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The Identification of the Causes of Business Cycles Across Countries

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Abstract

Empirical research has been conducted on the various theories of the business cycle over many countries. However, very little research has attempted to undertake a multi-country disaggregate investigation into the sources of output change. This paper decomposes fluctuations in industry output in a particular country into: (1) a nation specific shock; (2) an industry specific shock; (3) a world shock; and (4) an idiosyncratic factor. Using a dynamic factor analysis-state-space approach, the paper finds that the nation-specific shock is the most important impulse.

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1/ This paper was written while the latter author was a visiting scholar in the Research Department, International Monetary Fund.

Contents

Summary

In the United States and other developed countries, a wide variety of economic variables "co-move," or are correlated over time. This is an important reason why economists believe in the existence of business cycles. Most research has focused on providing an explanation for business cycles in the United States. Because of the co-movement characteristic of economic activities, economists have sought a common or single-factor explanation. Monetary, fiscal, and real supply-side shocks have been used in a variety of theories that purport to explain this co-movement property. Recently, Long and Plosser have presented a disaggregate explanation. In these models, when agents are confronted with taste or productivity shocks, decisions are made that smooth consumption or production, which results in the co-movement of activity across sectors. The presumption behind these models is that the business cycle originates in real industry-specific shocks. For countries other than the United States, the co-movement of economic variables is often explained not only in terms of an extension of the same theories but also in terms of an open economy. McKinnon and Swoboda, however, have provided an international or global explanation for business cycles.

This paper attempts to identify the sources of fluctuations in output using a multicountry approach. Such an approach allows the relative importance of nation-specific, industry-specific, and world shocks to be determined. Nation-specific shocks are defined as changes in output growth that are unique to a particular nation, but shared by all industries in that nation. Industry-specific shocks occur as a result of taste or technology changes that are unique to an industry, but common to all nations. World shocks, obviously, are common to all industries in all countries. It is important to obtain knowledge about the relative importance of these impulses, since this can help to guide economists undertaking future theoretical work on business cycles. For instance, a finding that a large percentage of the variation of output in a nation can be explained by industry-specific shocks could be viewed as support for a disaggregate real business cycle paradigm.

Our empirical findings indicate that the nation-specific factor is the most important in explaining variations in output. Our results are similar to those of Stockman, who used a different empirical approach, but we find even stronger evidence of independent policy sources of output fluctuations. The disaggregated technological shocks explain a small, but significant portion of the variance. The results provide little support for the disaggregate real business-cycle paradigm, indicating that in a cross-country context (disaggregated) technological shocks are not a major source of business cycle movements--a result that contradicts earlier empirical studies of disaggregated real business cycles. Additional research is required to establish the robustness of these results.

I. Introduction

A well documented fact in the United States and other developed countries is that a wide variety of economic variables co-move. This fact is an important reason why economists believe in the existence of business cycles. Most research has focused on providing an explanation for business cycles in the United States. Because of the co-movement characteristic of economic activities, economists have sought a common or single factor explanation. Monetary, fiscal, or real supply side shocks have all been used in a variety of theories that proport to explain this co-movement property. Recently, Long and Plosser (1983) have presented a disaggregate explanation. In these models, when agents are confronted with taste or productivity shocks, decisions are made so that consumption or production can be smoothed which results in the co-movement of activity across sectors. The presumption behind these models is that the business cycle originates from real industry-specific shocks. For countries other than the United States, the co-movement of economic variables is often explained in terms of an extension of the same theories but in terms of an open economy. However, McKinnon (1982) and Swoboda (1983) have provided an international or global explanation for business cycles. McKinnon's explanation is based on a world money supply concept while Swoboda suggests the existence of such a cycle results from increased sectoral integration of the world production system.

Empirical research has been conducted on the various theories of the business cycle over many countries. However, very little research has attempted to undertake a multicountry disaggregate investigation into the sources of output change. This type of study allows the relative importance of nation-specific, industry-specific, and world shocks to be determined. Nation-specific shocks are defined as changes in output growth that are unique to a particular nation, but shared by all industries in that nation. A nation-specific shock would occur if countries pursue individual monetary and/or fiscal policies. Of course, nation-specific shocks could be real such as a nation-wide union action or a nation-wide regulatory policy change. Industry-specific shocks occur as a result of taste or technology changes that are unique to an industry, but common to all nations. World shocks, obviously, are common to all industries in all countries. Knowledge of the relative importance of these impulses is important so as to guide future theoretical work on business cycles. For instance, a finding that a large percentage of the variation of output in nation can be explained by industry-specific shocks could be viewed as support for a disaggregate real business cycle paradigm. Two studies take a disaggregate approach to study business cycles. Norrbin and Schlagenhauf (1988,1989) conduct this type of study for the United States, while Stockman (1988) investigates the source of disturbances to fluctuations in the growth of industrial production in seven European countries and the United States over the past two decades.

This paper attempts to identify the sources of fluctuations in output using a multicountry approach. This paper re-examines and extends Stockman's work in a number of important ways. Stockman employs a time series model where the nation-specific and industry-specific impulses are correlated, which makes it difficult to determine the relative importance of each impulse. In addition, Stockman's statistical approach does not allow the impulses to be linked to economic variables. We employ a preferable estimation approach-dynamic factor analysis. This approach allows the various factors or impulses to be linked to observable economic variables that are suggested by various theories. Since the dynamic factor analysis methodology can be expressed in state-space form, we show how meaningful measures of the various factors can be obtained. Besides the methodological differences, this paper allows for a world factor and extends Stockman's sample. Stockman focuses on European countries. This paper examines fluctuations in economic activity in six European countries as well as Canada, Japan and the United States.

This paper is organized into four sections and a conclusion. The first section presents a multicountry time series model of business cycle fluctuations which serves as the basis for our empirical work. The second section discusses a set of econometric issues relevant to the estimation of our multivariate time series model. The third section discusses the data employed in this research while the fourth section presents the empirical results.

II. A Multivariate Time Series Model of Multicountry Output

The work of Frisch (1933) and Slutsky (1937) suggests that movements in output arise from the interaction of an internal propagation mechanism and impulses. In this framework, impulses or shocks affect output through the propagation mechanism resulting in serial correlated fluctuations in output. Most theories of economic fluctuations can be embedded into this general framework, although there are differences over the form of the propagation mechanism and the sources of the disturbances. 1/ In this section, we present a multivariate time series model of output in a multicountry context. This model is in the tradition of Frisch and Slutsky's work and is sufficiently general so as to encompass most competing linear business cycle theories. The model is developed at an industry level. We allow a propagation of output changes between industries and across countries. In addition, output fluctuations may arise from either nation-specific factors, industry-specific factors, a world factor, or idiosyncratic factors.

1/ Haberler (1937) summarizes many of the business cycle theories in the pre-Keynesian period. Zarnowitz (1985) presents a more current review of the theories and evidence on business cycles.

Consider a world consisting of N countries which are indexed by n. Each country is comprised of I industries which are indexed by i. Let Y_{nit} denote the change in the log of output in industry i of country n. Output changes in a particular industry in country n depends on output changes in their own industry as well as other industries in this and other countries. We represent the output change in industry j of country ℓ in period t-k as $Y_{\ell j,t-k}$. The propagation effect of an output change in industry j of country ℓ in period t-1 for industry i of country n in period t would be represented by $\pi_{ni,\ell j,t-1}$. In addition, the change in industry i output of country n can be influenced by an impulse or disturbance term $\varepsilon_{ni,t}$. Hence, the change in output in industry i of country n can be written as:

$$(1) \quad Y_{nit} = \beta_0^{ni} + \sum_{k=1}^{T} \sum_{\ell=1}^{N} \sum_{j=1}^{I} \pi_{ni,\ell j,t-k} \, Y_{\ell j,t-k} + \varepsilon_{ni,t}$$

The innovation term, $\varepsilon_{ni,t}$, can be decomposed into an influence that could be common to all industries over all countries, influences specific to industries in a nation, influences specific to an industry, and influences that are idiosyncratic. The influence of an impulse that is common to all industries over all countries will be referred to as a world factor. McKinnon's (1982) work provides one explanation for such an effect. The world factor will be denoted as $X_{w,t}$ while α_w^{ni} measures the response of output in industry i of country n to a change in the world factor. The industries that are located in a country may also be influenced by a common shock. We will refer to this type of shock as a nation-specific factor. Macroeconomic theory suggests possible determinants of this factor. Lucas (1977) provides one possible explanation with his imperfect information equilibrium model of the business cycle. In this model, a nation-specific factor would be associated with unanticipated changes in a country's nominal money supply. Other theories would point to alternative demand variables. This influence does not have to be restricted to either nominal variables or demand oriented variables. A nation-specific factor will be represented as $X_{n,t}$. Each industry in a country may respond differently to this factor. We will represent the industry response i in country n to such an impulse as α_n^{ni}. Economic activity in a particular industry may also be influenced by factors specific to that industry group. For example, economic activity in the machine industry may be influenced by a factor while the food industry may be influenced by a different factor. We will refer to this type of influence as industry-specific or disaggregate. These disaggregate influences may be motivated by real business cycle theories. The industry-specific influence is denoted by $X_{i,t}$ and the response of real economic activity in industry i of country n to this factor as α_i^{ni}. Hence, the disturbance term ε^{nit} may be written as:

$$(2) \quad \varepsilon_{nit} = \alpha_w^{ni} X_{wt} + \alpha_n^{ni} X_{nt} + \alpha_i^{ni} X_{it} + u_{ni,t}$$

where $u_{ni,t}$ is the idiosyncratic error term. It is assumed, for identification purposes that the influences $X_{n,t}$, $X_{w,t}$, $X_{i,t}$, and $u_{ni,t}$ are orthogonal to each other.

If equations (1) and (2) are combined, the change in output in industry i of country n can be written as:

$$(3) \quad Y_{ni,t} = \beta_0^{ni} + \sum_{k=1}^{T} \sum_{\ell=1}^{N} \sum_{j=1}^{I} \pi_{ni,\ell j,t-k} Y_{\ell j,t-k} + \alpha_w^{ni} X_{wt} + \alpha_n^{ni} X_{nt} + \alpha_i^{ni} X_{it} + u_{ni,t}$$

Let Y_t denote the IN x 1 column vector of the various individual industry output changes. If we aggregate over all industries, equation(3) can be rewritten as:

$$(4) \quad Y_t = \beta_0 + \sum_{k=1}^{T} \pi_k Y_{t-k} + \alpha_W X_{Wt} + \alpha_N X_{Nt} + \alpha_I X_{I\ It} + u_t$$

where $X_{W,t}$ is a scalar representing the world impulse, $X_{N,t}$ is a (n x 1) vector of nation-specific influences, $X_{I,t}$ is a (I x 1) vector of industry-specific influences, α_N and α_I are (NIxN) and (NIxI) coefficient matrices, respectively, and u_t is the vector of idiosyncratic influences on individual industry output change. The coefficient matrix π_k represents the feedback matrix at lag k. This equation indicates that the dynamics of real economic fluctuations can be thought of as arising from the interaction of the internal propagation mechanisms as captured by the feedback coefficients and the dynamics from the factors and influences.

Unfortunately, the model represented by equation (4) cannot be estimated due to the fact that it is overparameterized. As a result, we impose a set of restrictions to reduce the number of parameters to be estimated, yet maintain some feedback effects across countries and industries. In order to allow a feedback effect from other industries in a country, we create a set of N country composite variables. For country n, this composite variable is defined as:

$$(5) \quad Y^*_{n,t} = \sum_{i=1}^{I} w_i^n Y_{ni,t}$$

where w_I^n is a weighting matrix measuring the relative importance of each industry in country n. Another important part of the feedback or propagation matrix is the influence of industrial developments in other countries. This type of feedback effect is allowed for by creating seven industry composite variables for each country. For industry i in country n, the composite variable is:

(6) $$Y^*_{ni,t} = \sum_{n=1}^{N-1} w_{ni} Y^*_{nt}$$

where w_{ni} is the value of industry i's export to another country divided by total exports of industry i's output to the other N-1 countries. In other words, a growing economy in country ℓ is reflected in a growing $Y^*_{\ell t}$ which will create a demand for industry i goods in country n. The impact of this demand effect is determined by export relations as reflected in the weight w_{ni}. Own industry effects are another important part of the propagation mechanism. This type of effect is allowed for by directly introducing own industry lag variables.

Given these restrictions, the output model in matrix form can be written as:

(7) $$Y_t = \beta_0 + \alpha_W X_{Wt} + \alpha_N X_{Nt} + \alpha_I X_{It} + \sum_{k=1}^{T} \beta_{1k} Y^*_{N,t-k} + \sum_{k=1}^{T} \beta_{2k} Y^*_{IN,t-k} + \sum_{k=1}^{T} \beta_{3k} Y_{t-k} + u_t$$

where β_{1k} is a (IN x N) matrix, β_{2k} is a (NIxNI) matrix, β_{3k} is a (NIxNI) diagonal matrix, and Y_N and Y_{NI} are the vectors of the various composite variables.

III. Econometric Issues

In order to estimate the model presented in the previous section, the problems caused by the appearance of unobserved nation-specific, industry-specific and world variables must be addressed. While a number of empirical approaches have been suggested in the literature to deal with unobserved variables, we employ Watson and Engle's (1983) dynamic multiple indicator-multiple cause (DYMIMIC) model. 1/ This framework allows the unobserved variables or factors to be dynamic in nature as well as be associated with observed variables. This latter feature is important as an attempt can be made to identify or relate the unobserved variables to economic variables. In addition to discussing the DYMIMIC framework, we also show how to calculate the moving average representation of the state-space model. This representation allows the variance of output to be decomposed so that the relative importance of the variance factors can be

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1/ The DYMIMIC model is a type of index model. Sargent and Sims (1980) have used an index model to study business cycles. They employ a frequency domain method with unrestricted lag distributions. The Watson and Engle estimation approach is a time domain method.

determined. The reader not interested in these technical issues can skip this part of the section.

The DYMIMIC model is nothing more than a restricted version of the state-space representation of a model. The general state-space representation is:

$$(8) \quad Y_t = \zeta(L)X_t + \lambda(L)Z1_t + v_t$$

$$(9) \quad X_t = \delta(L)X_{t-1} + \gamma(L)Z2_t + e_t \qquad \text{and}$$

$$(10) \quad \begin{bmatrix} v_t \\ e_t \end{bmatrix} \sim N\left[0, \begin{pmatrix} Q & 0 \\ 0 & R \end{pmatrix}\right]$$

where Y_t is a (NIx1) vector of observed variables, (i.e., the various industry output changes in the various countries); X_t is a ((N+I+1)x1) vector of unobserved variables, (i.e., the N country-specific factors, I industry-group factors, and the world or common factor); $Z1_t$ and $Z2_t$ are (m x 1) and (q x 1) vectors, respectively, of observed exogenous and lagged dependent variables; v_t is a (NI x 1) vector of disturbances; e_t is a ((N+I+1)x1) vector of factor disturbances; and $\zeta(L)$,$\lambda(L)$, $\delta(L)$, and $\gamma(L)$ are matrix polynomials of parameters in the lag operator, L.

Equation (8) is known as the indicator equation while equation (9) is referred to as the transition equation. The latter equation allows the unobserved variables to be modeled. As can be seen, the unobserved variables can depend on past values of the own factor or other factors as well as exogenous causal variables. The introduction of causal variables aids in interpreting the factor as well as yielding more precise parameter estimates. For instance, we specify the country-specific factor to be dependent on current and lag changes in the country's money supply, and a country fiscal policy variable. These are variables that have been prominently mentioned as causes of output movements in the literature. On the other hand, observable variables for the world or common factors are an oil price variable and a world supply money variable. We will discuss the specification of the industry-specific factors later.

The model can be estimated by using general maximum likelihood techniques along with the Kalman filter recursive algorithm. If equation (9) is substituted into (10), we can define η_t as the difference between Y_t, and its best estimate, Y_t, based on information up to t-1 plus any exogenous variables at time t. If H_t represents the variance of η_t, then the log likelihood for equations (8)-(10) can be written as:

$$(11) \qquad L(\theta) = \text{constant} - 1/2 \sum_{t=1}^{T} (\log|H_t| + \eta_t' H_t^{-1} \eta_t)$$

where θ is a vector of unknown parameters. The innovations and their variances are calculated with the Kalman filter.

The EM algorithm is a method for maximizing a likelihood function where missing observations are present. The algorithm iterates between an estimation stage and maximization stage until convergence is achieved. Based on an initial guess of the parameters, the algorithm employs the Kalman filter to construct estimates of the missing observations conditional on the observed data and parameters. Once the unobserved state variables are estimated, the likelihood function is maximized assuming that this is the full observable data set. These parameter estimates can be used in conjunction with the Kalman filter to generate a new estimate of the state variables. This interactive process can be continued until an overall convergence is achieved. The parameter values associated with this convergence level can be employed to generate the minimum mean square estimates of the state using all available data by using the Kalman 'smoother.' 1/ Dempster, Laird, and Rubin have shown that this algorithm will always increase the value of the likelihood until it converges to a local maximum. The convergence is guaranteed under suitable regularity conditions. A more detailed explanation of this algorithm is available from the authors upon request.

In the disaggregated model studied in this paper, a large number of coefficients are estimated. Any attempt to base conclusions directly on these coefficients would be difficult. The results can be summarized by calculating the moving average representation of the state-space model. From this representation, the variance of (the forecast error) of output can be easily decomposed. In the general state space model, $Z1_t$ is comprised of exogenous and predetermined variables. 2/ If $Z1_t$ is apportioned into exogenous variables defined as $Z1_t'$ and lagged dependent variables, equation (8) may be written as:

$$(8') \quad \phi(L)Y_t = \varsigma(L)X_t + \lambda_t(L)Z1_t' + v_t$$

where $\phi(L_2) \equiv (I-\lambda\ (L))$. If both sides of (8') are premultiplied by

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1/ We attempt to avoid local optimization results by examining various starting values and employing a very severe convergence criteria, (i.e., .000001).

2/ In the application of the state space model employed in this paper, the only exogenous variable in $Z1_t$ is a constant term as each of the composite variable can be mapped into lagged Y_t. Hence, the $Z1_t'$ variable could be deleted in the following discussion. We leave this variable in the discussion so that general discussion on how to calculate the moving average representation of a state space model is available.

$\phi(L)^{-1}$, the state space model can be reformulated as:

(12) $$Y_t = \phi(L)^{-1} \zeta(L)X_t + \phi(L)^{-1}\lambda_1(L)Z1'_t + \phi(L)^{-1}v_t$$

(13) $$X_t = \delta(L)X_{t-1} + \gamma(L)Z2_t + e_t$$

By substituting (13) into (12), the moving average representation of the state space model is:

(14) $$Y_t = \phi(L)^{-1} \zeta(L) (I-\delta(L))^{-1} \gamma(L)Z2_t + \phi(L)^{-1} \zeta(L)(I-\delta(L))^{-1}e_t + \phi(L)^{-1} \lambda_1(L)Z1'_t + \phi(L)^{-1}v_t$$

This moving average representation is conditioned on current and past $Z1'_t$ and $Z2_t$. If generating equations are postulated for $Z1'_t$ and $Z2_t$, an unconditional moving average representation can be derived. We postulate a general univariate autoregressive forecasting equations for each element in $Z1'_t$ and $Z2_t$. 1/ That is,

(15) $$A(L)Z1'_t = \varepsilon_{1t}$$

(16) $$B(L)Z2_t = \varepsilon_{2t}$$

where A(L) and B(L) are diagonal matrices. 2/

Under the assumption that each exogenous variable can be modelled as a second order autoregressive processes, the moving average representations of (15) and (16) are:

(17) $$Z1'_t = \varepsilon_{1t} + q_{A1} \varepsilon_{1t-1} + q_{A2}\varepsilon_{1t-2} + q_{A3}\varepsilon_{1t-3} + \cdots\cdots$$

(18) $$Z2_t = \varepsilon_{2t} + q_{B1} \varepsilon_{2t-1} + q_{B2}\varepsilon_{2t-2} + q_{B3}\varepsilon_{2t-3} + \cdots\cdots$$

where:

$$q_{A1} = A_1$$

$$q_{A2} = q_{A1}A_1 + A_2$$

1/ It is a straightforward extension to allow for multivariate forecasting equations.
2/ The univariate forecasting equations were estimated with a constant.

$$q_{Aj} = q_{Aj-1}A_1 + q_{Aj-2}A_2 \qquad \text{for } j \geq 3$$

$$q_{B1} = B_1$$

$$q_{B2} = q_{B1}B_1 + B_2$$

$$q_{Bj} = q_{Bj-1}B_1 + q_{Bj-2}B_2 \qquad \text{for } j \geq 3$$

Combining (14) through (18) yields the unconditional moving average representation

(19) $$Y_t = v_t + \theta_1 v_{t-1} + \theta_2 v_{t-2} + \theta_3 v_{t-3} + \theta_4 v_{t-4} + \ldots\ldots$$

$$+ \theta_0^* e_t + \theta_1^* e_{t-1} + \theta_2^* e_{t-2} + \theta_3^* e_{t-3} + \ldots\ldots$$

$$+ \hat{\theta}_0 \varepsilon_{1t} + \hat{\theta}_1 \varepsilon_{1t-1} + \hat{\theta}_2 \varepsilon_{1t-2} + \hat{\theta}_3 \varepsilon_{1t-3} + \ldots\ldots$$

$$+ \tilde{\theta}_0 \varepsilon_{2t} + \tilde{\theta}_1 \varepsilon_{2t-1} + \tilde{\theta}_2 \varepsilon_{2t-2} + \tilde{\theta}_3 \varepsilon_{2t-3} + \ldots\ldots$$

where the matrices would be the following for the specific restrictions on lagged-lengths of our model:

$$\theta_1 \equiv \phi_1$$

$$\theta_2 \equiv (\theta_1\phi_1 + \phi_2)$$

$$\theta_3 \equiv (\theta_2\phi_1 + \theta_1\phi_2 + \phi_3)$$

$$\theta_4 \equiv (\theta_3\phi_1 + \theta_2\phi_2 + \theta_1\phi_3 + \phi_4)$$

$$\theta_j \equiv (\theta_{j-1}\phi_1 + \theta_{j-2}\phi_2 + \theta_{j-3}\phi_3 + \theta_{j-4}\phi_4) \qquad j \geq 5$$

$$\theta_j^* \equiv \sum_{i=0}^{j} (\theta_i \delta^{j-i})\zeta \qquad \text{where } j=0,\ 1,\ 2,\ \ldots\ \text{and } \theta_0 = 1$$

$$\hat{\theta}_j \equiv \sum_{i=0}^{j} \theta_{j-i}\, q_{Ai}\, \lambda \qquad \text{where } q_{A0} = 1$$

$$\tilde{\theta}_j = \sum_{i=0}^{j} \theta_i^{**} q_{Bj-i} \qquad \text{where } q_{B0} = 1$$

$$\theta_k^{**} = \sum_{i=0}^{k} (\theta \delta_i^{k-i}) \zeta \gamma \qquad \text{where } k = 0, 1, 2, \ldots \text{ and } \theta_0 = 1$$

Once the moving average representation is generated, a meaningful decomposition of the variance of output can be derived by calculating the variance of the forecast error at various horizons. If we let $\Omega \equiv \{v_t, v_{t-1}, \ldots, e_t, e_{t-1}, \ldots, \varepsilon_{1t}, \varepsilon_{1t-1}, \ldots, \varepsilon_{2t}, \varepsilon_{2t-1} \ldots\}$, then the j-period ahead forecast error of output has variance

$$(20) \qquad E\{[Y_{t+j} - E(Y_{t+j}|\Omega_t)][Y_{t+j} - E(Y_{t+j}|\Omega_t)]'\} \equiv \text{Var}(Y_{t+j}|\Omega_t)$$

$$= Q + \theta_0^* R \theta_0^{*\prime} + \hat{\theta}_0 \text{Var}(\varepsilon_1) \hat{\theta}_0' + \tilde{\theta}_0 \text{Var}(\varepsilon_2) \tilde{\theta}_0' \qquad \text{for } j = 1$$

$$= \text{Var}(Y_{t+j-1}|\Omega_t) + \theta_{j-1} Q \theta_{j-1}' + \theta_{j-1}^* R \theta_{j-1}^{*\prime} + \hat{\theta}_{j-1} \text{Var}(\varepsilon_1) \hat{\theta}_{j-1}'$$

$$+ \tilde{\theta}_{j-1} \text{Var}(\varepsilon_2) \tilde{\theta}_{j-1}' \qquad \text{for } j = 2, 3, \ldots$$

This equation indicates that the variance of the forecast error output can be segmented into various components. The $\text{Var}(Y_{t+j}|\Omega_t)$ is a matrix of individual industry output variances in each of the countries. An individual industry's variance can be decomposed into an industry specific or idiosyncratic component from Q; an error arising from the various factors from R; an error from forecasting the exogenous international variable, $\text{Var}(\varepsilon_1)$; and the error from forecasting the observable variables that enter the factor equations, $\text{Var}(\varepsilon_2)$. We will use this decomposition to evaluate the relative importance of the various factors.

IV. Data Issues

In order to estimate the disaggregate model of industrial output a large data set had to be assembled. In this section we define the data employed. Nine countries are focused upon. These countries are Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, and the United States. The sample covers the period 1957:I through 1986:IV prior to adjustment for lags.

Industry output is measured by quarterly seasonally adjusted industrial production. Our data are from various OECD publications which report indices of industrial production in ISIC industries 20, 31-38, and 40 for various countries. The industries included in our study are: mining, basic metals; food, beverages, and tobacco; textiles and clothing; chemical products; metal products; machinery, and equipment, and utilities OECD does publish industrial production indices for other industries. These other industries were excluded from our sample for a variety of reasons. The usual reason is that complete data sets as defined by our sample could not be assembled.

As would be expected, the quarterly output data are nonstationary. Many empirical studies of the business cycle deal with this problem by using a time trend to capture a (long-term) growth component. Nelson and Plosser (1982) suggest this procedure is likely to confound the growth component and cyclical component in the series, overstating the magnitude and duration of the cyclical component and understating the importance of the growth component. As a result, we follow their suggestion and first difference the (log of) output. This renders the series stationary, without removing the growth component which may be stochastic.

In order to apply the DYMIMIC framework, equations that specify the evolution of the unobserved variables--the world, nation-specific, and industry-specific factors--are required as these equations are estimated simultaneously with the output equations. According to the state-space formulation, each factor can be expressed as a function of previous factors and observable causal variables. For the nation-specific factors, we allow the previous period (own) nation-specific factor to be a determinant of the current factor. There may be some question on the appropriateness of specifying a serially correlated impulse in an environment where agents have rational expectations. We allow this issue to be determined empirically. In an attempt to give economic interpretation to the behavior of a nation-specific factor, we allow a monetary and fiscal policy measure as well as that country's trade weighted real exchange rate to enter the observable variable vector. The monetary policy variable is defined as the rate of change of M1 while the fiscal policy variable is defined as the rate of change of the deficit (except for Japan where a government spending variables had to be employed due to the lack of a deficit variable). The trade weighted real exchange rate in each country is intended to capture changes in comparative advantage, and is thus a real variable. The weights for a country are the value of imports plus exports for each country in the sample relative to total import and exports for that country. All data for the observable variables are from the International Monetary Fund's IFS data tape.

Industry-specific factors are assumed to follow a simple autoregressive process without causal variables. Theory suggests that taste changes and technological changes should account for the movement of an industry factor. The problem, of course, occurs in trying to find empirical counterparts for these variables. Industry Solow residuals have been suggested as a way to measure technological change. Because capital stock data for industries in other countries are highly suspect and because the use of Solow residuals to measure technological shocks has recently been questioned in the literature, we specify the industry-specific factors to be autoregressive. 1/ This is the specification that Prescott (1986) employs in his work on real business cycles. Furthermore, in a Schumpeterian business cycle, technological innovation leads to a host of further inventions and entrepreneurial development. Hence, in this model, technological bursts would be autocorrelated.

The world factor is postulated to be determined by a simple autoregressive process and four causal variables. Some literature has suggested that the world factor could be associated with changes in the world money supply. We follow McKinnon (1982) in the creation of this variable. Another observable variable that could account for a factor common to all industries and all countries is changes in oil prices. We follow Hamilton (1983) in the creation of this variable. In addition, we introduce a dummy variable that commences in 1973:II to account for the exchange rate regime change as well as a dummy variable that starts in 1979:III for the formation of the European Monetary Union. 2/

V. Empirical Results

In this section, we examine the empirical results from the estimation of the multivariate time series model. The estimation period covers the period 1957:1 through 1986:4. We begin by determining whether there is any statistical basis for the introduction of disaggregate factors or world factor. Once the statistical importance of the various factors is determined, the relative importance of each type of factor for the business cycle is measured and then discussed. The section concludes with a an attempt to identify observable economic variables that are correlated with each of the factors.

An obvious first step in the analysis is to identify whether there is any statistical basis for the introduction of world, nation-specific, and industry-specific factors in explaining industry output change. Before any estimation can be conducted, the length of the lag of the feedback terms must be specified. We specify the lag length to be four quarters.

1/ McCallum (1988) notes that Solow's method assumes that current capital and labor are the only relevant inputs. If adjustment costs exist, then labor and/or capital hoarding might cause the estimated Solow residuals to overstate the technological shock variance.

2/ It would be preferable to estimate the model over each exchange rate regime to see if the results are robust across regimes. The results from such an exercise would be questionable given the number of parameters to be estimated and the length of the data samples at this time.

In order to determine whether these factors are statistically significant, we conducted a series of likelihood ratio tests. Usually a test of the importance of a variable or a set of variables is accomplished by deleting such variables from the unrestricted model. In terms of the DYMIMIC model, deletion of a factor or set of factors from the indicator equations also requires that each coefficient in the transition equation be restricted for the factor or set of factors being examined. This explains the large number of restrictions associated with each chi square value. In Table 1, we present the results of the hypothesis tests. The null hypothesis for each test is strongly rejected for the world factor, the set of nation-specific factors, and the set of industry-specific factors indicating roles for these factors as impulses for output fluctuations.

Having established the statistical importance of the various unobserved variables in explaining industry output change, we now attempt to measure the relative importance of each type of factor. In the model, a large number of coefficients are estimated. Clearly, any attempt to base conclusions directly on the coefficients would be difficult. Instead, we have attempted to summarize the results emphasizing the relative importance of the various factors. The method employed to measure the relative importance of the various factors was discussed in Section III.

The aforementioned decompositions will be in terms of individual industries over all countries. Because of the number of industries and countries in our sample, further aggregation is required to ease interpretation. An obvious question is how important relatively are each of the factors in each country. In order to address this question, the variance of output for the various industries in a country must be collapsed into an aggregate variance of the forecast error of output over all industries. This can be accomplished by weighting the variance of the forecast error of each individual industry by the relative national share of that industry's output and then summing overall industries. For each country, a (NIx1) vector that contains the weights for each industry in that country can be constructed. If the nine country weighting matrices are stacked columnwise, a nation-specific weighting matrix W_n can be constructed with dimension (NIxN). By pre-multiplying the forecast error decomposition (i.e., equation (20)) by the transpose of this weighting matrix, and post-multiplying by this weighting matrix, the forecast error variance of the NI outputs can be reduced to a nine by nine matrix that yields nation-specific insights. Dividing the contribution of each component of the forecast error of output by the country forecast error will yield a measure of the relative importance of each component.

The relative importance of the various factors from an industry perspective can also be calculated. For each industry, a weighting matrix can be conducted where the weights are the fraction of total industry output over all countries accounted by industry output in a particular country. There are seven industry-groups. If all industry-group weighting matrices are stacked columnwise, an industry-group weighting matrix,

Table 1. Summary of Likelihood Ratio Tests for Significance of Factors

Set of Factors	Likelihood Ratio Statistic	p-Value
World	χ^2_{67} = 171.16	.0001
Nation-specific	χ^2_{70} = 777.36	.0001
Industry-specific	χ^2_{70} = 253.10	.0001

W_{IND}, can be constructed with dimension NIxI. By pre-multiplying equation (20) by the transpose of this weighting matrix and post-multiplying by this weighting matrix, the $VAR(Y_{t+j}|\Omega_t)$ can be reduced to a seven by seven matrix that yields industry insights.

Table 2 presents the decomposition of the variance of the forecast error, evaluated at various forecast horizons, explained by the various factors from a national perspective. In order to facilitate the comparison between the world and nation-specific sources of forecast errors, we sum the contribution of the error terms in the factor equations with the contribution of the error terms from the causal variables. For all countries, the fraction of the forecast error explained by a certain factor is dependent on the forecast horizon. In the United States, the nation-specific factor accounts for 60.37 percent of variance of the one period ahead forecast error in output while the industry-specific factor accounts for less than two percent of output variation. The world factor explains 12.13 percent of output variation. At the steady state, defined as 20 periods ahead, the fraction of the variance of the forecast error of output explained by such factor changes. However, conclusions on the relative importance of the nation-specific, world, and industry-specific factors do not change. The nation-specific factor is still the most important factor explaining approximately 25 percent of the variation in output. The world factor is the next most important factor accounting for 9 percent of the variation in output while the industry-specific factor explains 6 percent of the variation. Much of the decline in the variance of the forecast error of output explained by the nation-specific factor appears as an increase in the importance of the idiosyncratic error (or residual) which accounts for 49.50 percent of the steady state forecast error. While the fraction of the forecast error explained by a certain factor

Table 2. Decomposition of the Variance of the Forecast Error from a Nation Perspective

Country	Periods Ahead	World Factor	Nation-Specific Factor	Industry-Specific Factor	Idiosyncratic
		Fraction of Variation Explained by:			
Belgium	1	15.96	45.46	6.23	32.34
	2	14.86	41.71	9.24	34.18
	4	14.49	39.61	9.33	36.56
	8	13.79	40.19	9.08	36.93
	12	13.37	41.92	8.79	35.91
	∞	12.49	45.72	8.22	33.56
Canada	1	11.25	35.89	0.65	52.20
	2	10.12	28.36	1.39	52.32
	4	9.62	34.52	1.71	54.15
	8	10.40	34.32	2.27	52.99
	12	10.29	35.44	2.33	51.93
	∞	10.08	36.89	2.28	50.74
France	1	10.18	65.81	1.21	22.79
	2	7.53	66.59	1.60	24.28
	4	7.41	62.07	2.43	28.09
	8	8.05	59.54	3.92	28.48
	12	7.89	59.99	3.87	28.24
	∞	7.78	60.75	3.79	27.73
Italy	1	3.06	90.72	0.52	5.68
	2	2.79	90.03	0.59	6.58
	4	2.73	89.72	0.63	6.91
	8	2.33	90.76	0.58	6.33
	12	2.15	91.48	0.53	5.84
	∞	1.87	92.58	0.46	5.09
Japan	1	5.96	39.40	1.15	53.48
	2	7.87	40.29	1.75	50.09
	4	7.64	39.24	2.18	50.93
	8	8.52	38.83	2.60	50.05
	12	8.62	38.79	2.65	49.92
	∞	8.63	38.81	2.66	49.89

Table 2 (Concluded). Decomposition of the Variance of the Forecast Error from a Nation Perspective

		Fraction of Variation Explained by:			
Country	Periods Ahead	World Factor	Nation-Specific Factor	Industry-Specific Factor	Idiosyncratic
Netherlands	1	16.72	68.85	1.53	12.70
	2	14.47	62.93	4.85	17.74
	4	11.38	69.77	3.52	15.31
	8	7.17	79.18	2.92	10.72
	12	5.08	85.27	2.06	7.58
	∞	3.17	90.78	1.29	4.75
United Kingdom	1	0.31	55.11	11.02	33.55
	2	0.78	46.61	12.36	40.33
	4	0.70	45.60	12.36	41.26
	8	0.70	43.16	12.42	43.71
	12	0.71	43.80	12.26	43.24
	∞	0.70	44.60	12.07	42.61
United States	1	12.13	60.37	1.41	26.08
	2	8.14	37.19	6.17	48.51
	4	9.02	35.92	5.93	49.12
	8	8.84	34.84	6.07	50.25
	12	8.85	34.96	6.06	50.12
	∞	8.83	35.15	6.04	49.98
Germany	1	16.49	52.93	4.03	26.53
	2	17.09	47.13	10.69	25.07
	4	14.48	45.36	11.52	28.64
	8	12.93	50.99	9.88	26.17
	12	11.43	56.51	8.70	23.36
	∞	9.11	65.19	6.95	18.74

is dependent on the forecast horizon over all countries, the relative importance of the factors, in general, is not sensitive to the forecast countries. For the United States, the nation-specific factor was the most horizon. As a result, we will focus on the steady state results for other important factor. This finding seems to hold for other countries. For Canada, Japan, and the United Kingdom, the nation-specific factor accounts for 36.89, 38.81, and 44.60 percent respectively, of the variance in the forecast error. These magnitudes are similar to the value of the nation-specific factor in the United States. The size of the nation-specific factor in Belgium, France, Italy, the Netherlands, and Germany especially compared to the size of this factor in the United States is surprising. For example, in Germany the nation-specific factor accounts for 65 percent of the aggregate output variation, while in France this factor explains 61 percent of variation. For the Netherlands and Italy, the nation-specific factor accounts for over 90 percent of the variance in the forecast error of output. These results are surprising because the prevailing view among economists would suggest that the nation-specific factor should be relatively less important in more open economies. Since these results do not support this position, we will have more to say momentarily.

The second most important in explaining the variance of the forecast error of output from a nation perspective is the world factor. Over 7 percent of the output forecast error variance is explained by this factor in Belgium, Canada, France, Japan, and West Germany. Only in Italy and the United Kingdom is this factor quantitatively unimportant. In the United States the world factor accounted for 8.8 percent of the variance of the forecast error of output. Compared to the United States, the world factor is more important in Belgium, Canada and Germany. However, it would be difficult to draw the conclusion that the world factor is more important in more open economies.

Except for the United Kingdom, the industry-specific factor seems to be the third most important factor. Evaluated at the steady state, the industry-specific factor explains approximately 8 percent of the output forecast error in Belgium, 12 percent in the United Kingdom and 7 percent in Germany. In the remaining countries, this factor accounts for less than 4 percent of the variance in output. If the average variance of the forecast error explained by the industry-specific factor is calculated, one finds that this factor explains less than 5 percent of the variance of aggregate forecast error of output. Since the industry-specific factors are supposed to represent disaggregate impulses that may be technology driven, these results seem to suggest that a real business cycle model as suggested by Long and Plosser (1983) does not provide the dominant explanation for business cycles in developed countries. The only way to argue for a real business cycle story would be to claim that the idiosyncratic factor which is the residual in the various industry equations should be included as part of a real business cycle model. If this error is combined with the industry-specific factor, the evidence would be much stronger for a real business cycle model.

Since the findings from the analysis of Table 2 are surprising, it is important to consider whether the manner in which the model is designed or assumptions about error structure could introduce a bias into the analysis. There is some reason to believe that the orthogonality assumptions introduces a bias against finding a large industry-specific factor. Recall that the industry factor represents an influence common to a given industry across all countries. Any covariance that occurs between industries in a country or across countries would be reflected in either the nation-specific factor or the idiosyncratic factor or residual. This explanation is consistent with the size of the nation-specific factors and idiosyncratic factors presented in Table 2. However, it is unlikely that the covariance between industries dramatically biases the conclusions. For such a bias to occur, the covariation would have to be both positive and large. There is little reason to believe that either condition holds with respect to forecast error industry output covariation.

It is also important to consider the findings in this paper relative to the literature. As has already been mentioned, Stockman (1988) has also investigated the source of disturbances to fluctuations in the rate of industrial production. His paper shows that both industry-specific and nation-specific shocks are empirically important. However, he finds that a substantial fraction of changes in national aggregate industrial production growth rates can be attributed to industry-specific disturbances that are common across nations. He continues to argue that since it is unlikely that productivity on taste disturbances respect national boundaries, the nation-specific disturbances result from national economic policies. Given Stockman's findings, our decompositions are not quite as surprising. 1/

The relative importance of the factors can also be evaluated from an industry perspective. These results are presented in Table 3. The nation-specific factor is still the dominant factor. However, the world and industry-specific factor seems to increase in importance. The world and industry-specific factors are especially important in the chemical and utilities industries. One would expect the world factor to be important in these industries due to the sensitivity of each industry to global shocks such as the oil price changes. The importance of the industry-specific factor is understandable given the number of technological innovations that has occurred in this industry.

1/ Both this paper and Stockman's paper imposes the restriction that an industry specific technological shock influences that specific industry in all countries at the same time. This restriction may be a partial explanation for the large idiosyncratic error term. In addition, in Norrbin and Schlagenhauf (1988) we employ a similar framework where the disaggregation is across regions and industries. The importance of industry-specific shocks are more important.

Table 3. Decomposition of the Variance of the Forecast Error at the Steady State from an Industry Perspective

	Fraction of Variation Explained by:			
Industry	World Factor	Nation-Specific Factor	Industry-Specific Factor	Idiosyncratic
Mining	2.55	42.40	4.72	50.31
Basic metals	10.15	23.71	19.22	46.91
Food	12.59	20.94	6.13	60.33
Machines	13.56	35.24	8.11	43.09
Chemicals	25.38	32.54	14.41	27.66
Utilities	22.85	16.74	24.88	35.52
Textiles	18.77	32.07	13.10	36.04

The fact that the world factor and the industry-specific factors take on increased importance in an industry perspective decomposition may seem counter-intuitive. One might think that since the aggregate is a weighted average of the individual industries, the contribution of the nation-specific component to the variance of the aggregate should be a weighted average of its contribution to the industry variance. However, this logic is flawed since it ignores the contribution of the nation-specific component to the covariance between industries or the contribution of the world component to the covariance between nations. That is, the contribution of the nation-specific component to the national variance is not a simple weighted sum of the individual industry contributions, but is the weighted sum of the nation-specific contribution to each industry's variance plus any covariances between the industries. In constructing an industry summary, the industry factor explains output variation common to an industry, thus allowing for potentially a larger role for the industry factor within the industry.

Establishing the statistical significance and relative contribution and ranking of each factor is important. However, this analysis says nothing about what explains the movements in the factor. A statement that the nation-specific factor represents individual country demand management policies is premature and possibly inaccurate. However, the DYMIMIC framework allows the researcher to determine which observable variables are correlated with the factors. Hence, an analysis of the factor equations yields some insights on this issue. We only summarize our findings. A more complete analysis is available from the authors. In the nation-specific factor equation, the monetary variable seems to be the most important observable variable. Only in Belgium, Italy, and the Netherlands is the monetary variable insignificant at the five percent significance level. On the other hand, the deficit, or fiscal policy variable, is statistically significant with the correct sign only in Belgium and West Germany. The trade weighted real exchange rate--intended to measure changes in comparative advantage--is statistically significant only in Canada and the United Kingdom.

The explanatory variables in the world factor equation are a world money supply variable, a price of oil variable and two dummy variables. One dummy variable allows for changes in the international monetary regime while the other allows for possible effects from the European Monetary Union. The world money supply variable is statistically significant. This provides some additional support for McKinnon's world money supply story. However, the oil price variable is not statistically significant. The dummy variable introduced to capture the change in the exchange rate regime is significant and negative. This suggests that the move to a flexible exchange rate regime has reduced the importance of the world factor. This result is consistent with a large body of literature that suggests a flexible exchange rate regime should afford more independence with respect to output movements.

VI. Conclusion

This paper examined the importance of world, nation-specific, and industry-specific impulses as sources of the business cycle. Knowledge of the relative importance of these impulses is important to guide the direction of future theoretical work on business cycles. Our empirical findings indicate that the nation-specific factor is the most important factor in explaining variations in output. Our results are similar to Stockman's (1988) findings, but we find even stronger evidence of independent policy sources of output fluctuations. The disaggregated technological shocks explain a small but significnt portion of the variance. The results provide little support for the disaggregate real business cycle paradigm, indicating that in a cross-country context (disaggregated) technological shocks are not a large source of business cycle movements. This result contradicts earlier empirical studies of the disaggregated real business cycles. Further research is required to establish the robustness of these results.

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