WHAT ARE THE DRIVING FORCES OF INTERNATIONAL BUSINESS CYCLES?

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Abstract

This paper examines the sources of international business cycles as well as the driving forces of these cycles across the G-7 countries. We first decompose variation of output, consumption and investment in these countries into common, nation-specific and idiosyncratic components using a dynamic factor model. We then repeat this exercise for a comprehensive list of variables that are often used as driving variables in international business cycle models: total factor productivity; measures of fiscal and monetary policy; the terms of trade and the price of oil. We find that the G-7 factor plays a relatively large role in explaining oil prices, productivity, the terms of trade, and certain measures of fiscal and monetary policy variables. We then show that productivity is the main driving force of international business cycles. Projections of the macroeconomic aggregates in each country on the common and nation-specific shocks gauges their relative importance. The results suggest that both the G-7 and nation-specific components of productivity play significant and comparable roles in accounting for aggregate business cycle variation in each country. Our final exercise involves

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rolling correlations of the G-7 real factor with the G-7 driving factors. We find that the relationship of productivity and the global cycle is stable over time, while the relationship of the global cycle with other driving variables is time varying.

1. Introduction

"What are the driving forces of international business cycles?" This has been one of the central questions in the extensive literature on business cycles. The question is a challenging one since there are many driving forces to consider, including total factor productivity shocks, fiscal and monetary policy shocks, oil price shocks, shocks to the terms of trade, shocks to preferences, news and many others. Moreover, these driving forces are influenced by various domestic and external factors and understanding the relative importance of these factors is necessary to get a good grasp of the channels through which the driving forces affect business cycles.

In order to answer this question, most previous work follows Backus, Kehoe and Kydland (1992) focusing on total factor productivity as the single driving variable with the world divided into home and foreign locations. While the most common driving variable is total factor productivity, monetary and fiscal policy shocks along with many others have been receiving more emphasis over time.

The reason quantitative equilibrium models have focused on small dimensional models in both the number of countries and number of driving variables is tractability. There are two dimensions along which tractability is a concern. The first is related to the ability of the researcher or the researcher's audience to sort out an expanding list of theoretical interactions as the dimension of the model increases. To some extent this is alleviated by tracing out the time profile reaction of the macroeconomy to one shock in one location at a time. This is the dynamic comparative statics counterpart to an impulse response function in time series econometrics.

The second constraint is data limitations. Even if the researcher decides to calibrate preferences and technology using existing micro-studies, thereby economizing on the number of parameters to estimate using macroeconomic series, the number of remaining parameters necessary to capture the dynamic covariance structure of the shocks grows rapidly with the dimension of the model. This is a consequence of the need – in dynamic rational expectations models – to forecast the future evolution of exogenous variables and their interdependence.

The objective of this paper is to provide a detailed analysis of a number of driving forces of business cycles within and across G-7 countries over the period 1960-2005. We use the term driving force in the same manner as it is employed in dynamic rational expectations models of the international business cycle – variables assumed to be exogenous by the model builder. Our study contributes to the research program on international business cycles in three ways.

First, we mitigate the curse of dimensionality by employing dynamic factor models. This allows us to characterize the stochastic processes for both endogenous variables and exogenous variables.

Second, our methodology helps us to differentiate the domestic and external factors in explaining these variables. We model the endogenous and exogenous variables as the sum of three unobserved factors: a common G-7 factor, a nation-specific factor and an idiosyncratic factor. Aside from parsimony, this approach lends itself to the interpretation of shocks as arising from common or nation-specific sources; a distinction which is central for a number of international business cycle theories. For example, a class of intertemporal models of the current account have the property that only idiosyncratic movements in exogenous variables lead to current account imbalances. Common factors are obvious candidates for sources of international business cycle comovement, an enduring topic in the literature.

Third, we have a comprehensive list of driving variables. In particular, our list of driving variables includes total factor productivity, government expenditures, the monetary base, short-term interest rates targeted by the central bank, the relative price of oil and the terms of trade. Apart from parsing the endogenous and exogenous variables into common, nation-specific and idiosyncratic variation, we also estimate the fraction of variation of output, consumption and investment attributed to each component of each shock. This enables us to study the joint properties of fluctuations in output, consumption, and investment. Using multiple macroeconomic aggregates, rather than just output, allows us to derive more robust measures of common and nation-specific business cycles.

Our analysis is carried out using a dynamic factor model. Dynamic factor models have increasingly become a popular econometric tool for quantifying the degree of comovement among macroeconomic time series.[1] Kose, Otrok and Whiteman

[1] While these models are often used to analyze the degree of business cycle comovement in the international business cycle literature, they have also been employed in other contexts such as forecasting and monetary policy analysis. See Otrok and Whiteman (1998) for an application to a forecasting exercise, and Bernanke, Boivin and Eliasz (2005) for an application to the analysis

(2008) provide a brief survey of the literature employing these types of models to study the extent of business cycles comovement. However, these models have yet to be used to examine a large set of driving forces and their relationship to macroeconomic variables. We characterize these relationships in terms of a variance decomposition.

Our international business cycle variance decomposition is achieved using a three step procedure. First, we use national data on output, consumption and investment to estimate the common G-7, nation-specific and idiosyncratic components of each national business cycle. In step two, we use the same statistical model to estimate the common G-7, nation-specific and idiosyncratic components of each driving variable.

In step three, we project measures of the components of the shocks on components of the endogenous variables. The objective of this exercise is to generate a variance decomposition of the common and nation-specific components of G-7 business cycles into the common and nation-specific components of our driving variables. This allows us to answer the key question we are interested in "what are the driving forces of international business cycles?" We are also able to answer narrower questions such as: "How much of the German business cycle is accounted for by movements in G-7 productivity versus German productivity?"

In a related paper, Gregory and Head (1999) employ dynamic factor analysis and Kalman filtering methods to analyze the sources of fluctuations in productivity, investment and current account in the G-7 countries. They report that the common fluctuations have substantial impact on fluctuations in both productivity and investment in these countries, but very little impact on the current account. Empirical work using vector autoregressions to identify structural shocks and infer their contribution to output variance in an international context are few. An important early contribution is Ahmed, Ickes, Wang and Yoo (1993). They allow for home foreign and world supply shocks, a relative fiscal shock, a relative preference shock and a relative money shock. Their data sample includes the U.S. and an aggregate of five major industrialized countries. They find that supply shocks explain most of the variation in output.

In section 2, we explain how our empirical approach relates to existing dynamic stochastic general equilibrium models of international business cycles. Section 3 provides information about the dataset we use. Section 4 describes the first step of our variance decomposition of output, consumption and investment into the common and nation-specific components. Section 5 explains the results of

of monetary policy.

variance decompositions of driving forces. Section 6 analyzes the importance of the G-7 and nation-specific driving variables in explaining fluctuations in output, consumption and investment. Section 7 concludes.

2. The model

In this section, we first describe how a standard linear international business cycle model relates to our empirical framework. This serves to highlight the curse of dimensionality which limits the number of sources and number of driving variables in this class of models. Next, we provide a brief description of the dynamic factor model we employ.

2.1. Linear business cycle models

The common methodological approach in the business cycle literature is to specify tastes, technology, constraints and asset market structure. Parametric functional forms are specified and either estimated or calibrated. Typically the models are solved by linearizing the model around a steady-state level or balanced growth path.

A convenient example given the focus of this paper is Baxter and Crucini (1995). Their stochastic dynamic general equilibrium model may be conveniently summarized by two systems of linear equations. Linear here simply means a set of linear equations describing the equilibrium solution in either the levels of the variables or their logarithms (which one depends on the method of linearization employed).

The first system of equations describes the dynamic evolution of the vector of state variables:

$$S_t = MS_{t-1} + e_t \tag{2.1}$$

While the system above is a first-order vector autoregression, it can be adapted to richer dynamics in either the predetermined or exogenous variables by augmenting the length of the state vector. The state vector contains the irreducible collection of predetermined and exogenous variables necessary for agents to decide on their current period choices. In the Baxter and Crucini model they are: home and foreign capital stocks, k_t and k_t^*, one of the bond stocks, b_t^* and domestic and foreign total factor productivity, A_t and A_t^*.[2]

[2] The other bond stock is redundant because world market clearing requires that $b_t^* = -b_t$.

The second system of equations are the decision rules, linking the vector of endogenous choices, Z_t, to the current state vector, S_t:

$$Z_t = \Pi S_t \tag{2.2}$$

Each row in this system is the decision rule for an economic choice variable. For example, if the first element in Z_t is domestic consumption, the first row of the matrix Π contains the coefficients that describe the current period responses of consumption to each of the individual state variables. In the one sector two-country bond economy with only productivity shocks, the state vector, S_t, has only five elements as noted earlier. Home consumption is a positive function of all four (the coefficients in the first row of Π are positive).

A key facet of the dynamic structure is the strict exogeneity of a subset of the variables in the state vector. Expanding the first system of equations, makes this obvious:

$$S_t = \begin{bmatrix} k_t \\ k_t^* \\ b_t^* \\ A_t \\ A_t^* \end{bmatrix} = \begin{bmatrix} \mu_{kk} & \mu_{kk^*} & \mu_{kb^*} & \mu_{kA} & \mu_{kA^*} \\ \mu_{k^*k} & \mu_{k^*k^*} & \mu^*_{k^*b} & \mu_{k^*A} & \mu_{k^*A^*} \\ \mu_{b^*k} & \mu_{b^*k*} & \mu_{b^*b^*} & \mu_{b^*A} & \mu_{b^*A^*} \\ 0 & 0 & 0 & \rho & \psi \\ 0 & 0 & 0 & \psi & \rho \end{bmatrix} \begin{bmatrix} k_{t-1} \\ k_{t-1}^* \\ b_{t-1}^* \\ A_{t-1} \\ A_{t-1}^* \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \epsilon_t \\ \epsilon_t^* \end{bmatrix} . \tag{2.3}$$

This may be written more compactly by collecting the predetermined choice variables (capital and bonds) into one vector and the exogenous variables (productivity shocks) into a second vector. The generic representation of the state and exogenous equations is now:

$$S_t = \begin{bmatrix} \mathbf{P}_t \\ \mathbf{X}_t \end{bmatrix} = \begin{bmatrix} \mu_{PP} & \mu_{PE} \\ 0 & \Gamma \end{bmatrix} \begin{bmatrix} \mathbf{P}_{t-1} \\ \mathbf{X}_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ \boldsymbol{\epsilon}_t \end{bmatrix} . \tag{2.4}$$

Here it should be understood that the elements of the vector of predetermined and exogenous variables depend upon the model structure, the number of shocks and number of countries. What all models share, though, is the zero restriction in the lower left sub-matrix of the coefficient matrix, representing the exogeneity restriction placed on the vector of variables, $\mathbf{X}_t$. The block of coefficients immediately to the right of the zero matrix is a matrix of coefficients linking current shocks to past shocks (it need not be first-order as assume here). The remaining coefficients of the system, denoted by the μ's, are complicated functions of all the model's deep structural parameters as well as those governing the dynamics of the shocks, ρ and ψ. The last feature worth noting is the innovation vector, containing innovations to productivity at home and abroad, and zeros elsewhere. Since the predetermined variables are assumed to be perfectly controlled by agents, there are no random variations in them unrelated to the state vector itself.[3]

This business cycle model implies that the data generated from such a model has a representation as a dynamic factor model. In the example here output, consumption and investment are all driven by two common factors — home and foreign technology. In contrast, our factor model will have a common productivity shock, seven nation-specific shocks and idiosyncratic variation specific to the series. The canonical linear business cycle model lacks these idiosyncratic components. However, there are a number of ways to break this exact (and counterfactual) link between all variables in a business cycle model. For example, Sargent (1989) shows how measurement error on the part of a statistical agency would give rise to a model that meets the typical assumptions of a dynamic factor model. In this case we would measure output, consumption and investment imperfectly, the estimated factor model on this data would then reveal three factors (interpreted as world, home and foreign technology factors) as well as idiosyncratic movements interpreted as measurement error. A second way is to introduce sector specific technology shocks as in Long and Plosser (1983). Such a model will also give rise to a dynamic factor structure as their work shows that such shocks generate a common business cycle. A third way is to introduce additional shocks, such as monetary and fiscal shocks.[4]

We focus on the business cycle properties of output, consumption and investment of the G-7 countries. Output is not directly chosen; in the prototype business cycle model it is a function of home and foreign total factor productivity and the inputs of labor and capital. Effectively, then, the three choice variables are consumption, labor effort and investment for each of the G-7 countries, a total of 21 choice variables. Studying a large set of shocks, as we do, has a clear cost as the dimensionality and parameters to be estimated quickly becomes unwieldy.

[3] One could certainly think of reasons to deviate from this assumption: random natural events that destroy the capital stock, unanticipated inflation eroding the real value of bonds if they are nominally denominated, or simply measurement error.

[4] Forni and Reichlin (1998) develop a classical estimator for dynamic factor models and apply it to disaggregated sectoral output in the US. Their identifying assumptions allow them to identify these factors as sector specific and aggregate technological shocks. Our complimentary approach attempts to study the impact of a wider range of shocks.

Focusing on the exogenous driving variables in the business cycle model, X_t,

$$X_t = \Gamma X_{t-1} + \epsilon_t \ . \tag{2.5}$$

this vector is made up of I (the number of countries) subvectors, $X'_{i,t} = [A_{i,t}, m_{i,t}, g_{i,t}, p_{i,t}, q_{i,t}]$, ordered as national productivity, a target of monetary policy (a short-term interest rate and a narrow monetary aggregate), a fiscal policy variable (government spending, revenue and so forth), the relative price of oil and the terms of trade. Thus even if we reduce the number of variables to the absolute minimum, the minimum being total factor productivity, a single measure of fiscal and monetary policy and the relative price of oil, Γ will contain 784 parameters to be estimated, the same is true for the variance-covariance matrix of the innovations. Even this is an understatement if the dynamics of the exogenous variables extend beyond the first-order.

2.2. The dynamic factor model

To economize on the dimensionality of the system, we employ a dynamic factor model. We study each driving variable separately and decompose the variation in each variable into common, nation-specific and variable specific factors. In particular, we combine multiple measures of each driving variable and estimate the following factor model in growth rates:

$$\Delta x_{ij,t} = \alpha_{ij} + B_{ij} F_t + b_{ij} f_{i,t} + \varepsilon_{ij,t} \ . \tag{2.6}$$

Suppose $\Delta x_{ij,t}$ is the growth rate of the jth empirical proxy for productivity in country i. Then, F_t is a common productivity factor shared by the G-7, $f_{i,t}$ is a nation-specific productivity factor and $\varepsilon_{ij,t}$ is measurement error. The interpretation of measurement error here is that we have imperfect proxies for true total factor productivity. The error term is assumed to be uncorrelated cross-sectionally at all leads and lags, and follows an autoregressive process of order p_i for each element in the vector. The factor $f_{i,t}$ follows an autoregression of order q_k. The B's and b's are factor loadings on the common and nation-specific factors.

The estimation of the model is Bayesian and follows the procedure in Otrok and Whiteman (1998). The priors on the model parameters are loose enough to be uninformative except for the prior belief that the autoregressive polynomials are stationary, which seems reasonable for data in growth rates. The estimation procedure itself is based on the Gibbs sampler and is outlined in the **Appendix**.

There are at least three advantages to our approach. The first one is parsimony; the number of parameters has been reduced from $(I \cdot e)^2$ to $(2 \cdot I \cdot J \cdot e)$ where I is the number of countries, J is the number of measures of the driving variable and e is the number of driving variables. The decision rules go from having $I \cdot e$ exogenous influences to having $2 \cdot e$ exogenous influences. For example, if we consider the number of exogenous variables discussed above, the number of parameters to be estimated would go down from 784 to 42. This is a major advantage in the context of international business cycle research because the decision rules directly capture the response of domestic consumption, say, to the common component of that driving variable (shock). This would otherwise be captured in consumption response by some weighted average of the coefficients on each nation's driving variable.

Second, having the common component and nation-specific component is very useful in the context of international business cycle research. For example, Glick and Rogoff (1995) exploit the fact that a large class of models imply no current account reaction to 'common shocks,' which would imply a zero coefficient on the common (world) factor for the current account equation. Models of risk sharing imply that consumption should respond to common shocks, not nation-specific ones, which is the opposite restriction on the coefficients for the consumption decision rule.

The third advantage is more descriptive, allowing us to compare the movements of G-7 productivity with the G-7 component of output or the G-7 component of fiscal policy. This leads one to immediately think about international business cycle comovement in terms of common reactions to common shocks and, possibly, asymmetric reactions to common shocks. Productivity movements naturally fall into the former category and oil price shocks into the latter category if one chooses to organize countries as net exporters and net importers as Backus and Crucini (2000) do.

3. The data

To analyze the driving forces of international business cycles, we construct a comprehensive database of the main macroeconomic and driving variables. We use annual data covering the period 1960-2005. Our selection of annual frequency stems from the fact that we include a broad set of measures for driving variables, some of which are not available at higher frequencies. Our macroeconomic aggregate for output is real gross domestic product, consumption is real private consumption expenditure and investment is real gross private capital formation. These series are from the World Development Indicators (WDI) and World Economic Outlook (WEO) database. For the driving variables, we separate them into policy and non-policy variables; all are treated as strictly exogenous.

We use multiple measures of driving variables, not simply because the factor model methodology requires it, but because different measures of each driving variable contain different information about the theoretical variable of interest. An important by-product of the factor model is that the size of the idiosyncratic component of a particular measure indicates the extent of independent variation across competing measures of the same economic variable. This could be measurement error or conceptual differences in the variable construction. Consequently, empirical results that use the common factor may be more robust than those that examine only a specific measure, our analysis will help to distinguish these cases.

On the monetary policy side, we use short-term real interest rates and real stocks of money, narrowly defined. The interest rates we employ are call rates and other short-term interest rates, including the T-Bill rates and Discount Rates. These are most closely influenced by interest rates targeted directly by the central banks, such as the Federal Funds rate in the United States. In our empirical work, we use the ex post real interest rate, with inflation measured using the CPI. The real monetary aggregates are represented by the sum of money and quasi money series, also deflated by the CPI. Interest rates and monetary aggregates are from the International Financial Statistics (IFS) of the IMF and CPI series are from World Economic Outlook (WEO) database.

On the fiscal policy side, we include total expenditure, government consumption, and total revenue. This list is more extensive than is typically used in the business cycle literature, allowing us to provide a broad fiscal picture. The fiscal series are from the OECD and IFS sources, completed with the help of the WEO database whenever the series are missing. The series are then deflated by the CPI.

The non-policy variables are productivity, the relative price of crude petroleum and the terms of trade. Productivity is the central focus of the international real business cycle literature. We use four different productivity measures. The first two measures are based on the framework developed by Klenow and Rodriguez-Clare (2005). These measures both use capital and labor input measures in the computation of total factor productivity. One of the measures also includes human capital in the decomposition. To construct these productivity series, we employ data from the Penn World Tables 6.2 (Heston, Summers and Aten, 2006). The other two productivity measures use only labor data, not capital, which is consistent with the approach used by Backus, Kehoe and Kydland (1992). The first uses gross domestic product and employment (number employed, not hours) from the OECD. The second is from the Bureau of Labor Statistics and uses manufacturing output and total hours in manufacturing.

We have four prices of crude petroleum in U.S. dollars: i) the world average price, ii) the Dubai price, iii) the Brent price and iv) the West Texas price. The latter three are the products produced in the markets referenced, the first is an expenditure weighted average of these prices. These U.S. dollar prices are converted to domestic currency and then deflated by the domestic consumer price index. These series are taken from the IFS.

The terms of trade is the price of exports relative to imports. We have two measures, one taken from the WEO and the other from the IFS. In the former, the terms-of-trade is the terms-of-trade of goods and services computed using the trade shares of all trading partners. In the latter, terms-of-trade refers to the ratio of unit value of exports to unit value of imports.

4. International business cycles

Following Gregory, Head and Raynauld (1997), we start by estimating a factor model for the macroeconomic aggregates:

$$\begin{bmatrix} \Delta y_{i,t} \\ \Delta c_{i,t} \\ \Delta i_{i,t} \end{bmatrix} = \alpha_{ij} + \begin{bmatrix} B_{iy} \\ B_{ic} \\ B_{ii} \end{bmatrix} F_t + \begin{bmatrix} b_{iy} \\ b_{ic} \\ b_{ii} \end{bmatrix} f_{i,t} + \varepsilon_{ij,t} \quad . \tag{4.1}$$

where the elements of the data vector are the growth rates of real gross domestic product, real private consumption expenditure and real investment for country i, respectively. The factor F_t is a common factor shared by all aggregates across all of the G-7 countries and this is what we will refer to as the G-7 factor. The quantitative impact of the G-7 factor on an individual macroeconomic aggregate is determined by the factor loading B_{ij}. These factor loadings are different across macroeconomic aggregates and across countries.[5] Both the factors and the residual entering the equation follow autoregressive processes. Innovations to both the factors and the residuals are assumed to be contemporaneously uncorrelated.

An important starting point for our analysis is to compare the G-7 factor with a well-known measure of the G-7 business cycle. The measure that we use

[5]To save space, we do not report factor loadings, these are available from us upon request.

here is a country-size weighted average of the growth rates of the G-7 macroeconomic aggregates. Following the methodology employed by Crucini (1997), we use Purchasing Power Parity valuations to arrive at the country weights. While the G-7 economies on average constitute about 50 percent of total world output, the United States alone accounts for roughly 46 percent of G-7 output and this number drops dramatically to about 15 percent for Japan, the next largest member. The G-7 share of world output has declined in recent decades as emerging market economies, including China and India, have grown much faster than the G-7. However, the G-7 cycle is still – in a value-weighted sense – a good approximation to the world business cycle.

Figure 1 compares the estimated G-7 factor to a G-7 aggregate growth rate computed as a country-weighted average of national output growth rates and and to U.S. output growth.[6] The correlation between U.S. output and the G-7 aggregate is 0.81 and is readily evident in the figure. While this may reflect common disturbances and genuine business cycle propagation across the U.S. and other G-7, it also reflects the large economic weight of the U.S. in the construction of the G-7 aggregate. To a first approximation, the G-7 business cycle looks like a moderated version of the U.S. business cycle. The G-7 common real factor is the smoothest of the three measures; its correlation with G-7 output growth is 0.84 compared to a mere 0.43 in the case of U.S. output. We conclude from this that the simple view that the U.S. business cycle drives the G-7 cycle is not a reasonable description of international business cycles.

Casual inspection of **Figure 1** also indicates that the G-7 factor captures the major economic events of the past four decades: the relatively steady expansion of the 1960s; the rapid boom of the early 1970s; the sharp, but short recession of the mid-1970s associated with the first oil price shock; the less abrupt and more enduring recession of the early 1980s stemming from a variety of forces including the tight monetary policies of major industrialized nations; the mild recession of the early 1990s; the 2001 recession and the subsequent recovery and slowdown.[7]

How important is the G-7 factor in the evolution of national macroeconomic aggregates? After all, if it is not quantitatively important, we should be less

[6]The G-7 factor is estimated quite precisely evidenced by the tightness of 10 percent and 90 percent posterior quintile bands available from the authors upon request.

[7]While not the focus of this paper, we also examine the behavior of nation -specific factors in detail. The results suggest that the nation-specific factors capture most of the major peaks and troughs of business cycles in each of the G-7 countries. The figures of nation-specific factors are available from us upon request.

concerned about refining our measure of it. To address this question we compute variance decompositions using the factor model (see the Appendix). **Table 1** reports our findings. Beginning with output, the usual business cycle reference variable, the world and national components are of equal importance in accounting for variation in the typical G-7 country. Based on this statistic, the world cycle merits as much scrutiny as the nation-specific component. From the perspective of individual countries, though, the picture is quite different. The world factor dominates the business cycles of France, Italy and Japan, on average accounting for more than 70 percent of the variation. It is of less importance for the United Kingdom and the United States, where it accounts for less than 15 percent of output variation. There is no obvious correlation between the relative economic size of a country and the importance of the G-7 factor.

Consumption tells a different story in a couple of respects. First, the G-7 factor on average accounts for a lower share of consumption variance than does the nation-specific factor. At first blush this seems consistent with the consumption-risking sharing puzzle, national consumption variance is not shared even among these highly integrated, financial developed nations. Note, however, that the national component of consumption is not significantly different from what we see in output. The difference between income and consumption variance lies mostly in the larger idiosyncratic term in the consumption decomposition. Thus it could be that larger measurement errors in consumption than income measurement skew international consumption correlations toward zero. While this certainly does not solve the correlation or risk-sharing puzzle, it helps to mitigate the puzzle somewhat.

Investment has a slightly more pronounced national component than output or consumption. Averaging across the G-7 the nation-specific component accounts for roughly 50 percent of the variation. Though this is not much higher than was true of output or consumption, the idiosyncratic component is almost as large as the G-7 factor for the typical country. The international real business cycle model predicts a large nation-specific component in investment fluctuations as capital searches for its highest reward. The small G-7 component for investment is consistent with this prediction.

To summarize, we have found sizable G-7, nation-specific and variable-specific components in the main macroeconomic aggregates. The common and nation-specific components tend to be larger than the idiosyncratic component with the exception of investment where it is on par with the G-7 component. Most of the heterogeneity we see is across countries, with France, Italy and Japan sharing a large common component and the United Kingdom and the United States business cycles being mostly driven by national factors. Canada and Germany fall between these extremes. The remainder of the paper is devoted to understanding why there is a common cycle in the first place and how these similarities and differences arise across countries. To develop this understanding we begin with an analogous decomposition of our driving variables into G-7, nation-specific and variable-specific components.

5. Properties of the driving variables

We begin this section briefly discussing each driving variable in isolation. We ask similar questions regarding these driving variables as were addressed in our analysis of macroeconomic aggregates in the previous section. We first analyze the evolution of each driving variable. We then focus on the relative importance of the G-7, nation-specific and variable-specific components in explaining the volatility of the driving variables.

5.1. Productivity, oil prices and the terms of trade

We first examine the properties of driving variables that are not instruments of policy: productivity, oil prices and terms of trade. Policymakers clearly scrutinize these variables to refine their policy actions in light of the evolution of output growth and inflation. Economic growth accompanied by labor productivity advance is viewed as less likely to alter inflation and inflation expectations than situations when productivity growth stagnates. Oil price increases in the absence of broad movements in inflation are appropriately viewed as relative price changes, though unpleasant policy tradeoffs may present themselves as affirmed by the recent emergence of concern about stagflation voiced by officials at the U.S. Federal Reserve. Productivity changes have been the dominant driver of quantitative theory on business cycles in closed economy models, with oil prices and the terms of trade taking a more prominent role in small open economy models.

To compute our productivity series, we use a standard Solow residual decomposition for country i:

$$a_{i,t} = y_{i,t} - s_i n_{i,t} - (1 - s_i) k_{i,t}$$

where $y_{i,t}$ is the logarithm of output, s_i is the share of labor income in total factor income, and $n_{i,t}$ and $k_{i,t}$ are measures of labor and capital inputs. The most commonly used version of this decomposition in the international business cycle literature is the one employed by Backus, Kehoe and Kydland (1992), which uses gross domestic product for the output measure and total employment as the labor input measure. The capital stock is not included in their decomposition. A considerable amount of research has taken place since and we draw upon more recent data and methodologies.

As we briefly discussed in the data section, we use four different measures of productivity. The construction of the first two measures follows the methodology in Klenow and Clare-Rodriguez (2005), using both capital and labor input measures in the computation of total factor productivity. One of their capital measures includes human capital. Consistent with the approach used by Backus, Kehoe and Kydland (1992), our other pair of measures use only labor data on the input side. The first of these two uses gross domestic product and employment (number employed, not hours) from the OECD. The second is from the Bureau of Labor Statistics and uses manufacturing output and total hours in manufacturing.[8]

The first panel of **Table 2** reports the common, nation-specific and variable-specific components of productivity. We see that the nation-specific component tends to dominate when we use the more elaborate decompositions including physical and human capital than those using basic labor input measures. The nation-specific component accounts for about two thirds of the variance in productivity growth in these cases, the contribution of the G-7 and nation-specific components fall when we move to the simpler measures, but only to the point of equality. The appearance of large idiosyncratic components in the simpler measure is consistent with the omission of capital measures in the computation of the Solow residual in these cases. The fact that the BLS measure has a full third of its variance accounted for by the idiosyncratic component may be due to the fact that

[8]Focusing on the manufacturing sector in each country, we used manufacturing output and employment data from the BLS as our measures of output and labor input. Broadening our analysis to the entire economy, we used GDP measures and total civilian employment from the OECD. The correlation of the two productivity measures in growth rates averages 0.81, but there are important differences across them. First, manufacturing productivity is more volatile than overall productivity. The standard deviation of the growth rate manufacturing productivity is on average roughly 2.5 times higher than the analogous measure using total output (1.97 compared to 0.81). Second, the bilateral cross-country correlations of manufacturing productivity are higher than those computed for GDP in most cases, but the differences are not statistically significant. This is consistent with a broader literature that documents larger international productivity differences in the service sector than the goods sector.

this measure includes only manufacturing while the other three span the entire production side of the macroeconomy.

Taken at face value, the results indicate that while the G-7 countries are not technologically integrated in the literal sense of sharing a common productivity level, there is a large common component. **Figure 2** plots the G-7 business cycle factor against the G-7 productivity factor, their correlation is 0.69. As we shall see in the next section, productivity will be a key driving variable both at the G-7 and national level. The implication is that business cycle models focusing on productivity shocks will need the nation-specific components of productivity to generate positive international output spillovers. Models with supply-side complementarities such as Ambler, Cardia and Zimmerman (2002) fall into this category. Coordinated monetary and fiscal policies that shift world demand are two other candidates.

Turning to the relative price of oil in **Table 3**, we see that the G-7 component accounts for virtually all of the variation. Recall that this relative price is computed as the U.S. dollar price of, say, West Texas crude petroleum converted to domestic currency at the spot exchange rate between the U.S. dollar and the home currency and then deflated by the national CPI level. While it is well known that the U.S. dollar prices of varieties of crude petroleum correlate strongly, it is surprising that this is also true of the relative price of oil in terms of the broader consumer basket in each nation. As we shall we, oil is one of the few driving variables that could be said to literally be a common shock to all G-7 nations.

The variance decomposition for the terms of trade is found in **Table 4**. As noted by Backus and Crucini (2000), the terms of trade and the relative price of oil tend to be highly correlated for the G-7 due to the higher variance of oil prices relative to other goods and services entering into trade flows. Moreover, oil accounts for a non-trivial share of trade even in highly industrialized countries. **Figure 3** presents the G-7 common factor for oil and G-7 factor for the terms of trade along with the G-7 business cycle factor. The correlation of the terms of trade and the relative price of oil in terms of the common factors is evident in the figure, particularly at the points of the sharp oil price increases in 1974, 1979, 1999 and 2005 and the drop in 1986. The correlation between the two factors over the entire sample is 0.76.

Backus and Crucini (2000) conclude that exogenous shifts in oil supply from OPEC producers can account for only about 10% of output variance in a sample of countries overlapping significantly with those include here. Consistent with their findings, the correlation between the G-7 business cycle factor and G-7 oil price factor (G-7 terms of trade factor) is 0.03 (0.12) for the full sample. One should keep in mind, however, that theory predicts an ambiguous sign: exogenous oil supply shocks generate a negative correlation, while increases in oil demand by the G-7 generate a positive correlation. Since the oil price shocks are often associated with periods of dramatic oil price changes, we tend to see oil prices, the terms of trade and world output behaving consistently with the supply-shock interpretation. In most periods, however, the correlation of the terms of trade, oil and G-7 output is weak and ambiguous.

As one might expect, when the oil prices are less volatile the correlation of the terms of trade and oil prices falls considerably. This is evident when we compare the variance decomposition of the terms of trade to that of the relative price of oil. **Table 4** shows that the G-7 terms of trade is not dominated by the world component, though it remains considerable, at between 40 and 50 percent, depending on the terms of trade measure.

5.2. Monetary and fiscal policy variables

Our goal is to capture periods of monetary and fiscal expansion and contraction in each country as well as the extent to which these policies are followed concurrently across the G-7. What the dynamic factor model allows us to do is to extract the common dynamic component from the multiple observable measures of monetary or fiscal policy.

Formally, the model for fiscal policy variables in country, i, can be written as:

$$\begin{bmatrix} \Delta\tau_{i,t} \\ \Delta e_{i,t} \\ \Delta g_{i,t} \end{bmatrix} = \begin{bmatrix} B_{i\tau} \\ B_{ie} \\ B_{ig} \end{bmatrix} F_t + \begin{bmatrix} b_{i\tau} \\ b_{ie} \\ b_{ig} \end{bmatrix} f_{i,t} + \begin{bmatrix} \varepsilon_{\tau_{i,t}} \\ \varepsilon_{e_{i,t}} \\ \varepsilon_{g_{i,t}} \end{bmatrix} \tag{5.1}$$

where $\Delta\tau_{i,t}$, $\Delta e_{i,t}$ and $\Delta g_{i,t}$ are the growth rates of total revenue, total expenditure and consumption by the national government of country i.

Thus we have three measures of fiscal policy, each with a different amount of information about the intentions of the fiscal authority. Loosely speaking, if a variable contains a lot of information about fiscal policy its factor loading, B or b, will be larger in absolute value, indicating that it reacts more to the changes in fiscal policy. For example, it may be the case that a decision to change the thrust of fiscal policy is largely carried out through changes in government revenues, in this case the factor loading associated with revenues will be the highest (our variance decompositions give us more information on this). In the language of the dynamic factor literature we are extracting a signal (here of fiscal policy) from three measures of that signal.

The error terms (ε's) contain two components under this interpretation of the signal extraction problem. One component is the noise component, which may be interpreted as simply measurement error. The second component is the idiosyncratic movement in a particular variable that does not have an interpretation as changes in broadly defined fiscal policy but of targeted, sector specific changes, for example, perhaps changes aimed to lessen income inequality (by lowering labor tax rates and raising capital tax rates). We are unable to distinguish between the two interpretations of the error term.

For monetary policy we include a short-term real interest, $r_{i,t}$, and a narrow monetary aggregate, $m_{i,t}$:

$$\begin{bmatrix} r_{i,t} \\ \Delta m_{i,t} \end{bmatrix} = \begin{bmatrix} B_{ir} \\ B_{im} \end{bmatrix} F_t + \begin{bmatrix} b_{ir} \\ b_{im} \end{bmatrix} f_{i,t} + \begin{bmatrix} \varepsilon_{ir,t} \\ \varepsilon_{im,t} \end{bmatrix} \tag{5.2}$$

The short-term real interest rate is designed to capture changes in a variable targeted by the central bank. Of course, since we use market rates, much of the variation will be due to supply and demand factors in each country and care must be taken when we attempt to interpret movements in the context of monetary policy discussions. The narrow monetary variable is included to incorporate the fact that central banks use monetary growth as an instrument as well. This may take the form of medium term targeting of money growth with a particular inflation target in mind or some short term interaction of narrow monetary aggregates and the setting of short-term interest rate targets.

Tables 5 and 6 contain the variance decompositions for the policy variables. The most striking feature of these results is how different short-term interest rates and monetary aggregates look through the lens of the factor model. Short term real interest rates are dominated by a common G-7 component, with two-thirds of the variance attributable to the common factor and almost none attributed to the nation-specific component. Money growth, in contrast, is dominated by the idiosyncratic component though a sizable nation-specific variation is also found.

The large world component in short-term real interest rates has a number of possible interpretations. The most obvious interpretation is that financial markets are highly integrated and capital mobility tends to drive the rate of return to capital in the same direction internationally. This is good news for models that feature trade in bonds and physical capital mobility. A policy interpretation is also possible here, namely the desire to avoid either large short-term capital movements or sharp exchange rate responses to uncoordinated movements in the interest rate target across the G-7. Finally, the common factor could be picking up the common factor in the business cycles of the G-7. Since business cycles tend to be positively correlated across countries, it is natural to expect real interest rates to share that correlation pattern too. The latter explanation is of particular interest because the cyclicality of the real interest rate within individual countries have been difficult to establish. Therefore, to the extent we find one at the level of G-7 countries, is encouraging.[9]

That money growth lacks a large common component is not surprising given the different inflationary histories of the countries in the cross-section. Somewhat more surprising is the size of the idiosyncratic component. This could be due to shifts in money demand across near substitutes within a country and differences in the definitions of money across countries.

Figures 4 and 5 present the G-7 fiscal and monetary factors, respectively, alongside the G-7 business cycle factor. We see a dramatic swing in monetary policy from stimulative in the 1970's to contractionary in the late 1970s and particularly the early 1980's. This is consistent with the broad brush view that monetary growth and low nominal and real interest rates set the world economy into a boom and inflationary spiral, followed by a concerted effort by the U.S. Federal Reserve and other central bankers to tame inflation. The very gradual down-slope of the world monetary factor in the 1980's and 1990's is consistent with the gradual disinflation and moderating real interest rate levels that were at least partly a result of establishing central bank credibility on the inflation front.

The world fiscal factor is sharply countercyclical in the first part of the sample, most notable in the sharp recession of the early 1970's. Later in the sample, the correlation becomes ambiguous. The countercyclicality is likely due to the normal evolution of tax revenue and non-discretionary spending over the cycle with tax revenue falling and expenditure rising. The later period has some large discretionary changes in tax rates, such as the Reagan and Thatcher tax cuts. While tax cuts are unlikely to have a stimulative impact contemporaneously, they may be responsible for a shift in the business cycle phase of fiscal policy. We will have more to say about this when we turn to rolling correlation analysis of the G-7 factors.

[9] Barro and Sal-i-Martin (1990) construct a world interest rate variable using a different methodology and find it depends mostly on world factors.

6. What drives international business cycles?

Up to now we have described the common and nation-specific components of national business cycles and the variables that business cycle theorists have proposed as driving variables. What we would like to know is how much of a nation's output variation is generated by common and nation-specific sources of variation in each of the driving variables.

6.1. Deconstructing the G-7 and national business cycle

The first step in undertaking this exercise, is to regress the common component of the G-7 business cycle on the common G-7 components of each of the driving factors:

$$F_{Y,t} = B_M F_{M,t} + B_F F_{F,t} + B_O F_{O,t} + B_A F_{A,t} + B_T F_{T,t} + \varepsilon_{Y,t}$$

By applying the variance operator to the both sides of this equation, we can decompose the variance of the estimated G-7 real business cycle into the parts due to each of the driving variables plus an idiosyncratic component. In order to ensure that the variance sums to one hundred, we first orthogonalize the factors for each of the driving variables. Specifically, we orthogonalize the regressors by first regressing the second factor on the first factor, and retaining the residual as the orthogonalized second factor. We proceed sequentially projecting factors onto the orthogonalized factors until we have a set of 5 orthogonalized factors. The order of orthogonalization we employ is the order the variables appear above: monetary policy, fiscal policy, oil prices, productivity and the terms of trade. This ordering implies that we use the monetary factor as it is estimated by the factor model and the orthogonal terms of trade factor is the part of the estimated factor that is orthogonal to all other factors.

The result of this exercise suggests that productivity is the main driving variable for the common component of the business cycles among the G-7. In particular, this factor accounts for 47 percent of the fluctuations in the G-7 real factor over the full sample period. The terms of trade factor accounts for less than 1.5 percent of the movements in the G-7 cycle, while oil, fiscal and monetary factors account for even less than one percent. A caveat to these results is that they represent a decomposition of the unconditional variance over the whole period. It is certainly plausible that some variables, such as oil, play an important role in certain sub-periods, as pointed out in section 5.1.

To complete our variance decomposition at the level of individual macroeconomic aggregates we need to also include the national specific components. To accomplish this, we employ the procedure described above with one of the National Income and Product Accounts aggregates on the left hand side and *either* the complete list of G-7 common factors (i.e., the common factor driving monetary policy, fiscal policy, productivity, the terms of trade and oil across the G-7) or complete list of the nation-specific driving variables on the right hand side.

It is important to note that while the factors are orthogonalized with respect to each other in both the G-7 and nation-specific categories, these components need not have a zero covariance with each other. The nation-specific component of fiscal policy may be correlated with the G-7 component of productivity, for example. Thus, when we add up the contributions of the G-7 shocks and the nation-specific shocks, they need not add up to less than 100%. If these two factors are orthogonal, the result is a unique variance decomposition with only the idiosyncratic factors left as a residual. In practice, the G-7 factors and nation-specific factor have non-zero sample correlation so there are instances where some ambiguity arises in assigning, say, the U.S. output fluctuations to the G-7 productivity factor versus the U.S. nation-specific monetary factor. The results suggest that the sum of the two variance decompositions is usually less than one hundred, and rarely much greater than one hundred. We interpret the results as being an upper bound on the variance contribution of the G-7 and nation-specific components.

We begin with the decomposition of output, reported in **Table 7**. Taken together, the driving variables account for a substantial portion of the variation in output growth. The G-7 common factor on average explains a smaller share of the variation than the nation-specific factors. Italy and Japan appear to be the most idiosyncratic with the national components of driving variables accounting for more than 90 percent of the variation. Canada and the United States lie at the other end of the distribution with a very significant role for the common components of the driving variables.

At first glance the results for France, Italy and Japan that the main driving force of output in these countries is the nation-specific component seems at odds with the results in section 4 that output fluctuations have a large G-7 component. However, these results can be reconciled by first noticing that for these three countries productivity has a small G-7 component but a large nation–specific component. The latter component turns out to explain a large amount of output variation. At the same time, our results above show that movements in the G-7 productivity factor explain about 50 percent of the G-7 real factor. The G-7 component of movements in output in France, Italy and Japan are then due to the 50 percent of the G-7 real cycle that remains unexplained.[10]

Turning to the individual driving variables, the columns are ordered by the fraction of output variance accounted for by the national component of the driving variable. By this metric the most important driving variable, by far, is productivity, followed by fiscal factors and monetary factors. Oil prices and the terms of trade play a very small role overall. For oil prices, it is the common component that is slightly more important, which makes sense given the significant role of OPEC pricing decisions over the sample period we have.

To the extent that productivity movements reflect technological shifts, they are not universally shared. The nation-specific component rivals the common G-7 component, each on average accounting for between 30 and 50 percent of output growth. Variation in the contribution of the common factor in productivity in the cross-section of countries is significant, ranging from a low of 18 percent in the United Kingdom to a high of 54 percent in Canada. Thus the importance of the G-7 factors overall for Canada and the United States is a combination of productivity shocks and the fiscal factor.

Comparing monetary and fiscal factors, the nation-specific component plays a slightly more important role in the case of monetary factors while the G-7 factor tends to be more important in a few cases for fiscal factors. We do not want to overstate the differences here because the absolute variances associated with them are small and for most countries neither component plays a large role.

Table 7 reports the results for consumption growth. We see similar patterns to what was found in our examination of output growth. In particular, taken together, the G-7 and national components are both important and the productivity tends to dominate as a driving variable. Again, the nation-specific factors are particularly strong in Italy and Japan while the G-7 factor is more relevant in Canada and the United States. The nation-specific monetary factors and the G-7 common fiscal factor again account for a lower order of magnitude of business cycles in consumption. While the role of oil is still marginal, the terms of trade as a driving variable on average plays a slightly more important role in explaining consumption than it does output. Given that consumption on average constitutes two-thirds of aggregate output, the similarity of the output and consumption re-

[10] Recall also that the variance decomposition of the nation-specific and G7 components come from separate regressions and need not sum to one. It turns out that for France, Italy and Japan the correlation between the country and G-7 factors is the largest, implying that the results for these three countries must be somewhat less than the reported upper bounds.

sults is not altogether unexpected.

Table 7 also repeats the exercise for investment. Here a key difference relative to earlier variables emerges, namely that nation-specific factor plays a much more important role than the G-7 factor does when all of the driving variables are considered together. In particular, the nation-specific productivity factor is much more important than the G-7 productivity factor in explaining the investment growth variation. This is consistent with the view that changes in the marginal productivity of capital across countries is an important facet of investment dynamics in an integrated world economy. In the case of monetary and fiscal policy variables, while the G-7 factor is more important than the nation-specific factors, this results is mostly driven by a small set of countries. Neither oil price nor the terms of trade factor appears to matter in explaining investment fluctuations.

6.2. Toward a business cycle chronology

The seminal work by Friedman and Schwartz (1963) is most often associated with the robust correlation between monetary events and the real business cycle. However, part of what distinguishes their work from modern business cycle research is the attention to detail at the level of individual business cycles and even phases of individual business cycles. This allowed them to provide texture to the chronology, when monetary policy may have played a crucial role and when it was more passive. Modern analysis typically reduces the business cycle to a set of moment conditions, often without attention to possible shifts in the relationships among endogenous and exogenous variables over time. A recent exception is the Great Moderation literature which focuses on the falling business cycle volatility over the most recent quarter century.

Here we draw inspiration from Friedman and Schwartz, but follow the modern literature by characterizing the chronology of business cycles in terms of time series moments. We focus on the G-7 cycle. To accomplish this we compute ten-year centered moving average correlations between the common G-7 business cycle factor and the common G-7 components of each of the driving variables. Figure 6 presents the results.

Since we are relating the common components to each other, a good starting point is the correlation of the common real factor with aggregate G-7 output (not shown in **Figure 6**), which averages 0.76 over the period. Thus the common real factor we extract from the G-7 NIPA aggregates is strongly correlated with the G-7 business cycle measured as a country-size weighted average of their output series. The correlation is quite stable over time, rising from 0.71 to 0.80 as we move from the first 10 year interval to the last (recall we lose 5 years of data at each end point in the rolling correlation).

From here on we will use the term world business cycle to refer to the G-7 real factor. The correlation of the world business cycle and G-7 productivity is a healthy 0.51, it falls only slightly from 0.56 to 0.46 as we move from about 1970 to 1995. **Figure 6** shows the full time path of the rolling correlations. Note that the correlation of the other driving variables with the G-7 business cycle are both lower and less stable over time.

The G-7 fiscal factor, for example, is quite stable and negative over the first part of the sample, it then jumps to about zero from the late 1980's to the late 1990's, before falling back down toward the end of the sample. It is tempting to interpret the earlier period as fiscally passive in the sense of a tendency of tax revenue to fall and expenditures to rise in the absence of legislative actions due to the progressivity of the income tax, procyclicality of capital gains and profit taxes and movements in non-discretionary spending, such as welfare payments and unemployment assistance. The absence of a clear cyclical pattern to fiscal policy reported in many business cycle papers is consistent what we find toward the end of the sample. The fact that the correlation is strikingly negative across the world in the earlier period is important because it suggests a more important role for fiscal policy in the past, which may have been overlooked in the existing literature.

Monetary policy oscillates from a strongly positively correlated with the G-7 cycle to strongly negatively correlated. Broadly speaking, monetary policy appears to be accommodating in most periods except the early 1980's, when central bankers made concerted efforts to reduce inflationary trends, and in the mid-1990's which seems to match up with the increases in the discount rate during the productivity and stock market boom.

The correlation of the oil price factor and the world business cycle moves from -0.17 to 0.24 across the decades. While these averages are closer to zero than some of the others, it is instructive to examine **Figure 6** more carefully. We see what appears to be a rising trend in the correlation with sharp reversals at the dates of sharp increases in the relative price of oil. These patterns seem broadly consistent with a recent hypothesis concerning the relationship between the business cycle and the relative price of oil. Some economists have argued that the relative importance of negative oil supply disruptions versus positive demand shifts have changed significantly over time. The conventional wisdom of sharp exogenous increases due to supply disruption and OPEC pricing decisions seems consistent with the negative correlation, a contractionary oil price increase. The notion that sharply rising demand for energy by newly industrializing countries, India and China prominent among them, would give rise to a positive correlation to the extent the real growth spillovers to the G-7 are positive (which seems very likely).

Examining the contribution of G-7 and nation-specific movements in the driving variables over time and in particular business cycle episodes is an important area for future research. The broad correlations outlined here are suggestive of some of the themes that could emerge from such an examination.

7. Conclusion

We have studied the time series properties of the key driving variables that often appear in international business cycle models: productivity, monetary policy variables, fiscal policy variables, oil prices and the terms of trade. In particular, we employ dynamic factor models to estimate the common and nation-specific factors in each of these driving variables. We documented the role of a G-7 common factor in each of these variables and found that the common factor is very dominant for oil prices, considerable for productivity, interest rates targeted by central banks, and the terms of trade, but of minor importance for monetary aggregates and fiscal balance sheet items (such as total expenditure).

There has been much interest in the extent to which there is an international business cycle in macroeconomic aggregates such as output, consumption and investment. We confirm previous findings that such a cycle does indeed exist. We then take the next step and find the source of the international business cycle to be primarily driven by productivity, though we are only able to explain roughly half of the variation in the G-7 cycle. A visual inspection of the international cycle and the driving variables shows that in some episodes oil prices move with the cycle, but this relationship has changed over time.

Turning to individual countries, our findings suggest that the common G-7 business cycle is important for the evolution of most macroeconomic aggregates and the driving variables of business cycles, including policy variables. Despite the significance of the common G-7 component in many of these variables, most appear to play a relatively minor role in explaining aggregate real business cycle fluctuations, with the exception of productivity.

We believe that future work would benefit from developing a chronology of business cycles along the lines of Friedman and Schwartz and Burns and Mitchell. This could be done at the level of the world business cycle and nation-specific variations from the common component. Such an exercise would likely bring important nuances to individual business cycle episodes as well as policy responses to different causal factors than it possible with the first pass we have attempted here.

Statistical appendix

Bayesian estimation of dynamic factor models

This appendix reviews the methodology used in estimating the dynamic factor model. The model here is a multi-factor extension of the single dynamic unobserved factor model in Otrok and Whiteman (1998). Kose, Otrok, and Whiteman (2003) also employ a similar multi-factor model in an exercise studying International business cycles. Since they provide a detailed discussion of the multi-factor model, this section is brief and closely follows the description in that paper.

Our interest in estimating the dynamic factor model is to characterize the joint posterior of the model parameters and latent factors. Since analytic forms for the joint posterior of the factors and parameters are unobtainable, we employ numerical methods to simulate from the posterior. To do so we use a "data augmentation" algorithm to generate draws from the joint posterior of interest (see Tanner and Wong, 1987; Otrok and Whiteman, 1998). Data augmentation in this context builds on the following key observation: if the factors were observable, under a conjugate prior, the factor models we estimate would each constitute a simple set of regressions with Gaussian autoregressive errors. Then, conditional on the regression parameters and the data, one can determine the conditional distribution of the factors. It is straightforward to generate random samples from this conditional distribution, and such samples can be employed as stand-ins for the unobserved factors.

To be more specific, the dynamic factor models can be thought of as consisting of a specification of a Gaussian probability density for the data $\{y_t\}$ conditional on a set of parameters Ψ and a set of latent variables $\{f_t\}$. Call this density function $g_y(Y|\Psi, F)$ where Y denotes the vector of data on the observable data, and F denotes the vector of dynamic factors. In addition, there is a specification of a Gaussian probability density $g_f(F)$ for F itself. Given a prior distribution for Ψ, $\pi(\Psi)$, the joint posterior distribution for the parameters and the latent variables is given by the product of the likelihood and prior, $h(\Psi, F|Y) = g_y(Y|\Psi, F)g_f(F)\pi(\Psi)$. As is shown in Otrok and Whiteman (1998), although the joint posterior $h(\Psi, F|Y)$ is extremely cumbersome, under a conjugate prior for Ψ the two conditional densities $h(\Psi|F, Y)$ and $h(F|\Psi, Y)$ are quite simple. Moreover, it is possible to use this fact and Markov-Chain Monte Carlo methods (MCMC) to generate an artificial sample $\{\Psi_j, F_j\}$ for $j = 1, \ldots, J$ as follows:

1. Starting from a value F_0 in the support of the posterior distribution for F, generate a random drawing Ψ_1 from the conditional density $h(\Psi|F_0, Y)$.

2. Now generate a random drawing F_1 from the conditional density $h(F|\Psi_1, Y)$.

3. This process is repeated, generating at each step drawings $\Psi_j \tilde{} h(\Psi|F_{j-1}, Y)$ and $F_j \tilde{} h(F|\Psi_{j-1}, Y)$.

Under regularity conditions satisfied here (see Tanner and Wong, 1987), the sample so produced is a realization of a Markov chain whose invariant distribution is the joint posterior $h(\Psi, F|Y)$. What makes this process feasible is the simplicity of the two conditional distributions. For example, $h(\Psi|F, Y)$ is easily constructed from the linear factor model when F is known. In particular, the linear factor model is just a normal linear regression model for y_i given the factors (albeit a regression that has autocorrelated errors that requires the use of the procedure in Chib and Greenberg, 1994, to simulate from the posterior). The other conditional density, $h(F|\Psi, Y)$ is a little more complicated because it is the solution to a Gaussian signal extraction problem. Otrok and Whiteman (1998) derive this distribution, which turns out to be a Normal distribution.

The prior on all the factor loading coefficients is $N(0, 10)$, which is quite diffuse. For the parameters of autoregressive polynomials, the prior is $N(0, \Sigma)$, where $\Sigma = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 0.25 \end{bmatrix}$. Because the data are growth rates, this prior embodies the notion that growth is not serially correlated though the prior is loose enough to allow for significant serial correlation; also, the probability that lags are zero grows with the length of the lag.[11] Experimentation with tighter and looser priors for both the factor loadings and the autoregressive parameters did not produce qualitatively important changes in the results reported below. The prior on the innovation variances in the observable equations is *Inverted Gamma* $(6, 0.001)$, which is also quite diffuse.

Variance decompositions

[11] Otrok and Whiteman (1998) discuss the procedure for ensuring stationarity of the lag polynomial. The method involves drawing from a truncated Normal distribution in the Metropolis-Hastings step.

To measure the relative contributions of the G-7, nation-, and variable-specific factors to variations in aggregate variables in each country, we estimate the share of the variance of each macroeconomic aggregate due to each factor. In particular, we decompose the variance of each observable into the fraction that is due to each of the two factors and the variable-specific component. With orthogonal factors the variance of observable i can be written:

$$var(y_{i,t}) = (b_i^{G-7})^2 var(f_t^{G-7}) + (b_i^{nation})^2 var(f_t^{nation}) + var(\varepsilon_{i,t})$$

The fraction of volatility due to, say, the G-7 factor would be:

$$\frac{(b_i^{G-7})^2 var(f_t^{G-7})}{var(y_{i,t})}$$

These measures are calculated at each pass of the Markov chain; dispersion in their posterior distributions reflects uncertainty regarding their magnitudes.

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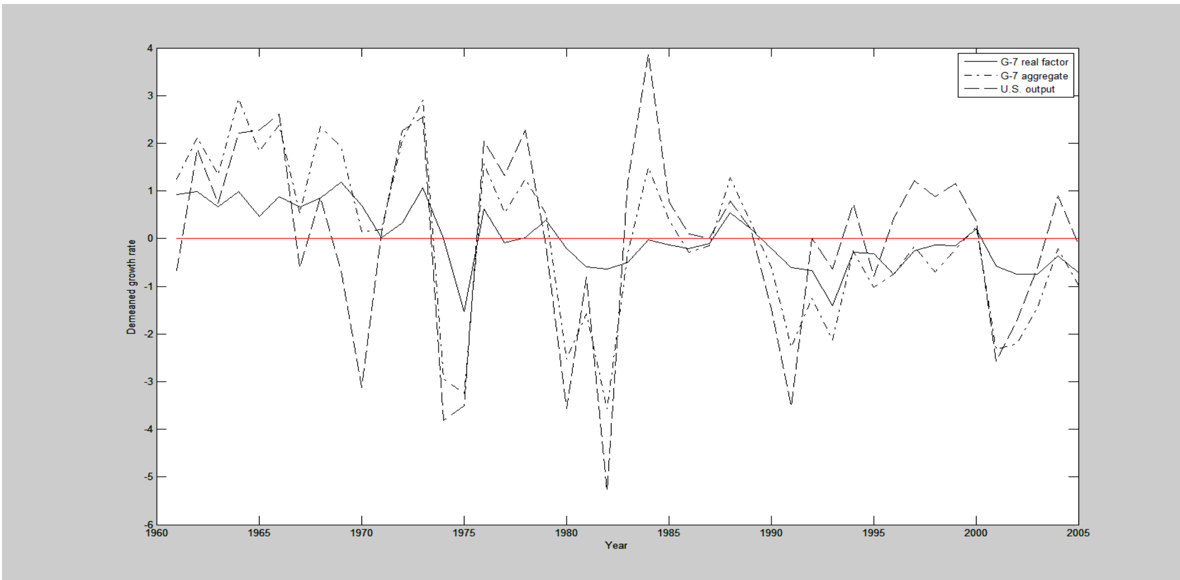

Figure 1. Three views of the world business cycle.

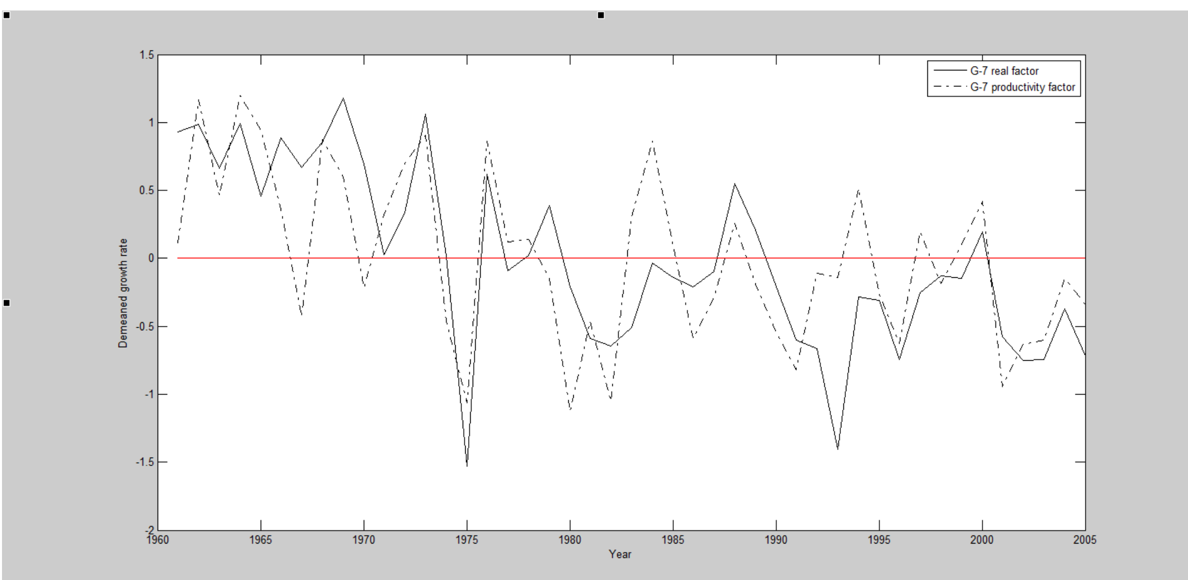

Figure 2. The G-7 business cycle factor and G-7 productivity.

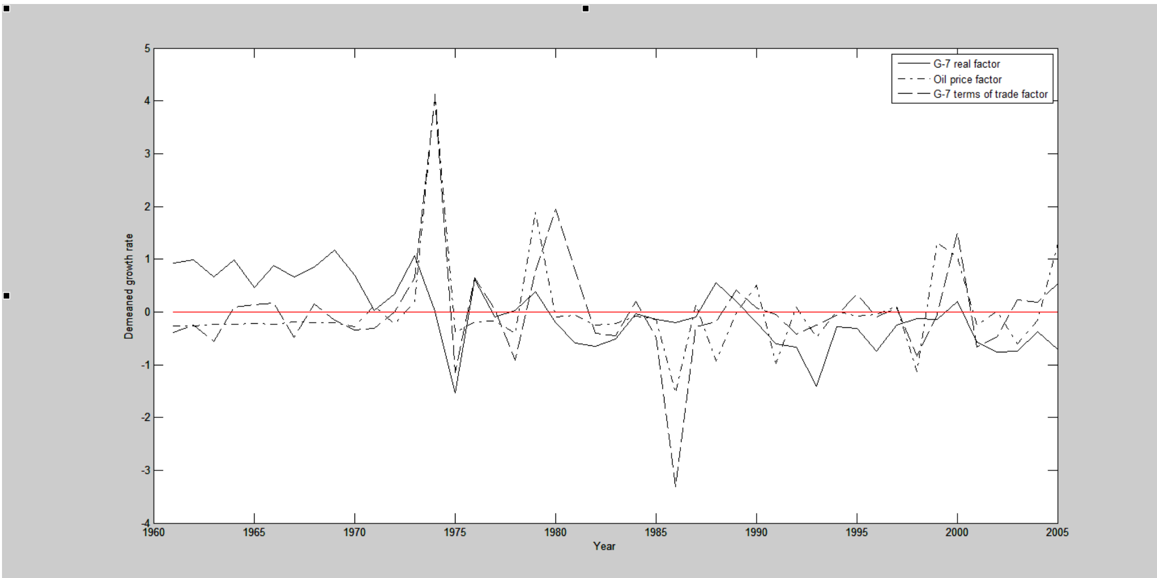

Figure 3. The G-7 business cycle factor, G-7 terms of trade and G-7 relative oil price.

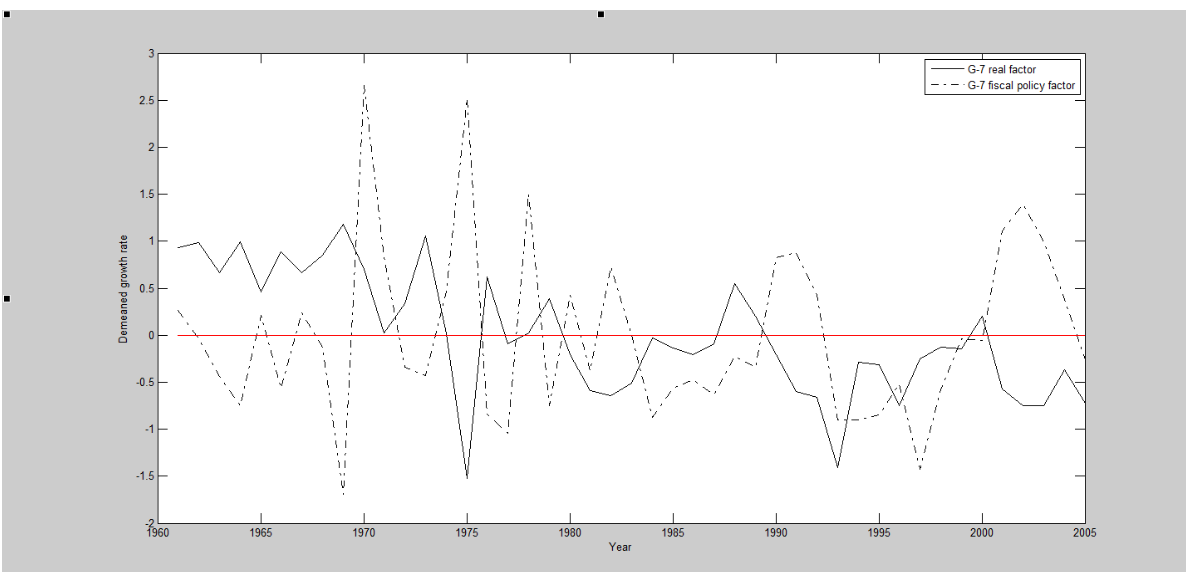

Figure 4. The G-7 business cycle factor and the common G-7 fiscal factor.

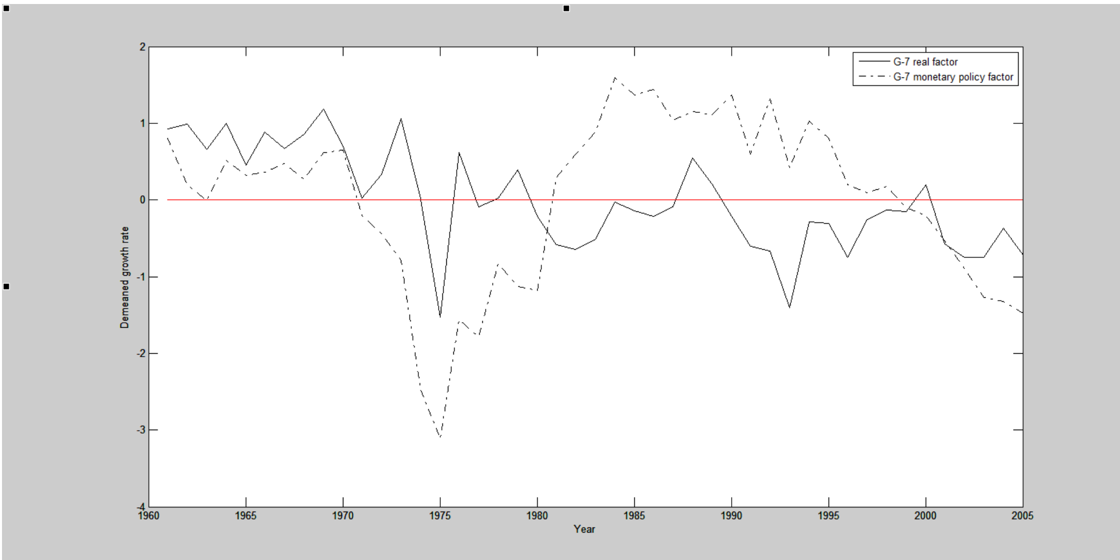

Figure 5. The G-7 business cycle factor and the common G-7 monetary factor.

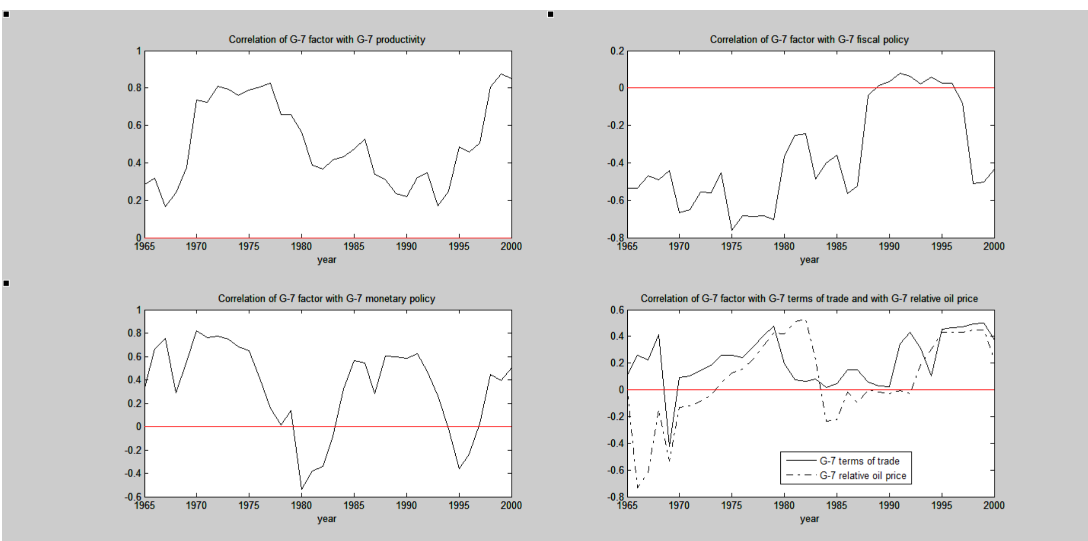

Figure 6. 10 year rolling correlations between the G-7 business cycle factor and the common factors of each of the driving variables.

Table 1. Variance Decompositions for Macroeconomic Variables

		Output			Consumption			Investment		
Country	**Factor**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**
Canada	G-7	33.50	35.91	38.43	17.61	19.57	21.46	5.17	6.55	8.05
	Nation-Specific	49.51	52.32	54.92	66.36	68.76	71.39	53.77	56.38	58.93
	Variable-Specific	10.19	11.67	13.20	9.64	11.45	13.20	34.80	36.88	38.84
France	G-7	77.21	79.98	82.68	51.11	56.15	61.09	51.24	54.32	57.57
	Nation-Specific	10.51	13.37	16.30	16.16	22.30	29.65	12.89	16.68	20.81
	Variable-Specific	5.28	6.59	7.90	18.17	20.83	23.00	26.44	28.74	30.69
Germany	G-7	45.73	48.97	52.26	30.71	33.37	35.67	19.11	21.64	24.35
	Nation-Specific	38.66	42.31	45.95	38.58	41.88	45.32	51.96	55.50	59.12
	Variable-Specific	6.72	8.34	10.02	22.77	24.91	27.09	20.67	22.84	24.90
Italy	G-7	70.15	73.98	77.53	60.28	64.91	69.36	28.20	31.45	34.66
	Nation-Specific	10.48	13.83	17.00	13.14	17.73	22.43	28.90	35.09	40.40
	Variable-Specific	10.28	12.00	13.70	15.64	17.29	18.94	30.75	33.92	37.35
Japan	G-7	54.83	57.96	61.16	48.26	52.04	55.64	51.60	54.82	57.74
	Nation-Specific	36.52	39.64	42.77	32.62	36.27	39.81	37.42	40.26	43.59
	Variable-Specific	1.85	2.24	2.71	10.96	11.62	12.33	4.27	4.84	5.39
UK	G-7	12.05	13.99	15.96	2.52	3.36	4.28	9.58	11.45	13.15
	Nation-Specific	69.48	72.86	76.02	63.97	66.87	69.98	40.58	43.30	46.12
	Variable-Specific	10.35	12.79	15.76	26.72	29.64	32.29	43.01	45.11	47.30
US	G-7	13.87	15.89	17.90	10.03	12.02	14.03	3.58	4.74	5.99
	Nation-Specific	76.96	79.40	81.74	61.39	63.76	66.06	80.24	81.99	83.69
	Variable-Specific	3.38	4.35	5.45	22.98	24.13	25.21	12.04	13.35	14.53
AVERAGE	G-7		46.67			34.49			26.42	
	Nation-Specific		44.82			45.37			47.03	
	Variable-Specific		8.28			19.98			26.53	
MEDIAN	G-7		*52.26*			*35.67*			*24.35*	
	Nation-Specific		*45.95*			*45.32*			*46.12*	
	Variable-Specific		*10.02*			*23.00*			*30.69*	

Table 2. Variance Decompositions for Productivity Measures

		KRC1			KRC2			OECD			BLS		
Country	**Factor**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**
Canada	G-7	34.05	47.23	55.32	33.22	46.55	54.61	61.48	69.33	74.31	62.77	70.57	76.49
	Nation-Specific	43.57	51.69	65.02	44.22	52.27	65.55	10.06	14.84	24.16	2.08	4.69	11.86
	Variable-Specific	0.74	0.88	1.04	0.80	0.95	1.12	14.20	15.48	16.56	21.07	23.51	25.97
France	G-7	25.94	27.93	30.25	27.34	29.42	31.67	35.62	40.93	46.73	35.07	38.87	43.04
	Nation-Specific	68.71	71.04	73.10	67.31	69.54	71.65	33.58	37.59	41.46	19.78	22.52	24.94
	Variable-Specific	0.67	0.79	0.95	0.65	0.78	0.94	19.97	21.61	22.92	37.23	38.89	40.20
Germany	G-7	9.04	10.82	12.88	13.86	15.95	18.59	45.25	49.92	57.42	43.29	47.72	52.76
	Nation-Specific	46.15	51.22	56.45	39.63	44.20	48.48	16.25	20.86	25.54	13.93	17.91	22.21
	Variable-Specific	32.76	37.21	42.16	35.69	39.11	42.57	22.12	25.41	29.21	29.65	32.37	35.39
Italy	G-7	13.82	16.23	18.35	13.34	15.70	17.79	28.04	31.80	35.63	25.95	29.58	33.77
	Nation-Specific	81.46	83.61	86.04	82.04	84.12	86.51	49.04	52.18	55.49	36.24	39.31	42.10
	Variable-Specific	0.11	0.13	0.16	0.11	0.14	0.17	15.55	16.16	16.73	30.46	31.45	32.19
Japan	G-7	13.55	16.10	19.86	12.98	15.55	19.13	16.53	20.74	27.03	12.17	15.00	19.97
	Nation-Specific	79.52	83.34	85.97	79.96	83.74	86.43	63.17	69.07	72.82	61.91	66.74	69.55
	Variable-Specific	0.32	0.39	0.48	0.45	0.52	0.63	9.84	10.36	10.78	17.93	18.28	18.56
UK	G-7	27.36	31.70	35.46	22.04	26.31	29.91	21.02	23.36	25.72	29.07	31.45	33.65
	Nation-Specific	63.08	66.84	71.22	68.77	72.39	76.62	44.07	46.40	48.83	19.88	21.89	24.19
	Variable-Specific	1.06	1.25	1.48	0.99	1.20	1.44	29.78	30.30	30.80	45.34	46.48	47.53
US	G-7	34.00	43.26	49.83	44.60	55.11	61.65	38.25	47.25	52.53	25.12	33.16	39.40
	Nation-Specific	43.54	50.34	59.61	34.11	40.95	51.07	34.15	39.73	48.24	20.30	26.45	34.63
	Variable-Specific	5.30	6.08	6.91	3.46	4.02	4.64	12.68	13.45	14.22	39.03	40.02	41.04
AVERAGE	G-7		27.61			29.23			40.48			38.05	
	Nation-Specific		65.44			63.89			40.10			28.50	
	Variable-Specific		6.68			6.67			18.97			33.00	
MEDIAN	G-7		*27.93*			*26.31*			*40.93*			*33.16*	
	Nation-Specific		*66.84*			*69.54*			*39.73*			*22.52*	
	Variable-Specific		*0.88*			*0.95*			*16.16*			*32.37*	

Table 3. Variance Decompositions for Measures of Oil Prices

		Average			Dubai			Brent			West Texas		
Country	**Factor**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**
Canada	G-7	88.23	89.31	93.14	89.65	90.53	94.22	86.75	87.91	90.70	85.80	86.98	91.49
	Nation-Specific	6.83	10.67	11.75	4.68	8.30	9.20	5.89	8.72	9.86	8.45	12.98	14.15
	Variable-Specific	0.03	0.04	0.05	1.13	1.15	1.17	3.37	3.40	3.43	0.03	0.05	0.06
France	G-7	88.98	89.76	94.59	89.25	90.06	94.60	86.97	87.72	91.81	86.53	87.37	92.86
	Nation-Specific	5.40	10.23	10.98	4.39	8.89	9.69	5.04	9.14	9.87	7.13	12.61	13.44
	Variable-Specific	0.02	0.03	0.04	1.02	1.03	1.05	3.13	3.15	3.17	0.02	0.04	0.05
Germany	G-7	89.20	89.99	94.71	90.06	90.85	95.23	86.94	87.68	91.63	86.68	87.56	92.94
	Nation-Specific	5.29	10.00	10.78	3.81	8.13	8.91	5.18	9.14	9.89	7.03	12.42	13.28
	Variable-Specific	0.02	0.03	0.05	0.96	0.99	1.02	3.15	3.17	3.19	0.02	0.04	0.05
Italy	G-7	89.34	89.99	94.67	89.71	90.36	94.73	87.22	87.97	91.77	86.88	87.60	92.94
	Nation-Specific	5.31	9.99	10.64	4.16	8.51	9.13	4.91	8.73	9.46	7.04	12.37	13.09
	Variable-Specific	0.02	0.03	0.05	1.10	1.12	1.15	3.29	3.31	3.33	0.02	0.04	0.05
Japan	G-7	85.09	86.25	90.53	87.32	88.40	92.41	81.94	83.08	86.33	82.70	83.95	88.88
	Nation-Specific	9.42	13.72	14.86	6.73	10.69	11.77	10.73	13.87	15.03	11.05	16.00	17.24
	Variable-Specific	0.03	0.04	0.05	0.90	0.93	0.95	2.98	3.02	3.06	0.03	0.05	0.07
UK	G-7	88.63	89.45	94.42	89.41	90.23	94.88	87.19	87.99	92.14	86.05	86.94	92.61
	Nation-Specific	5.56	10.54	11.34	3.98	8.55	9.37	4.45	8.62	9.39	7.36	13.04	13.92
	Variable-Specific	0.02	0.04	0.05	1.16	1.19	1.21	3.38	3.41	3.43	0.03	0.04	0.05
US	G-7	86.97	88.10	92.59	88.45	89.43	93.70	85.25	86.44	90.28	84.35	85.58	90.76
	Nation-Specific	7.38	11.88	13.01	5.20	9.44	10.39	6.36	10.19	11.37	9.20	14.40	15.61
	Variable-Specific	0.03	0.04	0.05	1.12	1.15	1.17	3.35	3.38	3.40	0.03	0.04	0.06
AVERAGE	G-7		88.98			89.98			86.97			86.57	
	Nation-Specific		11.00			8.93			9.77			13.40	
	Variable-Specific		0.04			1.08			3.26			0.04	
MEDIAN	G-7		*89.45*			*90.23*			*87.72*			*86.98*	
	Nation-Specific		*10.54*			*8.55*			*9.14*			*12.98*	
	Variable-Specific		*0.04*			*1.12*			*3.31*			*0.04*	

Table 4. Variance Decompositions for Measures of Terms of Trade

			TOT1			TOT2	
Country	**Factor**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**
Canada	G-7	30.28	32.28	34.32	6.70	7.63	8.70
	Nation-Specific	32.90	37.62	43.02	47.08	53.98	60.65
	Variable-Specific	24.59	29.71	34.37	31.39	38.17	45.25
France	G-7	70.76	73.25	75.83	68.04	70.50	72.89
	Nation-Specific	5.67	9.16	12.49	5.76	9.02	12.81
	Variable-Specific	14.21	17.52	20.28	16.85	20.53	23.25
Germany	G-7	42.48	44.75	47.07	64.65	66.59	68.40
	Nation-Specific	22.10	28.39	33.93	6.43	8.69	11.61
	Variable-Specific	21.22	26.90	33.03	21.73	24.55	26.85
Italy	G-7	37.43	39.83	42.24	75.56	77.76	80.15
	Nation-Specific	38.65	43.61	48.32	9.79	11.74	13.79
	Variable-Specific	12.44	16.41	20.56	8.18	10.04	11.73
Japan	G-7	56.29	58.50	60.69	57.35	59.43	61.61
	Nation-Specific	34.36	36.60	39.06	31.91	34.30	36.54
	Variable-Specific	3.30	4.53	5.82	5.31	6.57	7.63
UK	G-7	8.62	10.02	11.52	14.97	16.44	18.09
	Nation-Specific	48.78	54.05	60.24	46.00	51.46	57.06
	Variable-Specific	29.55	35.57	41.08	26.39	31.70	37.07
US	G-7	36.81	38.94	40.89	49.38	51.35	53.30
	Nation-Specific	47.58	50.50	53.26	37.52	39.99	42.46
	Variable-Specific	8.62	10.74	12.81	6.64	8.43	10.36
AVERAGE	G-7		42.51			49.96	
	Nation-Specific		37.13			29.88	
	Variable-Specific		20.20			20.00	
MEDIAN	G-7		*39.83*			*59.43*	
	Nation-Specific		*37.62*			*34.30*	
	Variable-Specific		*17.52*			*20.53*	

Table 5. Variance Decompositions for Measures of Monetary Policies

		Short-Term Real Interest Rates			Money Supply		
Country	**Factor**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**
Canada	G-7	79.23	81.40	83.41	3.90	4.90	5.93
	Nation-Specific	0.47	1.29	3.45	11.85	27.73	49.48
	Variable-Specific	12.76	15.44	17.82	45.44	66.88	83.37
France	G-7	65.49	68.16	70.94	1.05	1.61	2.21
	Nation-Specific	2.03	5.36	10.48	3.10	8.80	22.06
	Variable-Specific	19.60	23.87	27.53	76.24	89.05	94.77
Germany	G-7	32.38	34.47	36.69	1.12	1.63	2.19
	Nation-Specific	2.77	6.49	14.73	10.50	27.60	52.88
	Variable-Specific	49.46	56.48	60.96	45.04	70.73	87.50
Italy	G-7	64.84	67.23	69.46	0.38	0.78	1.32
	Nation-Specific	10.58	13.66	17.35	34.74	44.73	56.38
	Variable-Specific	15.24	18.38	21.39	42.67	54.31	64.27
Japan	G-7	44.19	46.41	48.58	13.93	15.53	17.17
	Nation-Specific	9.56	14.03	19.41	21.96	31.02	40.59
	Variable-Specific	33.82	38.90	43.41	43.80	53.33	62.20
UK	G-7	63.70	66.25	68.50	3.78	4.62	5.57
	Nation-Specific	3.37	5.54	9.04	24.73	41.78	58.87
	Variable-Specific	23.29	26.95	30.08	36.38	53.60	70.98
US	G-7	48.88	51.76	54.69	1.58	2.15	2.77
	Nation-Specific	2.82	5.76	10.55	8.49	20.53	35.07
	Variable-Specific	35.13	39.91	44.03	62.76	77.47	88.97
AVERAGE	G-7		59.38			4.46	
	Nation-Specific		7.45			28.89	
	Variable-Specific		31.42			66.48	
MEDIAN	G-7		*66.25*			*2.15*	
	Nation-Specific		*5.76*			*27.73*	
	Variable-Specific		*26.95*			*66.88*	

Table 6. Variance Decompositions for Measures of Fiscal Policies

		Government Consumption			Government Expenditure			Government Revenue		
Country	**Factor**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**	**33%**	**50%**	**66%**
Canada	G-7	12.28	14.94	17.97	0.31	0.74	1.40	11.57	14.77	18.23
	Nation-Specific	10.62	15.32	20.36	41.46	50.43	59.41	21.46	28.00	35.74
	Variable-Specific	62.57	68.58	73.83	39.36	48.32	57.00	46.82	55.52	63.17
France	G-7	16.71	21.01	25.47	18.49	21.49	24.59	0.80	1.65	2.84
	Nation-Specific	16.55	23.37	32.72	20.88	29.41	39.37	0.42	1.04	2.22
	Variable-Specific	44.92	54.41	61.45	38.37	49.02	57.41	94.56	96.19	97.44
Germany	G-7	4.03	5.80	7.98	16.44	20.20	24.26	3.05	4.35	5.83
	Nation-Specific	25.23	34.67	47.54	0.81	1.99	4.60	28.16	39.89	53.74
	Variable-Specific	45.31	57.63	67.22	70.48	74.96	78.98	41.01	55.25	67.03
Italy	G-7	5.89	8.58	11.78	34.30	38.52	42.73	3.09	4.73	6.78
	Nation-Specific	1.63	4.03	9.02	11.12	19.44	28.69	5.59	10.80	17.66
	Variable-Specific	78.57	84.85	88.67	31.58	40.37	48.46	77.23	82.83	87.03
Japan	G-7	0.87	1.68	2.73	1.40	2.62	4.34	1.20	2.15	3.49
	Nation-Specific	2.47	7.18	21.16	4.80	15.33	35.54	0.38	0.99	2.28
	Variable-Specific	76.28	89.80	94.83	60.58	80.79	90.67	93.38	95.51	97.26
UK	G-7	27.89	32.88	38.09	22.88	27.25	32.18	0.15	0.35	0.73
	Nation-Specific	13.60	19.84	26.18	31.35	39.53	47.28	12.32	17.13	23.27
	Variable-Specific	41.39	46.20	50.57	25.94	32.43	38.42	76.02	82.27	86.95
US	G-7	0.41	0.95	1.90	3.76	6.23	9.21	38.93	44.23	49.55
	Nation-Specific	54.72	60.36	65.97	51.59	57.53	63.14	1.74	3.48	5.90
	Variable-Specific	32.30	37.89	43.31	29.01	34.53	40.20	44.71	50.73	56.69
AVERAGE	G-7		12.26			16.72			10.32	
	Nation-Specific		23.54			30.52			14.47	
	Variable-Specific		62.77			51.49			74.04	
MEDIAN	G-7		*8.58*			*20.20*			*4.35*	
	Nation-Specific		*19.84*			*29.41*			*10.80*	
	Variable-Specific		*57.63*			*48.32*			*82.27*	

Table 7. Variance Decompositions for Macroeconomic Variables

Output

	Productivity		Fiscal Policy		Monetary Policy		Oil Price		Terms of Trade		Total	
	G-7	**National**	**G-7**	**National**	**G-7**	**National**	**G-7**	**National**	**G-7**	**National**	**G-7**	**National**
Canada	53.84	10.42	19.54	0.88	0.04	0.02	0.15	0.28	0.39	0.07	73.95	11.66
France	40.13	78.84	1.34	0.46	2.66	0.02	0.28	0.97	0.12	0.45	44.53	80.73
Germany	35.69	15.87	1.94	14.54	8.50	0.53	0.00	0.01	0.87	0.01	47.00	30.95
Italy	20.15	86.20	4.90	0.96	1.11	0.00	3.05	4.98	1.48	0.17	30.69	92.32
Japan	25.74	80.29	0.00	0.91	4.71	10.17	1.84	0.21	0.24	0.00	32.52	91.58
UK	18.11	43.70	9.44	5.12	7.15	24.25	3.23	0.00	9.45	0.27	47.38	73.34
US	38.43	24.45	25.71	2.91	4.06	6.38	3.10	0.21	2.41	1.31	73.71	35.25
AVERAGE	33.16	48.54	8.98	3.68	4.03	5.91	1.66	0.95	2.14	0.32	49.97	59.40
MEDIAN	*35.69*	*43.70*	*4.90*	*0.96*	*4.06*	*0.53*	*1.84*	*0.21*	*0.87*	*0.17*	*47.00*	*73.34*

Consumption

	Productivity		Fiscal Policy		Monetary Policy		Oil Price		Terms of Trade		Total	
	G-7	**National**	**G-7**	**National**	**G-7**	**National**	**G-7**	**National**	**G-7**	**National**	**G-7**	**National**
Canada	39.51	8.93	12.67	1.06	3.33	1.52	0.05	0.20	2.30	1.62	57.86	13.32
France	29.74	60.25	0.05	0.00	0.02	0.58	2.56	0.48	3.51	2.30	35.89	63.62
Germany	31.03	3.86	1.06	14.75	3.72	2.60	1.04	0.30	1.54	5.83	38.39	27.35
Italy	11.18	67.79	0.67	0.66	1.44	0.06	0.07	0.55	0.29	0.01	13.65	69.07
Japan	25.31	65.02	0.00	2.70	4.07	9.44	1.26	0.04	1.23	0.34	31.86	77.54
UK	4.23	35.24	0.67	0.68	7.47	29.40	1.85	0.32	13.61	1.40	27.82	67.04
US	42.60	12.20	11.26	3.90	4.79	18.63	8.84	0.21	8.77	0.30	76.27	35.23
AVERAGE	26.23	36.18	3.77	3.39	3.55	8.89	2.24	0.30	4.46	1.69	40.25	50.45
MEDIAN	*29.74*	*35.24*	*0.67*	*1.06*	*3.72*	*2.60*	*1.26*	*0.30*	*2.30*	*1.40*	*35.89*	*63.62*

Investment

	Productivity		Fiscal Policy		Monetary Policy		Oil Price		Terms of Trade		Total	
	G-7	**National**	**G-7**	**National**	**G-7**	**National**	**G-7**	**National**	**G-7**	**National**	**G-7**	**National**
Canada	7.90	29.29	16.45	1.66	3.25	0.55	0.21	1.04	0.43	1.61	28.24	34.16
France	17.40	71.63	3.55	1.92	5.76	0.74	0.59	0.05	0.01	3.19	27.30	77.54
Germany	17.34	12.40	0.26	15.00	13.88	3.68	1.15	0.35	0.06	0.40	32.69	31.82
Italy	0.50	54.05	1.22	0.00	1.63	0.68	1.69	0.24	0.29	3.80	5.34	58.77
Japan	18.63	75.75	0.01	1.88	9.95	13.84	1.74	0.20	0.04	0.21	30.36	91.89
UK	7.54	27.60	2.72	3.11	10.17	11.47	0.46	0.03	1.71	0.25	22.60	42.47
US	24.29	31.68	32.12	0.05	2.80	5.44	1.35	0.04	2.09	2.24	62.65	39.45
AVERAGE	13.37	43.20	8.05	3.37	6.78	5.20	1.03	0.28	0.66	1.67	29.88	53.73
MEDIAN	*17.34*	*31.68*	*2.72*	*1.88*	*5.76*	*3.68*	*1.15*	*0.20*	*0.29*	*1.61*	*28.24*	*42.47*