How Important is the Intermediate Input Channel in Explaining Sectoral Employment Comovements over the Business Cycle?

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Abstract

This paper studies a multisector dynamic stochastic general equilibrium model calibrated to the 2-digit SIC level intermediate input-use and capital-use tables to investigate the importance of the intermediate input channel in explaining the sectoral employment comovement over the business cycle. In general, the intermediate input channel is not sufficient to generate the strong business cycle comovement across sectors: it further requires some form of worker's reluctance to substitute labor hours across sectors. For example, as the labor hours become highly substitutable across sectors, some sectors' employment moves in the opposite direction to the aggregate employment. This reflects the key feature of the disaggregated actual input-use and capital-use matrices: only a few sectors serve as important inputs to all other sectors and most sectors use few intermediate inputs in production. Referring to some micro-level studies on the low wage elasticity of labor supply, a low substitution of labor hours is shown to generate the strong business cycle comovement in sectoral hours worked.

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." More recently, Christiano and Fitzgerald (1998) document substantial business cycle comovement for hours worked across sectors in the US.

Over the last two decades, however, macroeconomists have mainly focused on understanding the persistence and volatility in the cyclical fluctuations of aggregate economic data. Standard models of business cycles such as Kydland and Prescott (1982) and King, Plosser, and Rebelo (1988), consider a single sector economy to examine the ups and downs of aggregate economic activity. For the obvious reason, these models are not useful to explain a key defining characteristic of the business cycle: the comovement of economic activity across many sectors.

Motivated by the observation that some of the output of the nondurable goods sector is also used as intermediate goods in the production of durable (investment) goods, Hornstein and Praschnik (1997) modify a standard real business cycle model to accommodate this "intermediate goods channel" of the economy. During a boom, this has the effect of increasing the value of output in the nondurable (or consumption) sector with the increased need for its output for use in the investment sector. Despite perfectly mobile labor across the two sectors, their model generates strong contemporaneous correlation for sectoral employment.

However, with the perfectly mobile labor across sectors, the synchronized ups-and-downs of employment in the investment and consumption good sectors require that the use of the nondurable goods for the investment sector (i.e. intermediate goods channel) be sufficiently large relative to its use for final consumption. This may not necessarily be the case in a model with more disaggregated nondurable goods sector where certain sectors' outputs are hardly used as the other sectors' intermediate inputs.

This paper is to investigate the importance of the intermediate goods channel in the context of a multisector dynamic stochastic general equilibrium model with more disaggregated production sectors. Very recently, Horvath (1998, 2000) have developed a generalized version of Long and Plosser (1983).[1] Calibrated to the 2-digit Standard Industrial Code (SIC) level of disaggregation (using the intermediate input-use and the investment-use matrices), it shows that the model can match aggregate fluctuations in the US with independent sectoral shocks only. However, Horvath (2000)

[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.

focuses only on the issue of understanding the persistence and volatility in aggregate fluctuations along with the relative volatilities of sectoral fluctuations, ignoring the synchronized nature of economic activity (e.g., employment comovement) across sectors.

In order to examine the significance of the disaggregation level in Hornstein and Praschnik (1997) (which assume only two sectors, nondurable and durable), we first examine Horvath (2000) calibrated such that labor hours are close to perfect substitutes across sectors for the consumer/worker. The Hornstein-Praschnik's hypothesis holds for the sectors which have relatively strong interactions with the other sectors in the intermediate goods markets. However, not surprisingly, a sector having a relatively weak intermediate-goods link (to the other sectors) tends to have a weak or a negative business cycle comovement. The strong sectoral employment correlation in Hornstein and Praschnik (1997), driven entirely by the intermediate goods channel, is not robust to more disaggregated sectors. In general, the intermediate goods channel alone is not sufficient for the sectoral employment comovement over the business cycle.

Noting the low wage elasticity of labor supply and persistent wage differences across sectors, we simulate Horvath (2000) where elasticity of substitution of labor supply is relatively low across sectors.[2] An interpretation of this specification is that the representative worker/consumer has a preference for diversity of labor hours despite wage differences across sectors. This modification is analogous to Boldrin, Christiano, and Fisher (1999) which assume limited labor mobility between industry sectors, although they require additional restriction on preferences in the form of habit persistence to guarantee comovement.

We find that, as long as the elasticity of substitution of labor across sectors is sufficiently small, the multisector model calibrated to the 2-digit SIC level of disaggregation (i.e. 36 sectors) can generate the observed strong comovement of sectoral hours worked. Therefore, in the presence of the wide variation in the fraction of a given sector's output channeled (as intermediate inputs and capital goods) to the production processes of many other sectors, the intermediate channel is not sufficient to generate the strong business cycle comovement across sectors: it further requires some form of worker's reluctance to substitute hours worked across sectors.

The paper is organized as follows. Section 2 describes the model and its calibration as in Horvath (2000). Section 3 presents simulation results on the business cycle comovement of sectoral hours worked. Section 4 summarizes the paper.

[2] Altonji (1982) and Ashenfelter and Altonji (1980) are examples of micro-level studies on the wage elasticity of labor supply.

2 The Model and Calibration

In order to examine the significance of the intermediate-goods linkages in the business cycle comovement, we simulate 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 Horvath (2000), we briefly describe the model and its calibrations below.

The model economy consists of M distinct sectors, indexed by $h = 1, 2, ..., M$, each producing a different good. The technologies are distinct across the sectors. Multifactor 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 and 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

$$y_t^h = A_t^h \left(k_t^h\right)^{\alpha_h} (n_t^h)^{\beta_h} (M_t^h)^{\gamma_h}, \tag{1}$$

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

$$\ln(A_t^h) = \rho_h \ln(A_{t-1}^h) + \epsilon_t^h, \tag{2}$$

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

The index of intermediate inputs for sector h has a constant elasticity of substitution (CES) form with elasticity of substitution σ_m:

$$M_t^h = \left[\sum_{s \in B_h^M} x_{sh} (m_{t,s}^h)^{\frac{\sigma_m - 1}{\sigma_m}} \right]^{\frac{\sigma_m}{\sigma_m - 1}}, \tag{3}$$

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

$$k_{t+1}^h - (1-\mu_h)k_t^h = \eta(i_t^h), \tag{4}$$

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 CES form:

$$\eta(i_t^h) = \left[\sum_{s\in B_h^I} \tilde{x}_{sh}(i_{t,s}^h)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{5}$$

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 (3).

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

$$E_0 \sum_{t=0}^{\infty} \delta^t \frac{[C_t L_t^{\chi}]^{1-\psi} - 1}{1-\psi} \qquad \psi \geq 0, \quad 0 < \beta < 1 \tag{6}$$

subject to:

$$\sum_{s=1}^{M} p_t^s c_t^s = \sum_{s=1}^{M} p_t^{n_s} n_t^s + \sum_{s=1}^{M} (d_t^s + q_t^s) s_t^s - \sum_{s=1}^{M} q_t^s s_{t+1}^s \equiv a_t. \tag{7}$$

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. The parameter ψ controls the degree of risk aversion and is inversely proportional to the elasticity of intertemporal substitution. The parameter χ controls intratemporal substitution between consumption and leisure. Given an initial share s_0^s for $s = 1, ..., M$, the consumer's budget constraint (7) shows that the sum of goods purchased, c_t^s, valued at their respective prices, p_t^s cannot exceed a_t, total income in period t. Other notations concerning sector s at period t are: $p_t^{n_s}$ hourly wage, d_t^s dividend paid per share held, q_t^s share price per unit, s_t^s share holdings at the beginning of t, and s_{t+1}^s shares purchased for period $t+1$.

The aggregate consumption index has the CES form:

$$C_t = \left[\sum_{s=1}^{M} \xi^s (c_t^s)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{8}$$

where $\sigma > 0$ is an elasticity of substitution and ξ^s is aggregation weight. Further, the representative consumer is endowed with one unit of time in each period and the aggregate leisure index is assumed to take the following form:

$$L_t = 1 - \left[\sum_{s=1}^{M} (n_t^s)^{\frac{\tau+1}{\tau}} \right]^{\frac{\tau}{\tau+1}}, \qquad \tau > 0. \tag{9}$$

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.

As for the calibrations of the model parameters, the level of sectoral disaggregation is set to $M = 36$, following the sectoral definitions used by Jorgenson and Fraumeni (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 36 sectors using annual data from 1948 to 1985 (Jorgenson and Fraumeni 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 across sectors is 0.16, the mean value of β_h is 0.32, and the mean value of γ_h is 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 and Fraumeni (1987).

The time period considered is the quarter year. 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 elasticity parameters σ_m, σ, η, and ψ are set to unity, so that the consumer has logarithmic preferences in the aggregate consumption and leisure indices.

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 flow and intermediate input-use tables are converted respectively to Γ_I and Γ_m by properly aggregating to 36 sectors and then dividing columns by their sums.

Finally, noting the typical finding in labor economics that wage elasticity of labor supply is relatively low, Horvath(2000) set $\tau = 1$ to represent the worker's reluctance

[3] The simulation results under zero off-diagonal elements in Ω are very close to those with non-zero off-diagnoal elements as reported in Table 1.

to substitute labor hours across sectors. For comparisons, we also report simulations for a range of $\tau \in [1, 100]$. 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, $\tau = 1, 5$, and 100 imply $\chi = 13.4, 3.72$, and 1.93, respectively.

3 Results

The simulation results are presented in Table 1.[4] The second column reports the business cycle comovements of sectoral employment in the US, followed by their counterparts in the model economy for different values τ, the wage elasticity of substitution of labor across sectors. The comovements are measured simply by calculating correlation coefficients between the business cycle component of (quarterly) hours worked in a given sector and the business cycle component of total hours worked (quarterly). The hours worked in the US are based on the establishment survey data available in the DRI Economics database (formerly CITIBASE) covering from 1964 to 2000.[5] The correlation coefficients in the model economy are average statistics over 100 simulated economies of length 148 quarters. Both actual and simulated hours are HP (Hodrick-Prescott) filtered before they are used to estimate correlation coefficients.

The sectoral disaggregation level in the DRI database has some minor differences from Horvath (2000). For example, the DRI database does not cover agriculture and have the mining sector broadly defined including metal, nonmetallic, and coal mining. For those sectors whose definitions do not conform to Horvath (2000), the estimates of the business cycle comovement are as follows: transportation and public utilities (0.82), wholesale trade (0.87), retail trade (0.86), and services (0.67). Notice that there is substantial business cycle comovement in the data. Only two relatively small sectors (tobacco manufactures and petroleum & coal products) exhibit little tendency to move up and down with general economic conditions over the business cycle.

When labor hours are close to perfect substitutes across sectors for the consumer/worker (i.e. $\tau = 100$ and the implied $\chi = 1.93$), the model simulations imply

[4] The competitive equilibrium consists of the first-order conditions implied by the household's and firm's optimizations, plus the market clearing conditions. 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. See Horvath (2000) for the details.

[5] The DRI Economics database has monthly and seasonally adjusted data of hours worked, which are calculated from indices of aggregate weekly hours of production of nonsupervisory workers on private nonagricultural payrolls by industry. The quarterly data are obtained simply by adding the monthly figures for a given quarter. Using the monthly data, Christiano and Fitzgerald (1998) obtain similar estimates of the business cycle comovement in terms of the regression R^2 when the business cycle component of hours worked in a given sector is regressed on the business cycle component of total hours worked, at lags 0, 1, -1.

some negative business cycle comovements as well as positive ones. This is mainly due to the intermediate input-use and the capital-use matrices characterized by a few full rows and many sparse columns. Full rows in the matrices indicate sectors that are important inputs in the production processes of many sectors, whereas sparse columns indicate that most sectors' production processes are highly specific with regard to the intermediate inputs and capital uses. As for the intermediate input-use matrix, only 21 sectors are completely full and many of the non-zero elements are trivial in size. The row-sparse feature is more noticeable in the capital-use matrix where only 9 sectors are completely full. The sectors with full rows both in the intermediate input-use and the capital-use matrices are: construction, paper, non-elec. machinery, elec. machinery, communication services, finance, insurance, & real estate.

Many zero elements in the intermediate input-use and capital-use matrices indicate the sectors whose inputs in the production processes of the other sectors are trivial. Hence, under perfectly substitutable labor hours (across sectors) for the consumer/worker, during an economic boom there will be a swing in the labor supply from the sectors having relatively weak sectoral linkages (i.e. many zero elements in the input-use and capital-use tables) to those having strong sectoral linkages (i.e. full rows in the input-use and capital-use tables). It can be verified from Table 1 that, for $\tau = 100$, the negative sectoral comovements correspond to those sectors having less-than-full rows, whereas those sectors with full rows retain employment in the same direction as total hours worked over the business cycle.

These findings are in contrast to Hornstein and Praschnik (1997) where, despite perfectly mobile labor across the two sectors (durables and nondurables), the intermediate input channel generates strong contemporaneous correlation for sectoral employment. However, with the perfectly mobile labor across sectors, the synchronized ups-and-downs of employment in the investment (or durables) and consumption good (or nondurable) sectors require that the use of the nondurable goods as an input to the investment sector be sufficiently large relative to its use for final consumption. Our investigation of the disaggregated input-use and capital-use matrices reveals that this is not necessarily the case: that is, only a few sectors serve as important inputs to all other sectors and most sectors use a few intermediate inputs in production. Hence, in general, the strong sectoral employment correlation over the business cycle cannot be explained entirely by the intermediate goods channel.

Referring to the empirical studies in labor economics which find a relatively low wage elasticity of labor supply (e.g. Altonji (1982) and Ashenfelter and Altonji (1980)) and persistent wage differences across sectors, we simulate the model economy where elasticity of substitution of labor supply is relatively low across sectors. This is a way to capture persistent wage differences in the representative agent framework. Table 1 illustrates that a low elasticity of substitution of labor across sectors (e.g. $\tau = 1$), implying the low wage elasticity of labor supply, can generate the strong business cycle comovement of sectoral hours worked. Therefore, in general, the intermediate channel alone is not sufficient to generate the strong business cycle comovement across sectors: it further requires some form of worker's reluctance to substitute labor hours across sectors.

4 Concluding Remarks

We have studied a multisector dynamic stochastic general equilibrium model calibrated to the 2-digit SIC level intermediate input-use and capital-use tables to investigate the importance of the intermediate input channel in explaining the sectoral employment comovement over the business cycle. In general, the intermediate channel is not sufficient to generate the strong business cycle comovement across sectors: it further requires some form of reluctance (from the worker's point of view) and the implied low wage elasticity of labor supply to substitute labor hours across sectors.

As the worker becomes more willing to substitute labor hours across sectors, for example, some sectors' employment moves in the opposite direction to the aggregate employment. This reflects the disaggregated input-use and capital-use matrices characterized by a few full rows and sparse columns: there are only a few sectors that are important inputs in the production processes of many sectors and most sectors' production processes are highly specific with regard to intermediate inputs. As supported by some micro-level studies on the low wage elasticity of labor supply, the elasticity of substitution of labor hours appears to be low, implying the strong business cycle comovement in sectoral hours worked.

Table 1: Business Cycle Comovement for Sectoral Employment

Sector	US Data	$\tau = 1$	$\tau = 5$	$\tau = 100$
Agricultural products		0.99	0.98	-0.92
Agricultural services		0.99	0.93	-0.21
Metal mining		0.97	0.88	0.47
Coal mining		0.99	0.99	0.90
Petroleum & natural gas		0.99	0.98	0.58
Nonmetallic mining		0.99	0.90	0.08
Construction	0.89	0.95	0.78	0.10
Food & kindred products	0.62	0.99	0.99	-0.98
Tobacco products	-0.0012	0.99	-0.99	-0.99
Textile mill products	0.62	0.99	0.95	0.26
Apparel	0.64	0.99	0.73	-0.68
Paper	0.85	0.96	0.83	0.44
Printing & publishing	0.91	0.99	0.97	0.37
Chemicals	0.84	0.99	0.97	0.62
Petroleum & coal products	0.086	0.99	0.97	0.44
Rubber & misc. plastics	0.86	0.99	0.98	0.86
Leather	0.36	0.99	0.46	-0.97
Lumber & wood	0.75	0.98	0.92	0.41
Furniture & fixtures	0.84	0.99	0.57	-0.85
Stone, clay, glass	0.93	0.99	0.92	0.29
Primary metal	0.88	0.99	0.99	0.91
Fabricated metal	0.95	0.99	0.97	0.66
Non-elec. machinery	0.87	0.91	0.79	0.60
Elec. machinery	0.88	0.92	0.74	0.29
Motor vehicles	0.62	0.92	0.83	0.49
Transportation equipment	0.81	0.99	0.95	0.62
Instruments	0.71	0.79	0.51	0.21
Misc. manufacturing	0.88	0.94	0.85	0.51
Transportation services		0.98	0.84	0.38
Communication services		0.99	0.94	0.61
Electric utilities		0.99	-0.99	-0.99
Gas utilities		0.99	0.99	0.96
Wholesale & retail trade		0.99	0.99	-0.25
Finance, insurance, & real estate	0.58	0.95	0.82	0.52
Water & sanitary services		0.99	0.99	0.82
Other services		0.99	0.99	0.36

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