Can the Intermediate Input Channel Explain Industry Comovement of Stock Prices?

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January 26, 2004

Abstract

This paper is to document and explain the industry comovement of stock prices over the business cycle in the US. The stock price indices in each industry are shown to have substantial business cycle comovement in terms of strong contemporaneous correlation between industry stock price indices and the aggergate stock price index. As a first step to account for the industry comovement of stock prices over the business cycle, we consider a multisector dynamic stochastic general equilibrium model which allows for intersectoral linkages. In competitive equilibrium, the (ex-dividend) stock price in a given sector is equal to the market value of its capital stock. When calibrated to the 2-digit SIC level of the intermediate input and the capital-use tables in the US, the model simulations yield positive comovement for stock prices in most of the industrial sectors, although they are below the actual comovement. Further, the difference between the varaiance-covariance matrix of the model-generated industry indices (which represent fundamental values of sectoral stocks) and that of the actual industry indices, is found to be neither positive nor negative semidefinite and twenty seven industry indices out of thirty show excess volatility. The violation of market efficiency is regarded mainly due to excess volatility of industry indices, instead of excess comovements across industry indices.

This paper is very preliminary. Please do not cite. We wish to thank Daeil Kim for helping us with SAS code for constructing stock price indices by industry. Any errors are our own. The authors can be contacted by email to: kunhong.kim@vuw.ac.kr, kimy@khu.ac.kr, and wrhee@khu.ac.kr

1 Introduction

It is well known that, over the business cycle, most sectors of the economy move up and down together. This comovement is a central part of the definition of the business cycle. Under the National Bureau of Economic Research's (NBER) definition, for example, "a recession is a period of decline in total output, income, employment, and trade, usually lasting from six months to a year, and marked by widespread contractions in many sectors of the economy." Hornstein (2000) document industry comovement for employment, capital service, and output (or value added) in the US. Christiano and Fitzgerald (1998) also document business cycle comovement of hours worked acorss industrial sectors. However, the synchronized movement of sectoral stock prices over the business cycle has not been documented and its possible explanation is yet to be provided.

The goal of this paper is two fold. First, we document the industry comovement of industrial stock prices over the business cycle in the US. Second, we explore possible explanations for the observed stock price comovement in the context of a multisector dynamic stochastic general equilibrium model which allows for intersectoral linkages in terms of the use of a given sector's output as intermediate materials and capital inputs to other sectors.

We construct the quarterly composite stock price indices by industry at the 2-digit Standard Industrial Code (SIC) level using all the stocks listed on NYSE, AMEX, and NASDAQ in the CRSP Stock file. The data cover the period from 1947 to 1999. The constructed industry indices appear to be plausible in the sense that the aggregate stock price index based on the estimated industry stock price indices matches closely the actual stock market index (e.g. S&P 500). As a measure of the comovement of stock prices across industrial sectors, we estimate the maximal correlation in absolute value of the contemporaneous, one-period lagged, and one-period led correlation between the industry indices and the aggregate index. We find that the sectoral stock prices have displayed substantial comovement over the business cycle in the US.

What would be the possible explanations for the observed comovement? It has been argued that the observed comovement for employment, investment, and output is inconsistent with independent industry-specific shocks (e.g. Lucas 1981). The effect of uncorrelated industry-specific disturbances may tend to wash out since, by the law of large numbers, negative variations in some sectors offset positive variations in other sectors. This was recently refuted by Horvath (1998, 2000) in the context of a multisector dynamic stochastic general equilibrium model.

In a generalized version of Long and Plosser (1983) and calibrated to the 2-digit Standard Industrial Code (SIC) level of disaggregation using the intermediate input-use and the capital-use matrices in the US, Horvath (1998, 2000) shows that the model can match aggregate fluctuations in the US with independent sectoral productivity shocks only.[1] This is due to the propagation mechanism of the the sectoral shocks via the "sparse matrices" form of the intermediate input and the capital use tables, which have the effect of delaying application of the law of large numbers. Using a version of Horvath (2000), Kim and Kim (2003) also characterizes the role of the intermediate input channel and the preference specification with divisible or indivisible labor in generating the sectoral comovement for employment, investment, and output over the business cycle.[2]

As a first step to account for the industry comovement of stock prices over the business cycle, we consider a multisector model (e.g. Horvath 2000) to investigate

[1]Long and Plosser (1983) adopt several simplifying assumptions such as a complete depreciation of capital stock within a time period (e.g., a quarter). Despite allowing for analytical tractability, these assumptions make their model economy unsuitable for quantitative empirical analysis.

[2]Horvath (2000) emphasizes the persistence and volatility in aggregate fluctuations driven by independent sectoral productivity shocks, paying less attention to the comovement across sectors over the business cycle. In fact, he noted that as labor hours become perfect substitutes across sectors, wage differences between two sectors due to sector-specific productivity shocks cause large but opposite movements in employment in the two sectors as the worker allocates more time to the sector paying higher wages.

the relative importance of the production technology with intersectoral linkages and the specification of preferences with divisible or indivisible labor in explaining the industry comovement for stock prices. We show that, in competitive equilibrium, the (ex-dividend) stock price in a given sector is equal to the market value of its capital stock. Intuitively, for the two types of assets–physical capital and stock–to coexist in equilibrium, the rate-of-return equivalence implies that individual sector's stock price should be equal to the market value of the physical capital stock accumulated in the given sector.

In order to examine the quantitative implications of intersectoral linkages for the stock price comovement over the business cycle, we then simulate the model economy calibrated to the 2-digit SIC level (e.g., 30 sectors) of the intermediate input-use and the capital-use tables in the US. The model simulations yield positive comovement for stock prices in most of the industrial sectors, although they are below the actual comovement. We then investigate the implication of market efficiency by examining positive semidefiniteness of the difference between the varaiance-covariance matrix of the model- generated industry indices (which represent fundamental values of sectoral stocks) and that of the actual industry indices. We found that the matirx of covariance difference is neither positive nor negative semidefinite and twenty seven industry indices out of thirty show excess volatility. These rusults imply that the violation of market efficiency is mainly due to excess volatility of industry indices, instead of excess comovements across industry indices.

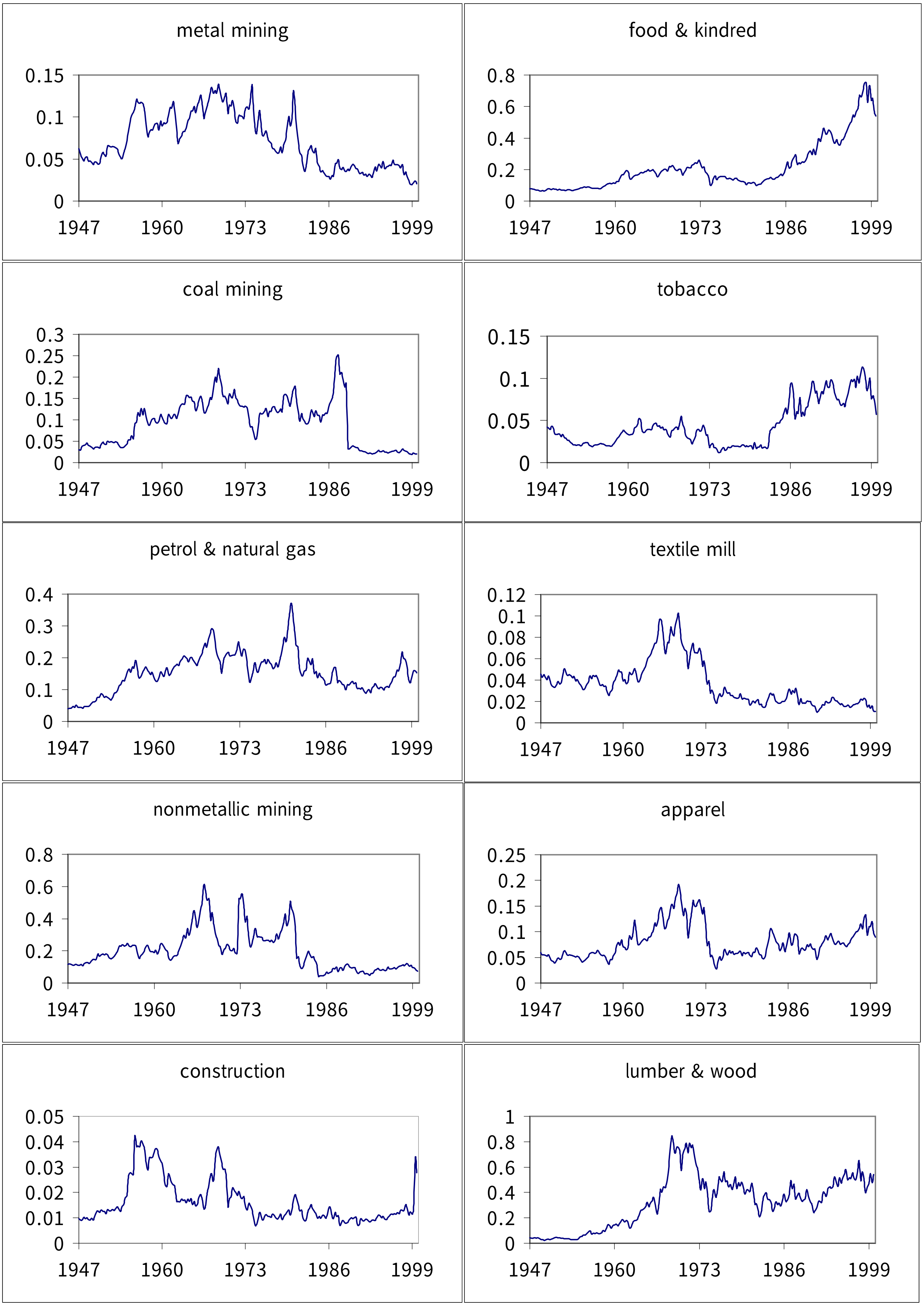
The paper is organized as follows. Section 2 documents industry comovement of stock prices over the business cycle in the US. Section 3 describes the model economy and its competitive equilibrium, including the characterization of equilibrium asset pricing relationships. In section 4 we present the model calibration and quantitative simulation results on the industry comovement of stock prices over the business cycle. Section 5 sums up the paper with a few remarks, followed by the Appendix which describes the procedure of constructing the composite stock price indices by industry.

2 Industry Comovement of Stock Prices

We first document comovement of stock prices across industrial sectors in the US. The composite stock price indices by industry at the 2-digit Standard Industrial Code (SIC) level is constructed using all the stocks listed on NYSE, AMEX, and NASDAQ in the CRSP Stock file. The data start in December 1925 and ends in December 1999. The procedure of constructing the industry-level stock price indices is described in the Appendix. The resulting indices are depicted in Figure 1. In order to see the plausibility of these indices, we also construct the aggregate stock price index using the estimated industry stock price indices. Panels (a) and (b) of Figure 2 show that the constructed aggregate index resembles closely the actual stock market index (e.g. S&P 500).

As a measure of the comovement of stock prices across industrial sectors, we focus on the comovement between sectoral indices and aggregate index in the US after removing trend by the Hodrick-Prescott (1997) filter. Hornstein (2000) also uses the same measure to document industry comovement for employment, capital service, and output (or value added) in the US over the business cycle, although he uses a band pass filter for detrending purposes as described in Christiano and Fitzgerald (1998) and Hornstein (1998).

More specifically, the industry comovement is measured by the maximal correlation in absolute value of the contemporaneous, one-period lagged, and one-period led correlation between industry indices and aggregate index. In Table 1, the second column reports the maximal correlation between the industry h's indices (q_t^h) and the corresponding aggregate index (Q_t): $corr(q_t^h, Q_{t+z})$ with $z = 1, 0, -1$. A plus (minus) superscript denotes that the industry h's stock price index is leading (lagging) the aggergate index, that is $z = 1 (z = -1)$. No superscript indicates that the contemporaneous correlation is maximal. It is worth noting that the stock price indices in each industry have strong contemporaneous correlation with the aggergate stock price index, ranging from 0.44 to 0.87.


metal mining
0.15
0.1
0.05
0
1947
1960
1973
1986
1999
food & kindred
0.8
0.6
0.4
0.2
0
coal mining
0.3
0.25
0.2
0.15
0.1
0.05
0
tobacco
0.15
0.1
0.05
0
petrol & natural gas
0.4
0.3
0.2
0.1
0
textile mill
0.12
0.1
0.08
0.06
0.04
0.02
0
nonmetallic mining
0.8
0.6
0.4
0.2
0
apparel
0.25
0.2
0.15
0.1
0.05
0
construction
0.05
0.04
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0.02
0.01
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lumber & wood
1
0.8
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Figure 1

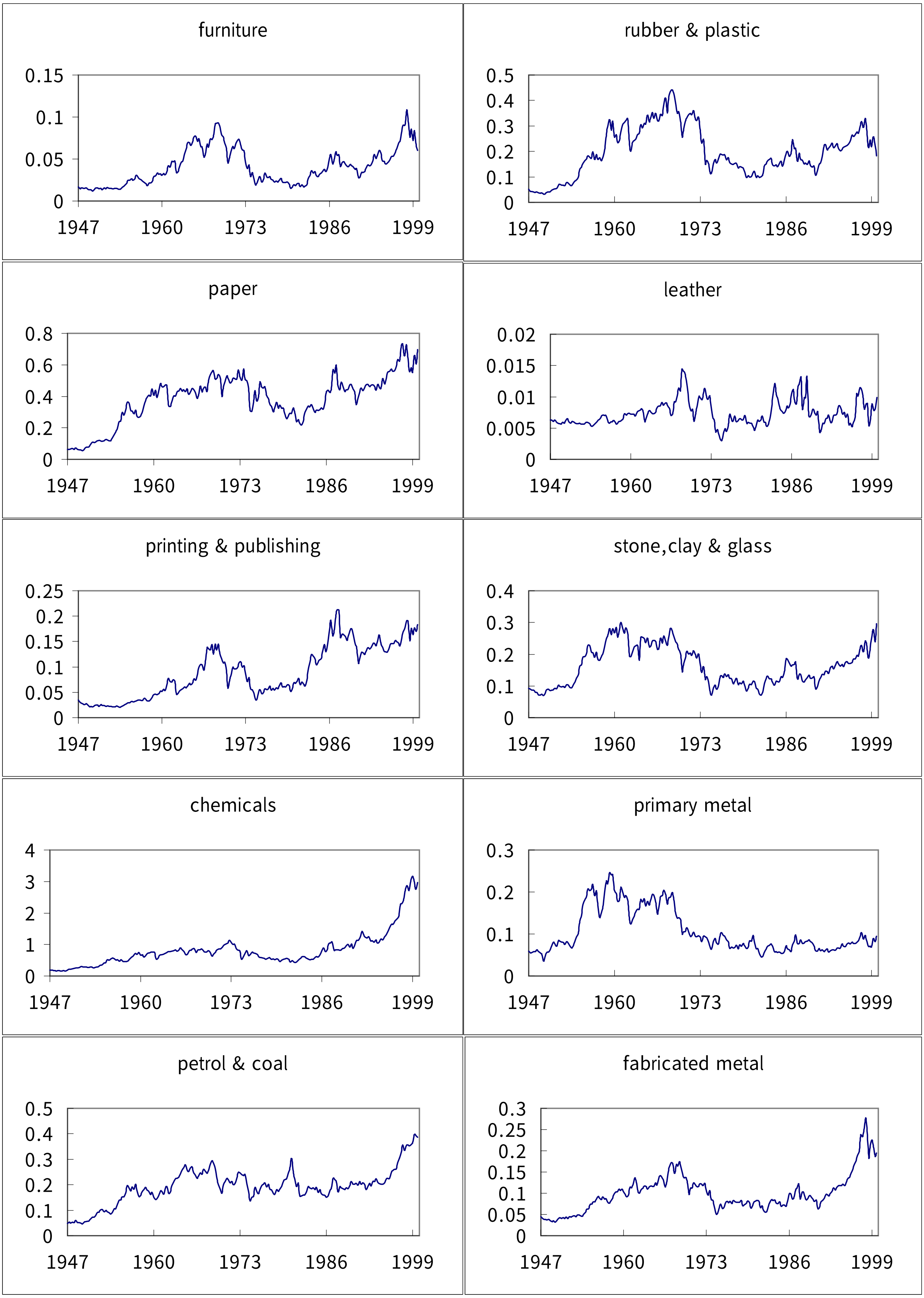


Figure 1 (continued)

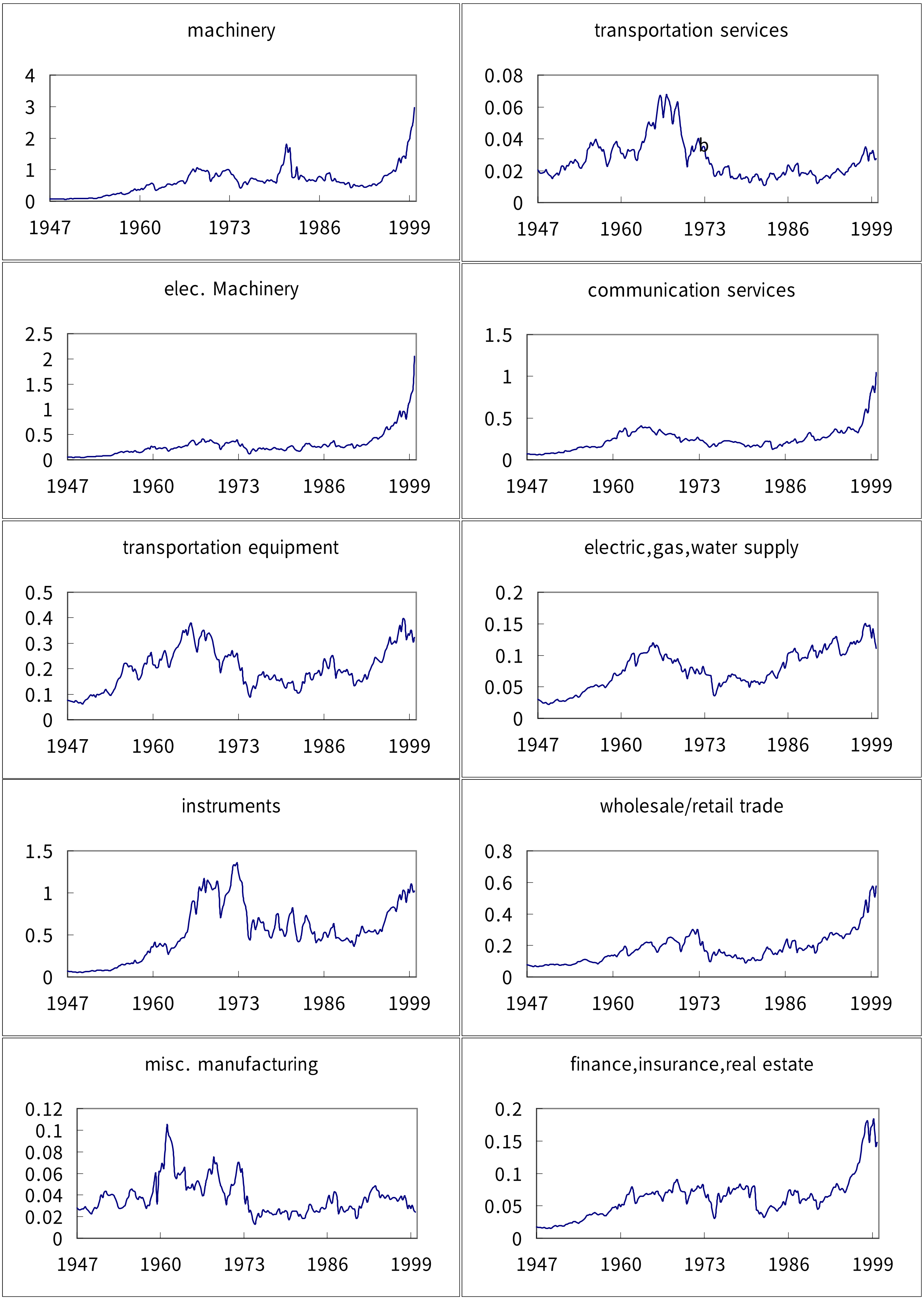
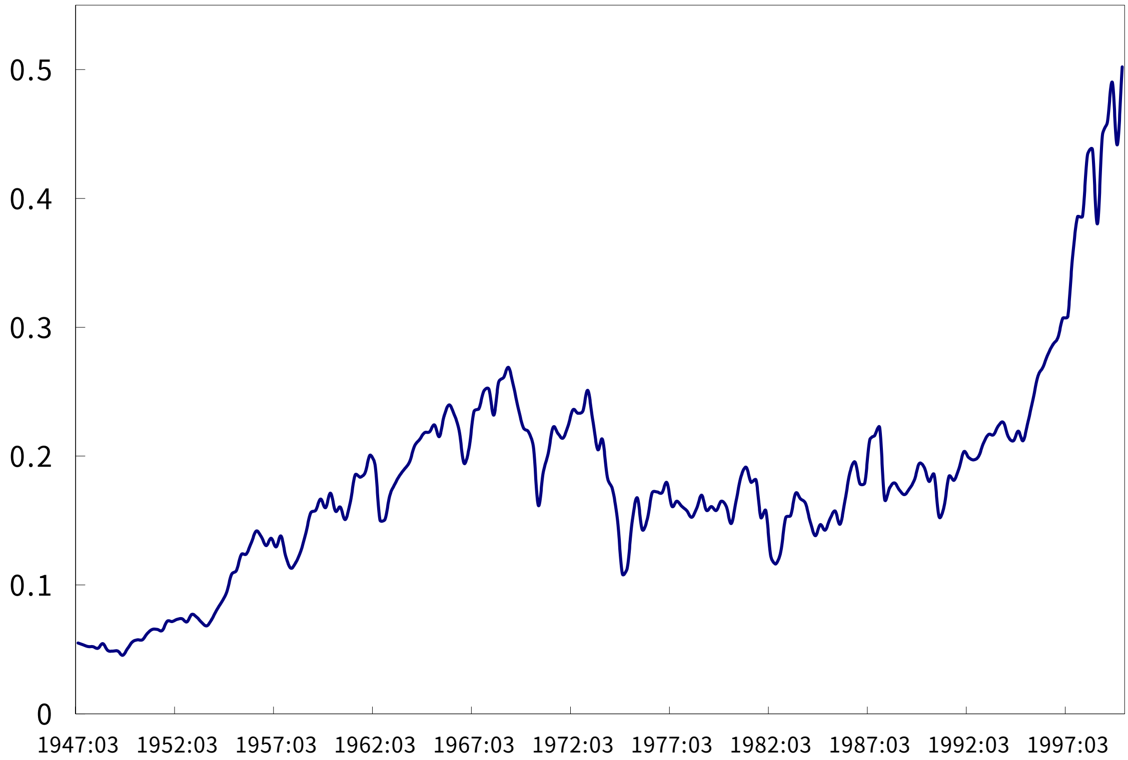


Figure 1 (continued)

(a) Aggregate Index (constructed)



(b) S&P 500 (actual)

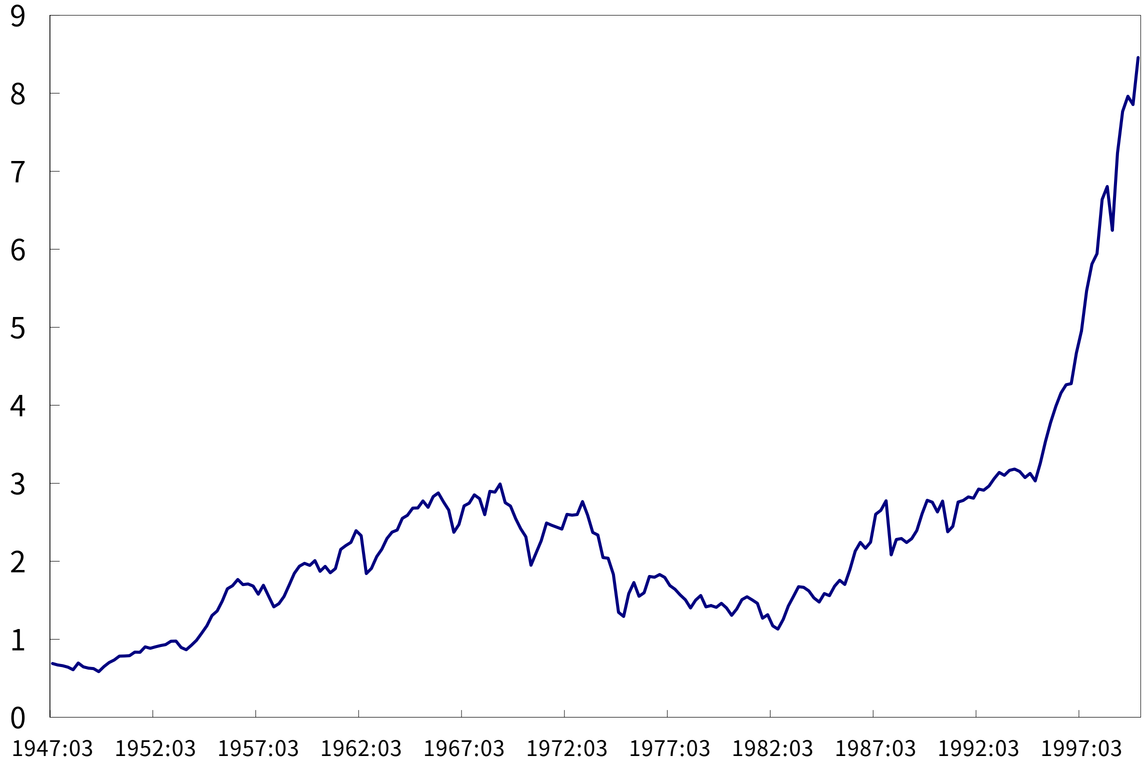


Figure 2

Table 1: Sectoral Stock Price Comovement in the US

Sector	(Q, q^h)	(Q_{-1}, q^h)	(Q_{+1}, q^h)	Maximal
Nondurables & Services				
Metal mining	0.4682	0.3975	0.2356	0.4682
Coal mining	0.4399	0.3922	0.2800	0.4399
Oil & natural gas	0.6757	0.5475	0.4249	0.6757
Nonmetallic mining	0.5122	0.3999	0.3129	0.5122
Construction	0.6848	0.4784	0.4328	0.6848
Food & kindred	0.7672	0.4462	0.5756	0.7672
Tobacco	0.5049	0.2296	0.4201	0.5049
Textile mill	0.7801	0.5149	0.5916	0.7801
Apparel	0.8044	0.5450	0.5728	0.8044
Paper	0.8354	0.5896	0.5441	0.8354
Printing & publishing	0.8023	0.5150	0.5577	0.8023
Chemicals	0.8651	0.5696	0.6229	0.8651
Petroleum & coal	0.7084	0.5560	0.4897	0.7084
Rubber & plastics	0.7841	0.5294	0.5603	0.7841
Leather	0.6614	0.4066	0.4974	0.6614
Transportation services	0.8404	0.5987	0.5470	0.8404
Communication services	0.5874	0.3713	0.3768	0.5874
Electric, gas, water supply	0.7071	0.4279	0.5669	0.7071
Wholesale & retail trade	0.8071	0.5099	0.5605	0.8071
Finance, insurance, real estate	0.7893	0.4414	0.6212	0.7893
Durables				
Lumber & wood	0.7526	0.5032	0.5252	0.7526
Furniture & fixtures	0.7913	0.4923	0.5941	0.7913
Stone, clay, glass	0.8573	0.5903	0.5874	0.8573
Primary metal	0.7223	0.5628	0.4226	0.7223
Fabricated metal	0.8705	0.5859	0.5783	0.8705
Machinery, non-electrical	0.7218	0.5298	0.4311	0.7218
Electrical machinery	0.8308	0.5636	0.5407	0.8308
Transportation equipment	0.8443	0.6017	0.6027	0.8443
Instruments	0.7764	0.5561	0.5080	0.7764
Misc. manufacturing	0.7669	0.5269	0.5527	0.7669

Can this correlation be justified by the theory? We now turn to this question. If markets are efficient,

$$q_t^h = E_t q_t^{h*}$$

where q_t^h is the stock price (or transformed price) of industry h at t and q_t^{h*} is the fundamental value of stock h, and E_t denotes the mathematical expectation operator conditional on the public information available at t. In vector notation, this can be rewritten as

$$\mathbf{q}_t = E_t \mathbf{q}_t^*.$$

where $\mathbf{q}_t$ and $\mathbf{q}_t^*$ are respectively the vector of industrial stock prices and their fundamental values. Further, let $\mathbf{u}_t$ denote the corresponding vector of forecasting errors with $\boldsymbol{\Sigma}_u$ its variance-covariance matrix. That is,

$$\mathbf{q}_t^* = \mathbf{q}_t + \mathbf{u}_t$$

Now let $\boldsymbol{\Sigma}$ and $\boldsymbol{\Sigma}^*$ denote respectively the variance-covariance matrices of the sectoral stock prices and their fundamental counterparts. Then, market efficiency implies

$$\boldsymbol{\Sigma}^* = \boldsymbol{\Sigma} + \boldsymbol{\Sigma}_u$$

In view of positive semidefiniteness of $\boldsymbol{\Sigma}_u$, this equation can be rewritten as the following condition:

$$\boldsymbol{\Sigma}^* - \boldsymbol{\Sigma} : \text{ positive semidefinite} \tag{1}$$

This condition can be violated in the following two cases: (i) $\boldsymbol{\Sigma}^* - \boldsymbol{\Sigma}$ is neither positive semidefinite nor negative semidefinite; and (ii) $\boldsymbol{\Sigma}^* - \boldsymbol{\Sigma}$ is negative semidefinite. In the former case, some portfolios of sectoral stocks (or individual sector's stocks) would show excess volatility ($\boldsymbol{\Sigma}^* < \boldsymbol{\Sigma}$), but others would not ($\boldsymbol{\Sigma}^* > \boldsymbol{\Sigma}$). In the latter case, all the possible portfolios of sectoral stocks would show excess volatility.

In general, the matrix $\boldsymbol{\Sigma}^* - \boldsymbol{\Sigma}$ is positive semidefinite if and only if all the eigenvalues of the matrix are greater than or equal to zero. We will examine positive semidefiniteness of $\boldsymbol{\Sigma}^* - \boldsymbol{\Sigma}$ in section 4.

3 The Model

In order to examine comovements in stock prices and dividends among industrial sectors, we simulate a version of Horvath (2000)'s multisector dynamic stochastic general equilibrium model calibrated to the intermediate input-use and the capital-use tables at the 2-digit SIC level of disaggregation. For those readers unfamiliar with Hovarth (2000), we briefly describe the model below.

3.1 The Environment

The model economy consists of M (say, 30) distinct sectors, indexed by $h = 1, 2, ..., M$, each producing a different good. The technologies are distinct across the sectors. Multi-factor productivity in each sector is subject to stochastic innovations which are not perfectly correlated across sectors. The output of each sector goes to potentially three different uses. First, some goods are used as intermediate inputs in the production of other goods. Sectors do not necessarily use the same intermediate inputs. Second, some goods are built into the capital stocks of the sectors in the economy and each sector has a distinct capital stock. Finally, a portion of output in each sector is supplied to a final consumption market. It is assumed that intermediate inputs are delivered and either used within one period or built into the capital stock of the purchasing sector. The production of each sector is controlled by firms which operate so as to maximize their expected present discounted value to shareholders.

An output, y_t^h, of good h is produced by combining capital in the sector, k_t^h, labor, n_t^h, and an index of intermediate inputs, M_t^h in a production process given by

$$y_t^h = A_t^h \left(k_t^h\right)^{\alpha_h} \left(n_t^h\right)^{\beta_h} \left(M_t^h\right)^{\gamma_h}, \tag{2}$$

where constant returns to scale implies $\alpha_h + \beta_h + \gamma_h = 1$. In (2), A_t^h represents the multifactor productivity or state of technology in sector h, which is assumed to follow a stochastic process given by

$$\ln(A_t^h) = \rho_h \ln(A_{t-1}^h) + \epsilon_t^h, \tag{3}$$

where ϵ_t^h is a serially uncorrelated, normally distributed random variable with mean zero and $E(\epsilon_t \epsilon_t') = \Omega$.

The index of intermediate inputs for sector h has a Cobb-Douglas form which implies a unitary elasticity of substitution between inputs:

$$M_t^h = \prod_{s \in B_h^M} (m_{t,s}^h)^{x_{sh}} \tag{4}$$

where $m_{t,s}^h$ denotes the quantity of good s purchased by sector h at period t for intermediate inputs and B_h^M denotes the set of sector indices which are inputs to the production of good h. The weights are normalized to satisfy: $\sum_{s \in B_h^M} x_{sh} = 1$ and $x_{sh} = \gamma_{sh}/\gamma_h$ where γ_{sh} is the sh^{th} element of Γ_m, the intermediate input-use matrix, denoting the cost share of total expenditure on intermediate goods in sector h due to purchases of intermediate goods from sector s. And γ_h denotes the sum of the h^{th} column in Γ_m.

Further, capital is accumulated through an investment process given by

$$k_{t+1}^h - (1 - \mu_h) k_t^h = \eta(i_t^h), \tag{5}$$

where $\mu_h \in (0, 1)$ is a sector specific depreciation rate. The (composite) investment good for sector h is created by combining inputs in a Cobb-Douglas form:

$$\eta(i_t^h) = \prod_{s \in B_h^I} (i_{t,s}^h)^{\tilde{x}_{sh}} \tag{6}$$

where $i_{t,s}^h$ denotes the quantity of good s purchased by sector h for investment purposes and B_h^I denotes the set of sectors from which sector h purchases intermediate goods for capital investment. And the weight $\tilde{x}_{sh}$ is derived from the capital input-use matrix, Γ_I, similarly to the weight x_{sh} in the index of intermediate inputs (4).

The consumer-shareholders allocate labor hours to the various industry sectors and make consumption-savings decisions. The representative consumer seeks to maximize his or her discounted expected utility given by

$$E_0 \sum_{t=0}^{\infty} \delta^t \left[\log C_t + \chi \log L_t\right], \quad 0 < \delta < 1 \text{ and } \chi > 0 \tag{7}$$

subject to:

$$\sum_{h=1}^{M} p_t^h c_t^h = \sum_{h=1}^{M} p_t^{n_h} n_t^h + \sum_{h=1}^{M} (d_t^h + q_t^h) s_t^h - \sum_{h=1}^{M} q_t^h s_{t+1}^h \equiv a_t. \tag{8}$$

In (6), $\delta \in (0,1)$ is a discount factor, C_t is an aggregate consumption index, and L_t is an aggregate leisure index at period t. Given an initial share s_0^h for $h = 1, ..., M$, the consumer's budget constraint (8) shows that the sum of goods purchased, c_t^h, valued at their respective prices, p_t^h cannot exceed a_t, total income in period t. Other notations concerning sector h at period t are: $p_t^{n_h}$ hourly wage, d_t^h dividend paid per share held, q_t^h share price per unit, s_t^h share holdings at the beginning of t, and s_{t+1}^h shares purchased for period $t+1$.

The aggregate consumption index has a Cobb-Douglas form:

$$C_t = \prod_{h=1}^{M} (c_t^h)^{\xi^h} \tag{9}$$

where ξ^h is the consumption expenditure share of good h. Further, the representative consumer is endowed with one unit of time in each period and the aggregate leisure index takes the following form:

$$L_t = 1 - \left[\sum_{s=1}^{M} (n_t^s)^{\frac{\tau+1}{\tau}} \right]^{\frac{\tau}{\tau+1}}, \qquad \tau > 0 \tag{10}$$

As $\tau \to \infty$, labor hours become perfect substitutes for the consumer/worker, implying that the worker would devote all time to the sector paying the highest wage. Hence, at the margin, all sectors pay the same hourly wage. For $\tau < \infty$, hours worked are not perfect substitutes for the worker. The worker has a preference for diversity of labor, and hence would prefer working a positive number of hours in each sector even when the wages are different among sectors.

3.2 Competitive Equilibrium

The competitive equilibrium consists of $(M \times 1)$ vectors of exogenous productivity shocks $\{\varepsilon_t\}_{t=0}^{\infty}$, $(M \times 3)$ price vectors $\{p_t, \pi_t, p_t^n\}_{t=0}^{\infty}$, and $(M \times 6)$ quantity vectors

$\{k_t, n_t, M_t, c_t, i_t, y_t\}_{t=0}^{\infty}$ such that

1. productivity levels $\{A_t\}_{t=0}^{\infty}$ follow their laws of motion given by (3) subject to shocks $\{\varepsilon_t\}_{t=0}^{\infty}$;

2. firms maximize present discounted value of dividends $\{d_t\}_{t=0}^{\infty}$ subject to the sectoral production technology (2) and the sectoral law of motion of capital accumulation (5):
$$\max E_0 \sum_{t=0}^{\infty} \delta^t \left(\frac{a_t}{P_t}\right)^{-1} \left(\frac{d_t^h}{P_t}\right)$$
where $d_t^h = p_t^h y_t^h - p_t^{n_h} n_t^h - \pi_t^h \eta(i_t^h) - P_t^{M_h} M_t^h$,
$$P_t = \prod_{h=1} (p_t^h)^{\xi^h}, \quad \pi_t^h = \prod_{s \in B_h^I} (p_t^s)^{\tilde{x}_{sh}}, \quad \text{and} \quad P_t^{M_h} = \prod_{s \in B_h^I} (p_t^s)^{x_{sh}}$$
Real dividends (d_t^h/P_t) are discounted by $(a_t/P_t)^{-1} = 1/C_t$, which is the consumer-shareholders' marginal utility of consumption with the logarithmic per-period utility function as assumed here.

3. consumers maximize lifetime utility (7) subject to:
$$\sum_{h=1} p_t^h c_t^h = \sum_{h=1} \left[p_t^{n_h} n_t^h + r_t^h k_t^h - \pi_t^h \eta(i_t^h) \right] \equiv a_t$$
where the wage rate $p_t^{n_h} = \beta_h p_t^h y_t^h / n_t^h$ and the capital rental rate $r_t^h = \alpha_h p_t^h y_t^h / k_t^h$;

4. prices clear labor markets and goods markets:
$$n_t^h = \left\{ \frac{\beta_h}{\chi} \frac{p_t^h y_t^h}{a_t} L_t (1 - L_t)^{\frac{1}{\tau}} \right\}^{\frac{\tau}{1+\tau}}$$
$$y_t^h = c_t^h + \sum_{s=1} i_{t,h}^s + \sum_{s=1} m_{t,h}^s.$$
The labor market-clearing condition for sector h is obtained from equating the sectoral labor demand determined by the marginal product of labor with labor supply determined by the consumers' marginal rate of substitution between leisure and consumption.

3.3 Equilibrium asset pricing relationships

In a given period t, there are two types of assets available in each sector of the model economy: physical capital (k_t^h) and equity or share of stocks (s_t^h) for $h = 1, ..., M$. First of all, differentiating present discounted value of dividends with respect to k_{t+1}^h yields the first-order condition for optimal capital stock in sector h:

$$\frac{\pi_t^h}{P_t}\left(\frac{a_t}{P_t}\right)^{-1} = \delta E_t \left\{ \frac{1}{P_{t+1}}\left(\frac{a_{t+1}}{P_{t+1}}\right)^{-1} \left[\frac{p_{t+1}^h y_{t+1}^h}{k_{t+1}^h}\alpha_h + (1-\mu_h)\pi_{t+1}^h\right] \right\}. \qquad (11)$$

Further, optimal share holdings are determined by the following intertemporal first-order condition in the maximization of the household's lifetime expected utility (7) subject to (8):

$$\frac{q_t^h}{P_t}\left(\frac{a_t}{P_t}\right)^{-1} = \delta E_t \left[\frac{1}{P_{t+1}}\left(\frac{a_{t+1}}{P_{t+1}}\right)^{-1} (d_{t+1}^h + q_{t+1}^h) \right]. \qquad (12)$$

In a competitive equilibrium where both types of assets exist in each sector, the same rate of return from each type of asset implies:

$$\frac{\alpha_h \left(\frac{p_{t+1}^h y_{t+1}^h}{k_{t+1}^h}\right) + (1-\mu_h)\pi_{t+1}^h}{\pi_t^h} = \frac{d_{t+1}^h + q_{t+1}^h}{q_t^h} \qquad (13)$$

Below we show that q_t^h, the ex-dividend share price at t in sector h, is equal to the market value of capital stock at the beginning of $t+1$ in the corresponding sector, $\pi_t^h k_{t+1}^h$.

Proposition 1 *In the period-t competitive equilibrium where both types of assets are valued in each sector, $q_t^h = \pi_t^h k_{t+1}^h$.*

Proof. The optimal level of the employment and the intermediate good index in sector h equates its per unit cost, $p_t^{n_h}$ and $p_t^{M_h}$, respectively with its marginal product:

$$p_t^{n_h} = \beta_h \left(\frac{p_t^h y_t^h}{n_t^h}\right) \text{ and } P_t^{M_h} = \gamma_h \left(\frac{p_t^h y_t^h}{M_t^h}\right).$$

Substituting these into (11) yields the following:

$$\begin{aligned} d_t^h &= p_t^h y_t^h(1-\beta_h-\gamma_h) - \pi_t^h\left[k_{t+1}^h-(1-\mu_h)k_t^h\right] \\ &= \alpha_h(p_t^h y_t^h) - \pi_t^h\left[k_{t+1}^h-(1-\mu_h)k_t^h\right] \end{aligned} \qquad (14)$$

where the second equality is obtained from the constant-returns-to-scale production technology. Now, the rate-of-return equivalence (13) along with (14) implies $q_t^h = \pi_t^h k_{t+1}^h$. ■

That is, for the two types of assets–physical capital and stock–to coexist in equilibrium, the rate-of-return equivalence implies that individual sector's stock price should be equal to the market value of the physical capital stock accumulated in the given sector.

Finally, aggregate stock price index in nominal terms are simply the sum over all sectoral nominal stock prices ($\sum_{h=1}^{M} q^h$). To obtain aggregate index in real terms, we follow an accounting method with Divisia indices which are defined in terms of growth rates of sectoral value added. Horvath (2000) and Basu and Fernald (1997) contain a detailed description of the construction of Divisia indices for this type of model economy.

4 Quantitative Results

Except for a special case of the parameter set, analytical solutions are not possible. An approximate solution is computed by log-linearizing all equilibrium equations with a first-order Taylor series expansion around the model's steady state.

As for the calibrations of the model parameters, the level of sectoral disaggregation is set to $M = 30$, following the sectoral definitions used by Jorgenson, et. al. (1987) which has a mixture of 1- and 2-digit SIC industries. The production technology parameters, α_h, β_h, and γ_h are set respectively as the time-series average of cost shares for capital, labor, and intermediate inputs for 30 sectors using annual data from 1948 to 1985 (Jorgenson, et. al. 1987) by dividing the cost of inputs by the value of output both evaluated at producer prices. The share parameter γ_{sh} is obtained from γ_h after being divided across all interacting sectors using the fraction that the purchases from these sectors represent out of total intermediate purchases by sector h. The mean value of α_h, β_h, and γ_h is respectively 0.16, 0.32, and 0.52. The "shocks" parameters, ρ_h and Ω, are also constructed using the Jorgenson data set. We consider the model economy where the productivity shocks are not independent across sectors: that is, off-diagonal elements from the estimated variance-covariance matrix of sectoral productivity residuals are not assumed to be zero.[3] The sectoral depreciation rates of capital stocks, μ_h, are those used in Jorgenson, et. al. (1987).

The time period considered is the quarter. Following the other business cycle models, the discount factor, δ, is set to be $(1.03)^{-0.25}$ implying an annual discount rate of 3%. The parameter χ is set so that total hours worked in steady state represent one-third of the worker's total time endowment. The share parameter ξ^h in the aggregate consumption index is obtained from the nominal consumption expenditure share of sector h in total consumption, $\xi^h = p^h c^h / \sum p^h c^h$, using consumption data from the National Income and Product Accounts. Following Horvath (2000), we set $\tau = 1$ to represent the worker's reluctance to substitute labor hours across sectors. This reflects the typical finding in labor economics that wage elasticity of labor supply is relatively low (e.g. Altonji 1982, Ashenfelter and Altonji 1980). The parameter χ is set so that total hours worked in steady state represent one-third of the worker's total time endowment. For example, $\tau = 1$ implies $\chi = 13.4$.

Data for the investment-use matrix Γ_I and the intermediate input-use matrix Γ_m are based on the 1977 capital flow table described in Silverstein (1985) and the 1977 detailed intermediate input-use table, respectively. The capital-use and intermediate input-use tables are converted respectively to Γ_I and Γ_m by properly aggregating to

[3] The simulation results under zero off-diagonal elements in Ω are very close to those with non-zero off-diagnoal elements.

36 sectors and then dividing columns by their sums.

The simulation results are presented in Table 2, along with the actual sectoral or industry comovement in stock prices in the US. The second column reproduces from Table 1 the actual comovement between the sectoral and the aggregate indices in the US. The third column ("MODEL") reports the industry comovement of stock prices in the model economy. This is measured similarly to the actual comovement by taking averages of 100 simulated economies of length 148 quarters. Simulated data are Hodrick-Prescott (HP) filtered before they are used to estimate correlation coefficients between the industry indices and the aggregate index. A plus (minus) superscript denotes that the industry employment is leading (lagging) the aggergate employment, whereas no superscript indicates that the contemporaneous correlation is maximal. Next to the maximal correlation coefficients are their respective standard errors (s.e.) in the last column. The model simulations yield positive comovement for stock prices in most of the industrial sectors, but they are below the actual comovement.

In order to compare directly the comovement in the model economy with the actual comovement, let $\mathbf{\Sigma}$ and $\mathbf{\Sigma}^*$ denote respectively the variance-covariance matrices of the sectoral stock prices in the real world and in the model economy. Then we examine the following condition as discussed in section 2:

$$\mathbf{\Sigma}^* - \mathbf{\Sigma} : \text{ positive semidefinite}$$

This condition was derived under the market efficiency in section 2 and will hold if and only if no eigenvalues of $\mathbf{\Sigma}^* - \mathbf{\Sigma}$ are less than zero. A simple calculation shows that only three of the thirty eigenvalues are positive, and the remaining twenty seven eigenvalues are either equal to zero or negative, implying that $\Sigma_{MODEL} - \Sigma_{DATA}$ is neither positive nor negative semidefinite.[4]

Recall that violation of the condition (1) implies the following two cases: (i) $\mathbf{\Sigma}^* - \mathbf{\Sigma}$ is neither positive semidefinite nor negative semidefinite; or (ii) $\mathbf{\Sigma}^* - \mathbf{\Sigma}$ is negative

[4] The three eigenvalues are 0.23, 0.012, and 0.0014.

semidefinite. Our results show that the condition is violated not because $\mathbf{\Sigma}^* - \mathbf{\Sigma}$ is negative semidefinite but because $\mathbf{\Sigma}^* - \mathbf{\Sigma}$ is neither positive semidefinite nor negative semidefinite. This suggests the possibility of excess comovements among sectoral stock price indices. However, the fact that $\mathbf{\Sigma}^* - \mathbf{\Sigma}$ is neither positive semidefinite nor negative semidefinite does not necessarily imply that the violation of the condition (1) is due to excess comovements rather than excess volatility. It can happen when some portfolios (or individual stocks) show excess volatility, whereas others do not. It can also happen when covariances between portfolios (or individual stocks) i and j are large relative to covariances between fundamental values of portfolios (or individual stocks) i and j, and hence we can construct portfolios that show excess volatility even though no components of P_t show excess volatility. Shiller (1989) relates this latter case to excess comovements.

In order to discriminate these two cases, we compare in Table 3 the variances of the sectoral stock price indices in the real world with their counterparts in the model economy which represent the variances of the fundamental value of each industry. In only three cases out of thirty, the variance of fundamental values is greater than the variance of actual values, satisfying the implication of market efficiency. In the remaining cases, the variance of actual values is greater than the variance of fundamental values. These results suggest that violation of the condition (1) is mainly due to excess volatility of industry indices not excess comovements across industry indices.

Table 2: Sectoral Stock Price Comovement

Sector	DATA	MODEL	(s. e.)
Nondurables & Services			
Metal mining	0.4682	0.1926	(0.148)
Coal mining	0.4399	-0.0021	(0.154)
Oil & natural gas	0.6757	0.0956	(0.155)
Nonmetallic mining	0.5122	0.0696^-	(0.159)
Construction	0.6848	0.4011	(0.132)
Food & kindred	0.7672	0.0010^-	(0.162)
Tobacco	0.5049	-0.0395^-	(0.155)
Textile mill	0.7801	-0.0278^-	(0.159)
Apparel	0.8044	-0.0462^-	(0.156)
Paper	0.8354	0.1203	(0.155)
Printing & publishing	0.8023	0.1254	(0.154)
Chemicals	0.8651	0.1726	(0.150)
Petroleum & coal	0.7084	-0.0356^-	(0.158)
Rubber & plastics	0.7841	0.1850	(0.150)
Leather	0.6614	0.0025^-	(0.156)
Transportation services	0.8404	0.1079^-	(0.160)
Communication services	0.5874	0.1339	(0.146)
Electric, gas, water supply	0.7071	0.0749	(0.159)
Wholesale & retail trade	0.8071	0.0887	(0.156)
Finance, insurance, real estate	0.7893	0.3119	(0.147)
Durables			
Lumber & wood	0.7526	0.1226	(0.155)
Furniture & fixtures	0.7913	0.0321^-	(0.157)
Stone, clay, glass	0.8573	0.2241	(0.147)
Primary metal	0.7223	0.3711	(0.135)
Fabricated metal	0.8705	0.2489	(0.147)
Machinery, non-electrical	0.7218	0.3912	(0.134)
Electrical machinery	0.8308	0.4588	(0.107)
Transportation equipment	0.8443	0.0888^-	(0.161)
Instruments	0.7764	0.2627	(0.152)
Misc. manufacturing	0.7669	0.1800	(0.139)

Table 3: Sectoral Stock Price Volatility

Sector	DATA	MODEL	(s. e.)
Nondurables & Services			
Metal mining	0.0266	0.0002	(0.00003)
Coal mining	0.0540	0.0002	(0.00004)
Oil & natural gas	0.0194	0.0091	(0.00171)
Nonmetallic mining	0.0605	0.0003	(0.00006)
Construction	0.0288	0.0057	(0.00121)
Food & kindred	0.0114	0.0098	(0.00206)
Tobacco	0.0266	0.0014	(0.00031)
Textile mill	0.0265	0.0004	(0.00009)
Apparel	0.0312	0.0003	(0.00006)
Paper	0.0140	0.0098	(0.00194)
Printing & publishing	0.0188	0.0029	(0.00056)
Chemicals	0.0124	0.0021	(0.00041)
Petroleum & coal	0.0123	0.0001	(0.00003)
Rubber & plastics	0.0229	0.0007	(0.00015)
Leather	0.0300	0.0001	(0.00002)
Transportation services	0.0188	0.0096	(0.00193)
Communication services	0.0120	0.0108	(0.00221)
Electric, gas, water supply	0.0090	0.0261	(0.00502)
Wholesale & retail trade	0.0159	0.1437	(0.02801)
Finance, insurance, real estate	0.0201	0.0607	(0.01390)
Durables			
Lumber & wood	0.0301	0.0032	(0.00058)
Furniture & fixtures	0.0251	0.0001	(0.00002)
Stone, clay, glass	0.0183	0.0010	(0.00017)
Primary metal	0.0203	0.0065	(0.00122)
Fabricated metal	0.0141	0.0019	(0.00034)
Machinery, non-electrical	0.0231	0.0122	(0.00260)
Electrical machinery	0.0190	0.0081	(0.00160)
Transportation equipment	0.0184	0.0006	(0.00013)
Instruments	0.0211	0.0008	(0.00016)
Misc. manufacturing	0.0385	0.0003	(0.00004)

5 Concluding Remarks

We have documented the business cycle comovement of stock prices across sectors in the US, and attempted to explain the observed comovement using a multisector dynamic stochastic general equilibrium model calibrated to the 2-digit SIC level intermediate input-use and capital-use tables. The stock price indices in each industry are shown to have substantial comovement over the business cycle in that sense that it has strong contemporaneous correlation with the aggergate stock price index.

Can this comovement be justified by a theory? As a first step to account for the industry comovement of stock prices over the business cycle, we have considered a multisector dynamic stochastic general equilibrium model to investigate the role of the production technology with intersectoral linkages in explaining the industry comovement for stock prices. In competitive equilibrium, the stock price in a given sector is equal to the market value of its capital stock. Calibrated to the 2-digit SIC level of the intermediate input and the capital-use tables in the US, the model simulations yield positive comovement for stock prices in most of the industrial sectors, although they are still below the actual comovement. We then moved on to test the implication of market efficiency, that is, positive semidefiniteness of the difference of the varaiance-covariance matrix of model generated fundamental industry indices and that of actual industry indices. We found that the matirx of covariance difference is neither positive nor negative semidefinite and twenty seven industry indices out of thirty show excess volatility. These rusults imply that violation of market efficiency is mainly due to excess volatility of industry indices, not excess comovements across industry indices.

6 Appendix: Construction of the Stock Price Index by Industry and the Aggregate Index

The composite stock price index by industry is constructed as follows. It includes all the stocks listed on NYSE, AMEX, and NASDAQ in the CRSP Stock file. The data start in December 1925 and ends in December 1999. The index at the starting month is 1. In order to get the index in period t, denoted I_t, the total market value of the securities in the index at t (MV_t) is divided by the total market value at the beginning period (MV_0), multiplying by the index at the beginning period (I_0) which is set to 1:

$$I_t = I_0 \times \frac{MV_t}{MV_0}$$

When a distribution event occurs, we use 'Factor to Adjust Shares Outstanding,' so that a comparison can be made on an equivalent basis between prices before and after the distribution. The base market value at t is updated according to the following formula:

$$\frac{MV_{t-1}}{\text{Old Base } MV} = \frac{MV_{t-1} + TC_t}{\text{New Base } MV}$$

where $TC_t =$ (share price at $t-1$)$\times$(change in the number of shares). This can be rewritten as

$$\text{New Base } MV = \text{Old Base } MV \times \frac{MV_{t-1} + TC_t}{MV_{t-1}}$$

The quarterly index is the end-of-quarter figure.

If distribution codes are 1 and 5, Factor to Adjust Shares Outstanding are set to 0. Distribution code 1 includes mostly cash dividend, whereas 5 includes mostly stock split and stock dividend.

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