\alpha_j-\sum_{i=1}^{N} \gamma_{ij}},$$

- M_{ij} - quantity of sector i material used in sector j. An input-output matrix for this economy is an N x N matrix, Γ, with typical element γ_{ij}
- $N + 1$ disturbances

$$\Delta lnA_{jt} = \epsilon_{jt}$$

- $\epsilon_t = (\epsilon_{1t}, \epsilon_{2t}, ..., \epsilon_{Nt})'$ has covariance matrix $\Sigma_{\epsilon\epsilon}$

Structural Factor Analysis

- preferences:

$$E\sum_{t=0}^{\infty}\beta^t\sum_{j=1}^{N}(\frac{C_{jt}^{1-\sigma}}{1-\sigma}-\psi L_{jt})$$

- resource constraints:

$$C_{jt}+\sum_{i=1}^{N}M_{jit}+K_{jt+1}-(1-\delta)K_{jt}=Y_{jt}, \quad j=1,\ldots,N$$

- Planner's solution for sectoral output allocations,

$$X_t=\Phi X_{t-1}+\Pi\epsilon_t+\Xi\epsilon_{t-1},$$

where $X_t=(\Delta\ln(Y_{1t}),\Delta\ln(Y_{2t}),\ldots,\Delta\ln(Y_{Nt}))'$

- Φ, Π, and Ξ are $N\times N$ matrices that depend only on the model parameters, α_d, Γ, β, σ, ψ, and δ

Structural Factor Analysis

- $$\epsilon_t = \Lambda_s S_t + v_t,$$

  where v_t has a diagonal variance-covariance matrix

- then

  $$X_t = \Lambda F_t + u_t,$$

  where $\Lambda(\mathbf{L}) = (I - \Phi \mathbf{L})^{-1}(\Pi + \Xi \mathbf{L})\Lambda_s$, $F_t = S_t$, and $u_t = (I - \Phi \mathbf{L})^{-1}(\Pi + \Xi \mathbf{L})v_t$

- The structural model produces a an approximate factor model as a reduced form. Common factors are associated with aggregate shocks to sectoral productivity. "Uniquenesses" are linear combinations of the sector-specific shocks.

Structural Factor Analysis

- Special case, Horvath (1998), Dupor (1999): no labor, full depreciation, and log preferences

- The model's exact solution is given by $\Phi = (I - \Gamma')^{-1}\alpha_d$, $\Xi = 0$, and $\Pi = (I - \Gamma')^{-1}$ so that

$$u_t = (I - (I - \Gamma^{'})^{-1}\alpha_d \mathbf{L})^{-1}(I - \Gamma')^{-1} v_t$$

- To eliminate the propagation of sector-specifc shocks induced by IO linkages, filter the vector of sectoral output growth

$$\epsilon_t = (\Pi + \Xi \mathbf{L})^{-1}(I - \Phi \mathbf{L}) X_t$$

Benchmark Calibration

- $\beta = 0.99$, $\delta = 0.025$, $\sigma = 1$ and $\psi = 1$
- γ_{ij} and α_j obtained from IO tables published by the BEA
- We consider two benchmark years for the IO tables, 1977 and 1998
- We choose two calibrations for $\Sigma_{\epsilon\epsilon}$, i) $\Sigma_{\epsilon\epsilon}$ is diagonal, and ii) $\Sigma_{\epsilon\epsilon}$ is represented by a factor model,

$$\Sigma_{\epsilon\epsilon} = \Lambda_S \Sigma_{SS} \Lambda_S' + \Sigma_{vv}$$

Sectoral Correlations and Volatility of IP Growth Rates

Quarterly U.S. Data and Values Implied by Model with Uncorrelated Sector-Specific Shocks

	(1998 IO Matrix)				(1977 IO Matrix)			
	72-83		84-07		67-83		84-02	
	Data	Model	Data	Model	Data	Model	Data	Model
Average Pairwise Correlation of Growth Rates	0.27	0.04	0.11	0.03	0.23	0.05	0.12	0.04
Std. Dev. of IP Growth Rate	8.9	3.7	3.6	2.2	8.5	4.0	3.9	2.4

Largest Eigenvalues of Sample Correlation Matrix

IO Model with Uncorrelated Sector-Specific Shocks

a. NAICS (1998 IO Matrix)								
	1972-1983				1984-2007			
Eigenvalue		Model %-tiles				Model %-tiles		
Rank	Data	1	50	99	Data	1	50	99
1	39.4	6.6	8.0	10.1	18.5	4.7	5.5	6.7
2	11.0	5.8	6.4	7.3	6.7	4.1	4.5	5.0
3	5.9	5.3	5.8	6.3	5.1	3.8	4.1	4.5
4	4.8	5.0	5.4	5.8	4.4	3.6	3.8	4.1
5	4.6	4.7	5.0	5.4	4.1	3.5	3.7	3.9
6	4.1	4.5	4.8	5.1	3.6	3.3	3.5	3.7
7	3.5	4.2	4.5	4.8	3.4	3.2	3.4	3.5

Largest Eigenvalues of Sample Correlation Matrix

IO Model with Uncorrelated Sector-Specific Shocks

	b. SIC (1977 IO Matrix)							
	1967-1983				1984-2002			
Eigenvalue		Model %-tiles				Model %-tiles		
Rank	Data	1	50	99	Data	1	50	99
1	30.8	5.9	7.4	9.2	16.9	5.2	6.2	7.7
2	9.1	4.6	5.1	5.8	6.0	4.3	4.8	5.5
3	4.6	4.3	4.6	5.1	4.7	4.0	4.4	4.8
4	4.2	4.0	4.3	4.7	4.3	3.8	4.1	4.4
5	3.6	3.8	4.1	4.4	4.0	3.6	3.9	4.1
6	3.4	3.6	3.8	4.1	3.9	3.5	3.7	3.9
7	3.1	3.4	3.7	3.9	3.6	3.3	3.5	3.7

Sectoral Correlations and Volatility of IP Growth Rates

Quarterly U.S. Data and Values Implied by 2-factor Model for Sector-Specific Shocks

	NAICS (1998 IO Matrix)				SIC (1977 IO Matrix)			
	72-83		84-07		67-83		84-02	
	Data	Model	Data	Model	Data	Model	Data	Model
Average Pairwise Correlation of Growth Rates	0.27	0.27	0.11	0.11	0.23	0.23	0.12	0.12
Std. Dev. of IP Growth Rate	8.9	9.1	3.6	3.7	8.5	8.8	3.9	4.2

Largest Eigenvalues of Sample Correlation Matrix

IO Model with 2 Factors for Sector-Specific Shocks

	a. NAICS (1998 IO Matrix)							
	1972-1983				1984-2007			
Eigenvalue		Model %-tiles				Model %-tiles		
Rank	Data	1	50	99	Data	1	50	99
1	39.4	30.1	39.7	48.4	18.5	14.9	19.2	23.6
2	11.0	8.4	12.2	16.9	6.7	6.3	8.3	10.6
3	5.9	3.6	4.2	5.0	5.1	3.4	3.8	4.4
4	4.8	3.3	3.7	4.3	4.4	3.2	3.5	3.8
5	4.6	3.0	3.5	3.9	4.1	3.0	3.2	3.5
6	4.1	2.8	3.2	3.7	3.6	2.8	3.1	3.3
7	3.5	2.7	3.0	3.4	3.4	2.7	2.9	3.1

Largest Eigenvalues of Sample Correlation Matrix

IO Model with 2 Factors for Sector-Specific Shocks

	b. SIC (1977 IO Matrix)							
	1967-1983				1984-2002			
Eigenvalue		Model %-tiles				Model %-tiles		
Rank	Data	1	50	99	Data	1	50	99
1	30.8	25.0	32.0	39.0	16.9	13.8	18.3	23.0
2	9.1	6.3	8.6	11.3	6.0	5.4	7.2	9.4
3	4.6	3.3	3.8	4.6	4.7	3.6	4.0	4.7
4	4.2	3.0	3.3	3.8	4.3	3.4	3.7	4.1
5	3.6	2.8	3.1	3.5	4.0	3.2	3.4	3.8
6	3.4	2.6	2.9	3.2	3.9	3.0	3.3	3.5
7	3.1	2.5	2.7	3.0	3.6	2.9	3.1	3.4

Decomposition of Variance from Statistical and Structural 2-Factor Models

	NAICS Definitions		SIC Definitions	
	72-83	84-07	67-83	84-02
Std. Dev. of IP Growth Rates	8.9	3.6	8.5	3.9
$R^2(F)$ - Statistical Model	0.89	0.87	0.85	0.94
$R^2(S)$ - Structural Model	0.88	0.69	0.83	0.72

Fraction of Aggregate IP Explained by Sector-Specific Shocks

2-Factor Model, 10 Largest Values

a. 1967-1983 (SIC)	
Sector	Fraction
Basic Steel and Mill Products	0.064
Coal Mining	0.034
Motor Vehicles, Trucks, and Buses	0.008
Utilities	0.007
Oil and Gas Extraction	0.005
Copper Ores	0.004
Iron and Other Ores	0.003
Petroleum Refining and Miscellaneous	0.003
Motor Vehicle Parts	0.003
Electronic Components	0.002

Fraction of Aggregate IP Explained by Sector-Specific Shocks

2-Factor Model, 10 Largest Values

b. 1984-2007 (NAICS)

Sector	Fraction
Iron and Steel Products	0.042
Electric Power Generation and Distribution	0.036
Semiconductors and Other Electronic	0.026
Oil and Gas Extraction	0.017
Automobiles and Light Duty Motor Vehicles	0.017
Organic Chemicals	0.017
Aerospace Products and Parts	0.015
Motor Vehicle Parts	0.013
Natural Gas Distributions	0.012
Support Activity for Mining	0.011

Structural Factor Analysis

- Horvath (1998), case where $\delta = 1$: independent sector-specific shocks contribute importantly to aggregate volatility - why?

- Importance of aggregate shocks as source of variation in IP depends on interaction of Γ and other model parameters

- $$\widetilde{Y}_{jt} = A_{jt} K_{jt}^{\alpha_j} \prod_{i=1}^{N} M_{ijt}^{\gamma_{ij}} L_{jt}^{1-\alpha_j-\sum_{i=1}^{N}\gamma_{ij}} + (1-\delta) K_{jt}.$$

Sectoral Correlations and Fraction of IP Variance Explained by Aggregate Shocks

Depreciation Rate	$\delta = 0.025$		$\delta = 1$	
a. NAICS (1998 IO Matrix)				
	72-83	84-07	72-83	84-07
Fraction of Aggregate Variance Explained by Aggregate Shocks, $R^2(S)$	0.88	0.69	0.74	0.30
Average Pairwise Correlation of Sectoral IP Growth Rates (0 factors)	0.04	0.03	0.09	0.07
b. SIC (1977 IO Matrix)				
	72-83	84-07	72-83	84-07
Fraction of Aggregate Variance Explained by Aggregate Shocks, $R^2(S)$	0.83	0.72	0.61	0.39
Average Pairwise Correlation of Sectoral IP Growth Rates (0 factors)	0.05	0.04	0.10	0.08

Sectoral Correlations and Fraction of IP Variance Explained by Aggregate Shocks Across Levels of Disaggregation

	1972-1983		1984-2007	
a. Average Pairwise Correlation of Sectoral Growth Rates				
	Model	Data	Model	Data
2-Digit Level, 26 Sectors	0.12	0.43	0.11	0.28
3-Digit Level, 88 Sectors	0.05	0.31	0.04	0.15
4-Digit Level, 117 Sectors	0.04	0.27	0.03	0.11
b. Fraction of IP Variance Explained by Aggregate Shocks				
2-Digit Level, 26 Sectors	0.87		0.70	
3-Digit Level, 88 Sectors	0.88		0.70	
4-Digit Level, 117 Sectors	0.88		0.69	

Conclusions

- Neither time variation in sectoral shares of IP, nor their distribution, are important factors in explaining aggregate IP variability
- Aggregate shocks largely explain variations in IP, and a decrease in the volatility of these shocks explain the decline in IP volatility after 1984
- Relative importance of sector-specific shocks has more than doubled over the “Great Moderation” period (from 12 percent to 30 percent)
- Changes in the structure of the input-output matrix between 1977 and 1998 do not suggest a greater propagation of sectoral shocks
- Analysis highlights the conditions under which multisector growth models first studied by Long and Plosser (1983) admit an approximate factor representation as a reduced form