International Comovement: Is Theory Ahead of Business Cycle Measurement?

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Abstract

We study the long-run and business cycle dynamics of aggregative economic activity across the G-7. We identify permanent and transitory shocks at the national and world level using the logic of the permanent income hypothesis. Next, we explore the implications of our estimates for the quantity anomaly in the context of the Baxter and Crucini (1995) international business cycle model.

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1. Introduction

Economists and business analysts have long appreciated the fact that economic activity in one's country of residence is affected by economic activity abroad. Up until fairly recently, however, quantifying the extent of international business cycle comovement was limited by the absence of broad indicators of economic activity such as indices of industrial production or modern national income and product accounts. Historically, contemporaries emphasized positive demand and supply spillovers: higher foreign output increased demand for domestic exports or additional demand for intermediate inputs into production, thereby raising import demand. The negative spillovers were often discussed in the context of the political tensions that arose in trade: the concern about the foreign country gaining market share or damage to import competing sectors.

Better measurement of aggregative activity and refinements in estimation of correlation structure has led to significant strides in our understanding of 'the international business cycle.' Figure 1 is an example of what we hope to explain, it displays the Hodrick-Prescott cycle for Canada and Germany against that of the United States. The two countries were chosen because of their contrast. Canada and the United States have cycles in output that are practically indistinguishable while the comovement between Germany and the U.S. cycle appears very much a function of the time period of study. Evidence relating to the 'quantity anomaly' is also evident in the figures as the lower panels show cycles for consumption. While Canadian and U.S. consumption are positively correlated, they are not nearly as positively correlated as output; Germany's consumption cycle looks very different from that of the U.S.

In accounting for common and idiosyncratic features of cycles, modern business cycle theory has focused on the behavior of aggregate productivity and monetary and fiscal policy. Moreover, the predominant channels of business cycle transmission have been related to capital flows and the extent of financial market integration. When financial markets offer rich opportunities for risk-sharing, the demand side spillovers are strongly positive. First, risk-sharing gives rise to common movements in wealth across countries since agents are assumed to hedge idiosyncratic income risk. Second, a bond market links intertemporal relative prices across countries giving rise to common intertemporal substitution effects across countries. The supply-side spillovers, in contrast tend to be negative. When productivity rises or taxes fall in the home country, efficient resource allocation dictates that capital accumulation and employment rise at home and fall abroad.

International consumption correlations close to unity and international output and factor input correlations below zero are typical in the international business cycle literature. While numerous mechanisms have been developed to increase output comovement, they tend to involve economic specialization or explicit sectoral dependence, such as the extension of the seminar contribution of Long and Plosser (1983) to the international context by Ambler et al. (2004). Our view is that the main puzzle with which we grapple arises when comparing individuals (or nations) that produce similar products and therefore one would expect the demand and supply elasticities across them to be very high (if not perfect). Thus our analysis is set in the context of the one-sector, two-country model without any built-in demand or supply dependencies, exactly the type of economic environment in which it is challenging to get the correlations right.

Our benchmark theoretical framework is Baxter and Crucini (1995) who demonstrated that asset market structure has a central role to play in business cycle transmission, with stark implications for international business cycle correlation patterns. The key insight follows from permanent income reasoning. Wealth effects are common across nations when risk pooling occurs and specific to nations in the absence of risk pooling. Since the interest rate channel is present in both asset structures, the key is the differential wealth effects. Since wealth effects are larger the more persistent a disturbance, the persistence of the deviation of productivity across countries is key to determining the international consumption pattern. Moreover, with endogenous labor supply the output correlation is also affected by the magnitude of the wealth effect. Baxter and Crucini show that when shocks are trend stationary with positive spillovers, output correlations are negative and consumption correlations are close to unity. However, when productivity follows a random walk with correlated innovations across countries, the international output and consumption correlations change sign. Given that the range of international output and correlation patterns fall between these two extremes, it remains an open empirical question as to how far the incomplete markets model helps to solve the quantity anomaly (need to define this somewhere).

While our work is motivated by the international business cycle literature, the role of the permanent income hypotheses in our empirical work is closely related to papers by Quah (1990) and Cochrane (1994). Quah makes the point that the predicted variance of consumption depends on the relative importance of permanent and transitory shocks to income (components which may be only observed by the individual and not the econometrician). Cochrane used the permanent income hypothesis to estimate the stochastic trend in U.S. output from a bivariate relationship involving consumption and income. We extend Cochrane's approach to an international setting in a manner that allows us to identify a permanent and a temporary shock to income which are orthogonal to each other but have arbitrary correlation patterns internationally.

Our procedure may be thought of as developing a simple 'economic filter' for business cycle research that has many of the statistical properties of the Hodrick-Prescott filter or the Baxter-King high-band-pass filter. Our main motivation for doing so is to advance our knowledge of the persistence and international correlation properties of economic shocks in a manner that is ideally suited in meeting the empirical demands of the Baxter and Crucini (1995) model and others like it.

The paper is organized as follows. Section 2 briefly reviews the two-country one-sector incomplete risk–sharing model and its predictions about international comovement. Section 3 extends Cochrane's (1994) methodology to estimate a permanent and temporary innovation in each of these countries: Australia, Canada, France, Italy, Germany, Japan, the United Kingdom, and the United States. Section 4 uses these estimates along with the dynamic equilibrium model to assess the ability of the incomplete markets model to account for observed international comovement. Section 5 concludes.

2. Theory

2.1. Partial equilibrium

We begin with a brief review of Quah's (1990) analysis since it capture the wealth effects that will be central to the workings of the more complex general equilibrium model.

Quah assumes quadratic utility, rational expectations, a constant interest rate and exogenous labor income. Because income is equated with labor (wage) income, effectively the only asset market in operation is a loan market. Such an asset market structure is restrictive in the sense that holding of equity is ruled about, but generous in the sense that agents are assumed to be able to draw on the annuity value of their future income. The model is attractive because it fits neatly into the small open economy paradigm that formed the basis for the first generation of intertemporal models of the current account.

The key implication of permanent income theory, of course, is that consumption responds one-for-one to an increase in wealth. The level of consumption is given by:

$$C_t = rb_t + \frac{r}{1+r}\sum_{k=1}^{\infty}(1+r)^{-1}[E_tY_{t+k} - E_{t-1}Y_{t+k}]$$

where C_t is consumption, r is the (constant) real interest rate; for concreteness, we simplify the income process as follows:

$$\begin{aligned} Y_t &= Y_t^p + Y_t^T \\ Y_t^p &= Y_{t-1}^p + \varepsilon_t^P \\ Y_t^T &= \rho^j Y_t^T + \varepsilon_t^T \ , \end{aligned}$$

in which case consumption growth is a simple weighted average of the innovations to the permanent and temporary components of labor income:

$$\Delta C_t = \varepsilon_t^P + \phi\varepsilon_t^T$$

where $\phi \equiv r/(1+r-\rho) \leq 1$. The coefficient on the temporary innovation will be much less than unity for a "near" random walk – at a persistence level of 0.95 and interest rate of 2%, the coefficient is below 0.3!

The minimal extension of Quah's model to an international setting is to consider parallel economies in which agents solve analogous maximization problems. Assuming the discount rates and persistence parameters (and the implied real interest rate) are the same abroad as at home, foreign consumption growth is given by an analogous equation and the implications for consumption covariance (and correlation) is immediate:

$$\begin{aligned} cov(\Delta C_t, \Delta C_t^*) &= cov(\varepsilon_t^P + \phi\varepsilon_t^T, \varepsilon_t^{*P} + \phi\varepsilon_t^{*T}) \\ &= cov(\varepsilon_t^P, \varepsilon_t^{*P}) + \phi^2 cov(\varepsilon_t^T, \varepsilon_t^{*T}) \\ &\quad +\phi cov(\varepsilon_t^P, \varepsilon_t^{*T}) + \phi cov(\varepsilon_t^{*P}, \varepsilon_t^T) \ . \end{aligned}$$

The covariance of consumption across countries depends on a weighted average of the covariance of the four components of 'news' about future income. One can see immediately that generating consumption correlations that are negative when consumption follows permanent income will require a negative covariance in the shock structure. Moreover, given the weight ϕ falls quickly as the persistence of the shock declines, the negative covariance will most likely have to reside in the news about the permanent component of income.

The general equilibrium model described next shares these features – permanent shocks imply larger wealth effects than temporary ones. While consumption also responds to the time paths of the world real interest rate and the real wage, the wealth effects turn out to be very important quantitatively in distinguishing complete and incomplete markets version of the model as we shall see.

2.2. General equilibrium

Baxter in Crucini (1995) assume agents in each country maximize the expected lifetime utility, given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma}[C_t^{\theta} L_t^{1-\theta}]^{1-\sigma} \tag{2.1}$$

where C and L are consumption and leisure with hours worked N and leisure constrained to sum to unity (a normalization of the time period). This specification of preferences is also used in papers by Baxter and Crucini (1993), Backus, Kehoe, and Kydland (1992, 1995), and Prescott (1986) among others. A number of papers (more in the closed economy than in the open economy framework) use:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma}[C_t - \frac{N_t^{\omega}}{\omega}]^{1-\sigma}$$

including: Correia, Neves, and Rebelo (1995), Devereux, Gregory, and Smith (1992), Greenwood, Hercowitz and Huffman (1988), and Mendoza (1991). As we will see, these two specifications have dramatically different implications for international comovement of aggregate variables.

Each agent operates a neoclassical technology which utilizes inputs of capital, K, which is internationally mobile, and labor, L which is not. Output is subject to stochastic variation in productivity, denoted A, so we have:

$$Y_t = A_t K_t^{1-\alpha} N_t^{\alpha} \ , \tag{2.2}$$

which is the standard specification in the one-sector models of the business cycle (both closed and open economy versions).

An important point of departure of the model from its closed economy counterpart is the introduction of adjustment costs in capital accumulation. As a number of authors have clearly demonstrated, adjustment costs are essential in the one-sector model to avoid counterfactual implications for the location of physical capital internationally (i.e. to prevent the existing physical capital stock from moving to its most productive location in the period a shock arises). Thus, new capital goods are internationally mobile, but investment is subject to costly adjustment governed by the function $\phi(I/K)$, with the properties: $\phi > 0$, $\phi' > 0$, $\phi'' < 0$, as in Hayashi (1982). The capital accumulation equation is thus:

$$K_{t+1} = (1-\delta)K_t + \phi(I_t/K_t)K_t. \tag{2.3}$$

The incomplete asset market assumption is evident in the fact that each agent (of which there is a representative for each country) has a flow budget constraint given by:

$$P_t^B B_{t+1} + C_t + I_t \leq Y_t + B_t \tag{2.4}$$

and a boundary condition:

$$\lim_{t\to\infty} \beta^t P_t B_{t+1} = 0 \tag{2.5}$$

where P_t is the multiplier associated with the intertemporal budget constraint. The model is closed by imposing the market clearing conditions for the goods market and the bond market:

$$[Y_t - C_t - I_t] + [Y_t^* - C_t^* - I_t^*] = 0 \tag{2.6}$$
$$B_t + B_t^* = 0\ . \tag{2.7}$$

Details of the solution are found in Baxter and Crucini (1995).[1]

Income, is, of course, endogenous in the IRBC model. The fact that income follows productivity levels fairly closely in this class of model allows us to get a similar implication to the simple PIH model by assuming productivity has the same stochastic properties we assumed earlier for income. Thus, we simply replace y with A in the driving process

$$A_t = A_t^p + A_t^T \tag{2.8}$$
$$A_t^P = A_{t-1}^P + \epsilon_t^P \tag{2.9}$$
$$A_t^T = \rho A_{t-1}^T + \epsilon_t^T \tag{2.10}$$

[1] [Check this...] The model studied by Quah is, in effect, a very restrictive version of this model. To see this, set the production function to $Y_t = A_t K_t$, remove the adjustment cost from the capital stock and restrict the utility function to be quadratic. The resulting model is a two-country endowment model with trade in bonds and a constant interest rate.

where ϵ_t^P and ϵ_t^T are the innovations to the permanent and temporary components of productivity in the home country. The foreign country faces analogous processes for the disturbances with an asterisk indicating the foreign variables in equations (2.8) – (2.10) above. Given the assumptions we made about the innovations, the covariance matrix of the innovations is given by:

$$E(\epsilon\epsilon\prime) = \begin{bmatrix} \sigma_P^2 & \vartheta_P & 0 & 0 \\ \vartheta_P & \sigma_P^2 & 0 & 0 \\ 0 & 0 & \sigma_T^2 & \vartheta_T \\ 0 & 0 & \vartheta_T & \sigma_T^2 \end{bmatrix} \tag{2.11}$$

where $\epsilon' = [\epsilon_{Pt} \quad \epsilon_{Pt}^* \quad \epsilon_{Tt} \quad \epsilon_{Tt}^*]$. The pure random walk case examined in Baxter and Crucini (1995) involves setting the variance of the transitory innovation to zero while the trend stationary specification is approximated by setting the random walk innovation variance to zero (the early paper had spillovers of productivity but these are not essential in what follows). The remaining parameters of tastes and technology follow BC.[2]

2.3. Quantitative predictions

Table 1 summarizes output and consumption comovement in theory and in the data. We see that the average consumption correlation in the data is 0.22, about half the magnitude of the international output correlation (0.44). While there is obviously cross-country heterogeneity in each of the correlations, the consumption correlation is lower than the output correlation in all but two cases. More importantly for the risk-sharing model, the consumption correlations are well below unity (which is a standard benchmark value for risk-sharing models).

[2] The model is calibrated with two equally size countries with identical preferences and technology. Labor's share is α =0.58; the discount factor, β is set to yield a steady state annual real interest rate of 6.5 percent, the quarterly depreciation rate is set at δ =0.025. When the Cobb-Douglas preferences are used the parameter θ is determined from steady state conditions so as to yield a fraction of 0.2 of the day is spent in the workplace. The parameter ω is set at 1.455 as in Mendoza (1991). The coefficient of relative risk aversion is set at 2 for both types of preferences. Because we linearize the model in the solution procedure we do not have to set the functional form for the cost of adjustment function of capital explicitly. What must be set is the level, slope, and curvature of the function at the steady state point. This is accomplished by setting Tobin's "q" to one (which is ϕ'), and the elasticity of the investment-capital ratio to variation in Tobin's "q", $\eta = -(\phi'/\phi'')/(i/k)$ is set to 15 which delivers about the amount of investment volatility that we observe in international data.

Turning to the theory, we see that for trend-stationary productivity, the quantity anomaly arises for both specification of preferences. Despite the lack of ex ante risk pooling, consumption correlations are above 0.9 and income correlations are below 0.4. However, the random walk specification (with correlated innovations) generates negative consumption correlations and positive income correlations. Note also, that the two parameterizations of productivity now encompass the cross-country averages found in the data. In fact, the theoretical range of prediction actually encompasses most of the individual bilateral correlations.

The preference specification is also important. The Greenwood-Mendoza specification is more sensitive to the stochastic process for productivity than the Baxter-Crucini specification. Moreover the international correlations move in opposite directions as persistence rises under Cobb-Douglas preferences, but in the same direction with the Greenwood-Mendoza preference specification. The Greenwood-Mendoza specification encompasses virtually the entire span of possible consumption correlations (i.e. close to a range from -1 to 1) and easily encompasses the entire range of output correlations found in the data. With this quantitative theory as a backdrop, our goal will be to explore the relative importance of permanent and temporary shocks as well as their international correlation patterns. While these facts will be interesting in their own right, we also hope to shed some light on the implications they hold for international business cycle predictions under incomplete risk pooling.

3. Measurement

The novel element of our analysis involves the measurement part of 'theory and measurement.' The theoretical section made clear that wealth effects are a key element in the sensitivity of international comovement to persistence and international correlation patterns of productivity shocks.

There is no consensus on the appropriate statistical decomposition of macroeconomic time series into permanent and temporary components.[3] This is pre-

[3] Most methods applied in the macroeconomics literature are statistical decompositions. An excellent review of many of these methods is Canova (199x). While his focus is on how business cycle facts are affected by different methods of parsing the growth trend from the cycle, he covers most of the popular methods. Some methods are best described as pure filters, such as the Hodrick-Prescott filter, deterministic trend estimation, or first differencing. Other methods acheive the decomposition by fitting a time series model to the data, such as with the Beveridge-Nelson decomposition or state-space models (see, for example, Kose, Otrok and Whiteman (2003)).

cisely the point made by Quah (1990) in the context of the consumption volatility (Deaton) paradox: there are an infinite number of decompositions of a non-stationary time series into permanent and temporary components. The common practice in the business cycle literature is to choose a decomposition method or filter that isolates cycles in the range considered to be relevant for business cycles and the remainder of the variation is consider secular or growth-related. The problem with this method from a structural perspective is that economic models do not have implications that are isolated to particular frequency bands. Thus, while filtering the data and examining moments may be informative in terms of developing intuition about the quantitative properties of dynamic equilibrium theories and to informally gauge their fit, it is generally not possible to recover structural disturbances by first filtering the data and then working with the resulting series.

Our approach is motivated by a very interesting paper by Cochrane (1994). Cochrane's identification strategy is to combine the logic of the permanent income hypothesis with the general equilibrium restriction that the consumption to output ratio is stationary. To see how this works, consider a period in which income increases relative to consumption. Given that consumption returns to a fixed fraction of income in the stationary state: output must be predicted to decline. Thus the consumption–income ratio should have predictive power for future output.[4] Cochrane's identification strategy is to impose the restriction that consumption does not respond contemporaneously to the innovation in the income equation while income responds to both the innovations. The resulting bivariate system in income and consumption growth contains error-correction terms in both equations. In a nutshell, consumption choices by forward-looking agents follow the evolution of the 'permanent income time path' thus providing a natural economic filter of income into permanent and transitory components.

3.1. Estimates

In our specification, we only include the error correction term, or consumption-income ratio, in the income equation and exclude it from the consumption equation, since such a restriction guarantees the Cholesky decomposition will provide an exact decomposition into permanent and transitory shocks (see Gonzalo and

[4] As Campbell (1987) showed, the permanent income hypothesis implies current saving should be negatively correlated with future income. Logarithmic version implies consumption income ratio is positively correlated with future income growth (Campbell and Deaton, 1989). In our theoretical economy this is only approximately true since output can deviation from consumption permanently as a result of incomplete financial markets.

Ng, 2001, for this point in detail). In addition, we include both constant and time trend in the error correction model. Unlike Cochrane's specification, OLS estimation is not efficient since a zero restriction is imposed in one of the equations in the system. Therefore, we employ restricted multivariate GLS method which is described in the Appendix:

$$\Delta c_t = \alpha_{c1} + \alpha_{c2}t + \beta_{c1}\Delta c_{t-1} + \beta_{c2}\Delta c_{t-2} + \beta_{c3}\Delta y_{t-1} + \beta_{c4}\Delta y_{t-2} + \varepsilon_t^c \quad (3.1)$$

$$\Delta y_t = \alpha_{y1} + \alpha_{y2}t + \gamma_y(c_{t-1} - y_{t-1}) + \beta_{y1}\Delta c_{t-1} + \beta_{y2}\Delta c_{t-2} + \beta_{y3}\Delta y_{t-1} + \beta_{y4}\Delta y_{t-2} + \varepsilon_t^y \quad (3.2)$$

where $c_t = 100 \times \ln C_t$ and $y_t = 100 \times \ln Y_t$. For the income Y_t and consumption C_t we use per capita GDP and total consumption from the IFS database. The countries is our sample are: Australia, Canada, France, Italy, Germany, Japan, the United Kingdom, and the United States.

Table 3 reports the estimation results. We see that in most cases income growth is more predictable than consumption growth but consumption growth is not as unpredictable in other countries as Cochrane found for the United States. The coefficient on the error correction term is of the expected sign in all cases (i.e. output growth falls when output rises above consumption to restore a stable consumption-output ratio), and the coefficients are statistically significant except for France and the United Kingdom.

3.2. Impulse responses

Figure 2 shows the impulse response of output and consumption for the United States, separately for each of the innovations in the bivariate system. The temporary shock gives a dynamic profile for consumption that is humped-shaped; much like the basic stochastic neoclassical model. In that model the profile is determined by a positive wealth effect and intertemporal substitution effects of an initially high, but falling real interest rate. Our econometric model has no way of separating out wealth and substitution effects, but it interesting that the response of consumption is qualitatively quite similar to that found in the basic neoclassical model (see, for example, King, Plosser and Rebelo (1988)). The output path is very similar to what one sees in the case of a temporary, but persistent innovation to productivity in the basic neoclassical model.

Theory predicts that a permanent shock to productivity moves output to a new higher steady-state. In the basic neoclassical model the new steady-state is typically approached monotonically from below, with consumption converging to income from below as rapid initial investment moves the capital stock up to its higher permanent level. Our estimated impulse response for the U.S. is also quite close to this prediction except that output overshoots its long-run level.

Impulse responses for the other countries show similarly dramatic long-run effects of the permanent shock, but consumption sometimes converges from above (i.e. consumption exceeds income along the transition to a new steady-state). Our main interest, however, is in the role of the permanent and transitory disturbances in accounting for output and consumption variability at various horizons. We turn, now, to this question.

3.3. Variance decompositions

Using the same orthogonalization assumption as Cochrane we can compute the impulse response to the Choleski transformations of the original error terms in the estimated equations. That is, we define new errors $\nu_t = R^{-1}\epsilon_t$ such that $E(\nu_t \nu_t') = I$ and R is the Choleski decomposition of the variance–covariance matrix of the innovations in the estimated equations: $RR' = E(\epsilon_t \epsilon_t') = \Sigma$. Thus the innovation in the original consumption equation ϵ_t^c impacts both consumption and income contemporaneously while the innovation from the income equation impacts only income contemporaneously.

Table 3, reports the results. The results for consumption at horizon 1 are determined by our identification strategy; namely, that our orthogonalization requires all of the variance of $\Delta c_t - E_{t-1}\Delta c_t$ be attributed to the permanent component and none to the temporary component. Thus only news about permanent shocks alter consumption on impact, temporary shocks have no effect. While not literally true of the permanent income theory, the algebra of wealth effects in infinite horizon models makes it reasonable approximation.

The fact that consumption growth at all horizons is largely unaffected by transitory disturbances is consistent with the view that consumption is close to a random walk. Thus at the horizon grows, the variance decomposition tells basically the same story.

More important from the perspective of the comovement puzzle is the decomposition of income between the transitory and permanent components. Recall that for asset market structure to matter in a way that alters overall business cycle correlation predictions we require: 1) a substantial part of the variance in output be attributable to permanent shocks; and 2) these shocks must not be too highly correlated across countries. The second pair of columns of Table 4 get at the first issue.

For the United States, which is the most studied country from the perspective of this question, the variance decomposition is about 50-50 in terms of permanent and temporary shocks and this is robust across horizons. Our results are consistent with Cochrane's, which is not too surprising given the similarity of our methodologies. In much of the existing econometric literature the permanent shock accounts for the bulk of output growth variability. We suspect that the difference is the use of consumption information in extracting the permanent component in income as opposed to studying the statistical properties of income alone, which characterizes many existing studies.

Germany and the U.K. seems similar to the U.S. experience, with the permanent shocks being somewhat more important in Germany. Given the dramatic shift due to reunification of east and west Germany this result may be sensitive to the sample period of study (something we hope to explore in future work). Australia, Canada, France and Italy seem to behave like small open economies in the sense that their growth paths are buffeted by very substantial transitory shocks (accounting for more than two-thirds of output growth variability). It could also be that this variation is a reflection of the greater difficulty small open economies have in responding to shocks than their larger counterparts. Japan is a dramatic outlier in that almost all of output growth variation is attributed to the permanent shock. Readers familiar with the time path of Japanese output over the post-World War II period may not find this surprising; Japan seems recession proof, but has experience long secular swings in its growth path.

3.4. International comovement

Thus far we have been discussing our results for each country as if they were closed economies. Our empirical methodology lends itself to that interpretation since it does not explicitly capture international interdependencies (i.e. we have no foreign variables in the consumption or output equations). However, we view the procedure as very useful in addressing the comovement issue in the following sense.

The power of the logic of the permanent income hypothesis is that consumption movements will help us to identify news about permanent or transitory income changes. In practice some of these changes may be driven by foreign shocks and policy responses to them. What we will do in this section is examine the correlation structure of the innovations that we identify from our bivariate models. If income is expected to commove positively for a sustained period in the future we would expect the permanent innovations that we identify to be positively correlated. Table 4 gets at this issue by examining the international correlation patterns of the residuals from the estimated equations, ϵ_t^c and ϵ_t^y, and their orthogonalized counterparts. Focusing on the transformed innovations (ν, which were used in the impulse responses and variance decompositions), Table 4 reports the correlation matrix of "news" relevant for the permanent and transitory components that we estimate.

The first thing to note about these correlations is that they tend to be close to zero as opposed to large positive or large negative values. Thus, to the extent that permanent and transitory income components are strongly correlated in a particular way, consumers are apparently receiving noisy signals or not ready the signals clearly. Second, there are more positive correlations than negative correlations, particularly for the transitory shock. This is consistent with positive international business cycle comovement. The fact that more of the negative correlations are found in the permanent component is important for the consumption correlation issue, since permanent shocks should affect consumption growth much more than transitory shocks. Canada and the U.S. have particularly strong positive correlations of both types of news: the correlation of transitory innovations is0.38, while that for permanent innovation is 0.31.

While the correlation matrix of shocks is a useful starting point for examining the comovement question, it may obscure the fact the common shocks are shared by multiple countries. For this purpose we utilize principal components. Table 5 reports the fraction of the variance of each shock accounted for by the first three principal components and the remaining 5 (8 principal components will complete exhaust the variation since there are 8 time series for each type of shock).

The most important principal component for the permanent shocks to these 8 countries (the first principal component) accounts for a disproportionate share of the variance in Canada and the United States. The second principal component is largely related to permanent shocks in Australia and Germany and the third to France and the United Kingdom. Thus there appear to be important common permanent shocks shared by some countries in the group of six, excluding Japan and Italy.

Turning to the transitory shocks we see a significant difference in that four countries (Australia, Canada, United Kingdom and the United States) now have a substantial fraction of variation in common. The second component is very important for France and Italy, while Japan and the United Kingdom share the third. The only country with less than 30% of the variance in the transitory shock accounted for by the 3 largest principal components is Germany. It is likely that this is due to the reunification process in which Germany experience a unique and dramatic business-cycle-type episode.

4. International comovement revisited

The goal of this section is to revisit the international comovement issue in view of the analysis of permanent and transitory shocks identified in the last section. Our strategy here will be to assume that the shocks we identify are productivity shocks and feed them into the Baxter-Crucini model (extended to 8 countries of different size). We will then compute the correlation of output and consumption that results and compare this to the data. How will then compare these predictions to the data formally. Success or failure of the model to match the correlations, however, will depend on two factors. One is, obviously, how useful the model is in describing the real world. The other, more subtle issue, is that the shocks we identify using our empirical model may not be shocks in the strict sense or may not correspond closely to productivity movements. We will therefore undertake an analysis of how well our strategy recovers the productivity shocks we feed into the model by estimating our empirical model using the simulated values for consumption and output.

5. Conclusions

TBA

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Table 1 - Theory and evidence: Baseline case

Panel A: Predictions of Baxter-Crucini incomplete markets IRBC model			
Preferences	Productivity processes	corr(c,c^{us})	corr(y,y^{us})
$U(C_t, N_t) = \frac{1}{1-\sigma}[C_t^{\theta} L_t^{1-\theta}]$	random walk	-0.28	0.54
$U(C_t, N_t) = \frac{1}{1-\sigma}[C_t^{\theta} L_t^{1-\theta}]^{1-\sigma}$	trend stationary	0.92	0.06
$U(C_t, N_t) = \frac{1}{1-\sigma}[C_t - \frac{N_t^{\omega}}{\omega}]^{1-\sigma}$	random walk	-0.97	-0.73
$U(C_t, N_t) = \frac{1}{1-\sigma}[C_t - \frac{N_t^{\omega}}{\omega}]^{1-\sigma}$	trend stationary	0.96	0.36

Panel B: Data			
Country	Sample period	corr(c,c^{us})	corr(y,y^{us})
Averages		0.42	0.22
Australia	1970:1 to 1998:4	0.05	0.47
Canada	1970:1 to 1998:4	0.78	0.63
France	1970:1 to 1998:4	0.49	-0.03
Germany	1970:1 to 1998:4	0.08	-0.04
Italy	1970:1 to 1998:4	0.34	0.22
Japan	1970:1 to 1998:4	0.10	0.11
United Kingdom	1970:1 to 1998:4	0.66	0.59

Notes: Statistics are based on Hodrick–Prescott–filtered quarterly data with smoothing parameter 1200. Variables are y, real per capita gross national production; c, real per capita consumption. Source: International Financial Statistics.The parameterization of the Cobb–Douglas preferences is as in Baxter and Crucini (1993, 1995) with $\sigma = 2$ and θ determined by the requirement that hours worked divided by total time available equal 0.20. The preferences in the second panel use the same σ value and ω is set to equal 1.455 as in Mendoza (1991). The random walk and trend stationary specifications are as in Baxter–Crucini (1995). The random walk specification has productivity in each country following a random walk with innovations that have a cross-country correlation 0.258 and unit variance while the trend stationary specification has productivity following an AR(1) process with coefficient 0.9, also with the cross-country correlations of the innovations set at 0.258 and a unit innovation variance.

Table 2 - Bivariate Cointegrated VAR Estimates

Country		const.	trend	$c_{t-1} - y_{t-1}$	Δc_{t-1}	Δc_{t-2}	Δy_{t-1}	Δy_{t-2}
Australia								
	Δc_t	0.71*	0.00	0.00	-0.61*	-0.29*	0.08	0.00
		(2.60)	(1.17)	(—)	(7.24)	(3.49)	(0.76)	(0.03)
	Δy_t	6.67*	0.00	0.11*	-0.15*	-0.06	0.02	0.03
		(3.45)	(0.07)	(3.18)	(2.09)	(0.90)	(0.23)	(0.36)
Canada								
	Δc_t	0.63*	0.00	0.00	-0.09	0.07	0.24*	-0.19
		(3.39)	(1.05)	(—)	(1.04)	(0.83)	(2.36)	(1.95)
	Δy_t	2.72*	0.00	0.04*	-0.04	0.11	0.28*	0.00
		(3.18)	(0.92)	(2.48)	(0.45)	(1.47)	(3.12)	(0.01)
France								
	Δc_t	0.91*	-0.01*	0.00	-0.02	-0.08	0.05	0.14
		(2.58)	(2.12)	(—)	(0.24)	(0.82)	(0.22)	(0.64)
	Δy_t	1.06	0.00	0.01	0.02	-0.02	0.19	0.25*
		(0.94)	(1.15)	(0.56)	(0.47)	(0.35)	(1.87)	(2.45)
Germany								
	Δc_t	0.58	0.00	0.00	-0.11	-0.06	0.20	0.28*
		(1.78)	(0.84)	(—)	(0.94)	(0.47)	(1.57)	(2.20)
	Δy_t	6.77*	0.00	0.11*	0.11	0.16	-0.02	0.04
		(2.53)	(1.50)	(2.31)	(1.00)	(1.43)	(0.16)	(0.34)

Notes: The regressions are of the form:

$$\begin{aligned}\Delta c_t &= \alpha_{c1} + \alpha_{c2} t + \beta_{c1}\Delta c_{t-1} + \beta_{c2}\Delta c_{t-2} + \beta_{c3}\Delta y_{t-1} + \beta_{c4}\Delta y_{t-2} + \varepsilon_t^c \\ \Delta y_t &= \alpha_{y1} + \alpha_{y2} t + \gamma_y (c_{t-1} - y_{t-1}) \\ &\quad + \beta_{y1}\Delta c_{t-1} + \beta_{y2}\Delta c_{t-2} + \beta_{y3}\Delta y_{t-1} + \beta_{y4}\Delta y_{t-2} + \varepsilon_t^y\end{aligned}$$

where where $c_t = 100 \times \ln C_t$ and $y_t = 100 \times \ln Y_t$. Restricted multivariate gerenalized least squares estimates.

Table 2 (continued) - Bivariate Cointegrated VAR Estimates

Country		const.	trend	$c_{t-1} - y_{t-1}$	Δc_{t-1}	Δc_{t-2}	Δy_{t-1}	Δy_{t-2}
Italy								
	Δc_t	0.34	0.00	0.00	0.17	0.03	0.16	0.10
		(1.44)	(0.38)	(—)	(1.74)	(0.35)	(1.20)	(0.71)
	Δy_t	3.69*	0.00	0.07*	-0.01	0.06	0.40*	0.06
		(2.31)	(0.94)	(2.10)	(0.17)	(0.89)	(4.05)	(0.62)
Japan								
	Δc_t	4.42*	-0.03*	0.00	-0.34	0.01	-0.18	-0.49
		(3.48)	(2.14)	(—)	(0.63)	(0.02)	(0.33)	(0.91)
	Δy_t	8.13*	-0.03*	0.06*	-0.32	-0.06	-0.19	-0.41
		(3.95)	(2.14)	(2.20)	(0.59)	(0.11)	(0.35)	(0.77)
United Kingdom								
	Δc_t	0.34	0.00	0.00	-0.14	-0.03	0.03	0.12
		(1.58)	(1.19)	(—)	(1.39)	(0.26)	(0.30)	(1.01)
	Δy_t	1.91*	0.00	0.03	0.18*	0.17*	-0.18	-0.07
		(2.24)	(0.91)	(1.63)	(2.27)	(2.06)	(1.76)	(0.74)
United States								
	Δc_t	0.45*	0.00	0.00	0.00	0.07	0.16	0.08
		(3.61)	(0.16)	(—)	(0.03)	(0.72)	(1.85)	(1.02)
	Δy_t	5.34*	-0.01*	0.10*	0.37*	0.17	0.04	0.07
		(3.24)	(3.37)	(3.06)	(3.06)	(1.39)	(0.42)	(0.78)

Table 3 - Consumption and Income Variance Decompositions

Variance of:		Δc_t		Δy_t	
		Accounted for by:		Accounted for by:	
		Permanent shocks	Transitory shocks	Permanent shocks	Transitory shocks
Country	Horizon				
Australia	1	100.0	0.0	21.3	78.7
	4	99.6	0.4	22.0	78.0
	∞	99.6	0.4	21.7	78.3
Canada	1	100.0	0.0	28.6	71.4
	4	95.8	4.2	31.2	68.8
	∞	95.7	4.3	30.5	69.5
France	1	100.0	0.0	14.9	85.1
	4	99.6	0.4	16.6	83.4
	∞	99.5	0.5	18.5	81.5
Germany	1	100.0	0.0	60.9	39.1
	4	96.8	3.2	63.2	36.8
	∞	96.7	3.3	62.9	37.1
Italy	1	100.0	0.0	7.1	92.9
	4	97.2	2.8	16.6	83.4
	∞	96.8	3.2	24.0	76.0
Japan	1	100.0	0.0	97.9	2.1
	4	99.6	0.4	98.2	1.8
	∞	99.6	0.4	98.1	1.9
United	1	100.0	0.0	42.3	57.7
Kingdom	4	99.4	0.6	43.1	56.9
	∞	99.4	0.6	43.0	57.0
United	1	100.0	0.0	42.5	57.5
States	4	97.8	2.2	52.2	47.8
	∞	97.6	2.4	51.5	48.5

Notes: Forecast error variance decomposition based on the bivariate cointegrated VAR model.

Table 4 - International Correlation of Shocks

Contemporaneous correlation of:

Permanent shocks

	Aus	Can	Fra	Ger	Ita	Jpn	UK	US
Australia (Aus)	1.00	—	—	—	—	—	—	—
Canada (Can)	0.01	1.00	—	—	—	—	—	—
France (Fra)	-0.03	-0.08	1.00	—	—	—	—	—
Germany (Ger)	0.22	-0.08	0.00	1.00	—	—	—	—
Italy (Ita)	-0.12	0.18	0.00	0.01	1.00	—	—	—
Japan (Jpn)	0.15	0.02	0.03	0.03	0.02	1.00	—	—
United Kingdom (UK)	-0.07	0.07	0.12	0.05	-0.01	-0.08	1.00	—
United States (US)	0.13	0.31	0.09	0.02	0.09	-0.17	0.12	1.00

Temporary shocks

	Aus	Can	Fra	Ger	Ita	Jpn	UK	US
Australia (Aus)	1.00	—	—	—	—	—	—	—
Canada (Can)	0.24	1.00	—	—	—	—	—	—
France (Fra)	0.08	0.06	1.00	—	—	—	—	—
Germany (Ger)	0.21	0.06	0.16	1.00	—	—	—	—
Italy (Ita)	0.00	-0.07	0.33	0.18	1.00	—	—	—
Japan (Jpn)	-0.08	0.05	0.05	0.09	0.08	1.00	—	—
United Kingdom (UK)	0.16	0.15	0.19	0.07	-0.04	-0.11	1.00	—
United States (US)	0.10	0.38	0.03	-0.06	-0.13	0.07	0.03	1.00

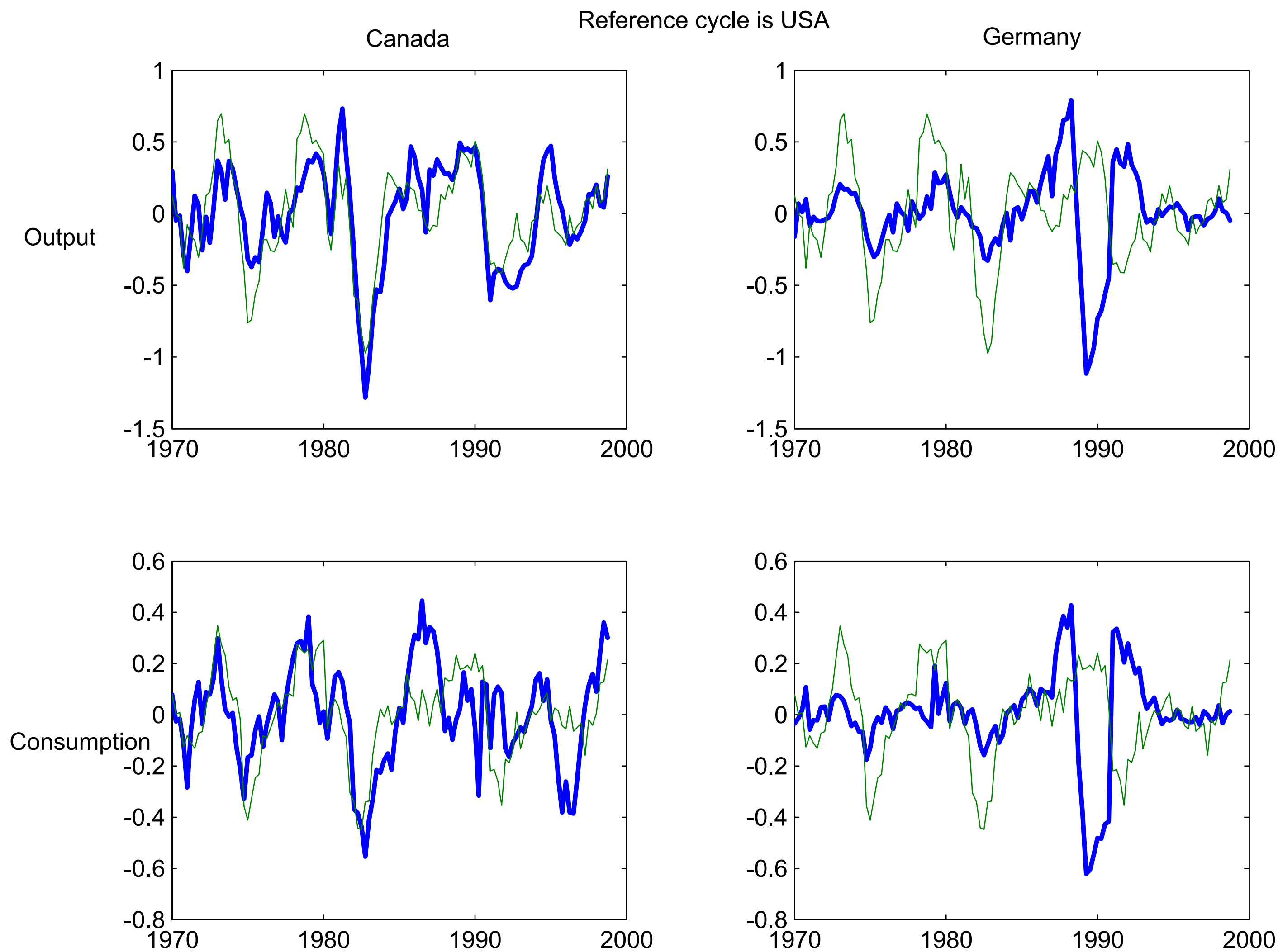
Table 5 - Principal Component Analysis of Shocks

Variance of permanent shocks

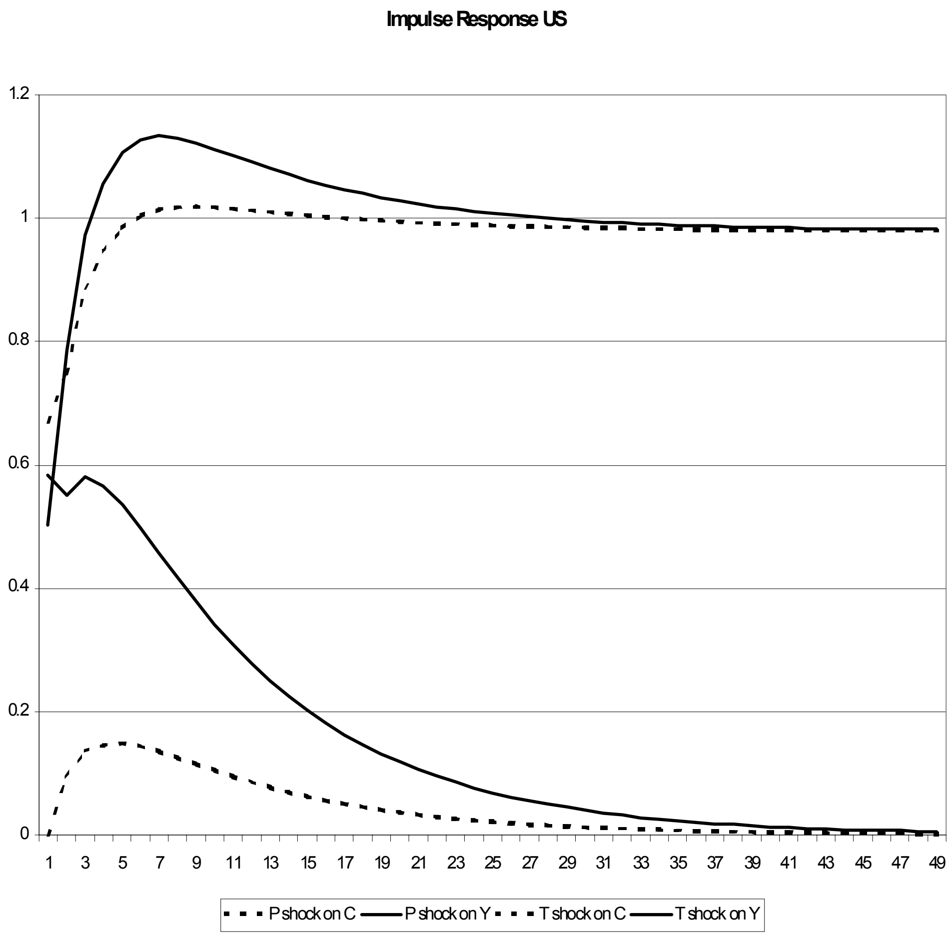
Country	Accounted for by: 1st principal component	2nd principal component	3rd principal component	Others
Australia	5.0	59.8	5.0	30.2
Canada	40.3	5.8	13.7	40.3
France	2.3	0.1	40.8	56.8
Germany	1.8	51.3	3.4	43.5
Italy	9.7	9.4	5.0	76.0
Japan	1.4	2.4	1.1	95.1
United Kingdom	13.9	1.3	45.6	39.3
United States	69.1	0.0	0.2	30.6

Variance of transitory shocks

Country	Accounted for by: 1st principal component	2nd principal component	3rd principal component	Others
Australia	27.9	0.4	3.7	68.0
Canada	52.7	7.2	4.6	35.5
France	14.6	45.9	1.8	37.8
Germany	5.0	15.0	0.2	79.9
Italy	0.0	58.4	10.9	30.7
Japan	0.0	0.5	30.4	69.0
United Kingdom	29.3	2.9	43.3	24.4
United States	33.7	18.8	18.6	28.9



Reference cycle is USA
Canada
Germany
Output
Consumption
1
0.5
0
-0.5
-1
-1.5
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1970
1980
1990
2000



Impulse Response US
1.2
1
0.8
0.6
0.4
0.2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
P shock on C
P shock on Y
T shock on C
T shock on Y

Figure 5.1: