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Trends and Cycles in Small Open Economies: Making The Case For A General Equilibrium Approach*

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Abstract

Economic research into the causes of business cycles in small open economies is almost always undertaken using a partial equilibrium model. This approach is characterized by two key assumptions. The first is that the world interest rate is unaffected by economic developments in the small open economy, an exogeneity assumption. The second assumption is that this exogenous interest rate combined with domestic productivity is sufficient to describe equilibrium choices. We demonstrate the failure of the second assumption by contrasting general and partial equilibrium approaches to the study of a cross-section of small open economies. In doing so, we provide a method for modeling small open economies in general equilibrium that is no more technically demanding than the small open economy approach while preserving much of the value of the general equilibrium approach.

JEL codes: C55, C68, F41, F44

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1 Introduction

The veracity of business cycles differs dramatically across countries. Figure 1 presents a comprehensive view: it displays the standard deviation of annual output and consumption growth rates computed over the period 1971 to 2011 for 66 countries (countries are ranked from the most to least volatile).[1] The standard deviation of output growth ranges from an astounding 24.3% in Iraq (not shown) to a mere 1.58% in Australia; the median country is Luxembourg (3.53%). An important goal of quantitative business cycle theory is to explain these differences.

In this respect, the work-horse small open economy model has considerable appeal because it is possible to treat the world interest rate as given (i.e. determined in the rest-of-the-world), an exogeneity assumption and conduct a partial equilibrium analysis. Aguiar and Gopinath (2007) is a recent leading example of this approach. They argue persuasively that much of the cross-country heterogeneity in the veracity of business cycles is accounted for by differences in the relative importance of permanent and transitory shocks to total factor productivity. The logic is simple. A permanent shock leads to larger jump in consumption than a persistent, but transitory, shock because it entails a larger wealth effect. Output, to a reasonable first-approximation, follows the path of productivity and therefore inherits the volatility and persistence properties of the shock itself. Altering the relative importance of the two shocks therefore allows one to match the standard deviation of output and consumption patterns displayed in Figure 1. Applying this method to 13 emerging and 13 developed economies, Aguiar and Gopinath find that the permanent component accounts for 84% of productivity growth for emerging markets compared to 61% for developed countries.[2]

The use of a partial equilibrium model comes at a cost however, as it fails to capture any meaningful economic interactions across nations. The most obvious is the international correlation of business cycles. To fill this gap, we revisit the study of AG, using the two-country general equilibrium model developed by Baxter and Crucini (1995). The BC model

[1] The PWT 8.1 starts from 1951 and ends in 2011. The starting year of 1971 allows for a comprehensive and balanced cross-country panel.

[2] Note, they do not report a variance decomposition of output growth in their paper, though productivity and output tend to move closely in neoclassical models of the business cycle.

is a natural choice because it shares virtually all features of preferences, technology and the asset market structure of AG, while closing the model by imposing world market clearing in the goods market and the market for one-period non-contingent bonds.

In our simulations, the 'home' country is parameterized to mimic the business cycle of an aggregate of (listed in descending economic size) the United States, Japan, the United Kingdom, Germany, Italy, France, Canada and Australia (hereafter the G-8). This massive economic block effectively determines the world interest rate (marginal product of capital). The 'foreign' country is one of the 58 economies in our panel dataset. Individual countries are rotated through in separate model simulations to produce the entire cross-section of business cycle implications that are consistent with the domestic and foreign business cycle facts.

Total factor productivity in the G-8 is the sum of a pure random walk component and a transitory but persistent component. Matching the standard deviation of: i) consumption growth, ii) income growth and iii) the consumption-GDP ratio for the G-8 block yields an estimated standard deviation of 0.9% (1.2%) for the innovation to the permanent (transitory) component. The persistence of the transitory component is 0.9. The implication of these estimates is that the transitory component contributes 58% to the standard deviation of TFP growth, compared to 42% for the stationary component. These estimates are broadly consistent with the less structural approach of Crucini and Shintani (2015); they estimate a bivariate error-correction model of output and consumption growth for each country of the G-8 and find comparable contributions of stochastic trend and cycle shocks to output growth.

For each country outside of the G-8, we match the standard deviation of output growth, the standard deviation of consumption and the correlation of output and consumption growth of each country with the output and consumption growth of the G-8 block. To accomplish this – in addition to an idiosyncratic permanent and transitory shock to productivity in each country – we allow for a spillover from the G-8 permanent and transitory shock. The productivity spillovers from the G-8 is the point of departure from the partial equilibrium approach and allows us to match international business cycle comovement of consumption and output.[3]

On average (across countries), the permanent shocks account for 45% of output growth in developing countries compared to 51% in developed countries. These results contrast sharply with AG who attribute 84% of productivity growth to permanent shocks for emerging markets compared to 61% for developed countries. While there are a number of differences in terms of the sample of countries and sample period, the main driver of the difference is our general equilibrium approach and the additional empirical discipline of matching international business cycle comovement. We demonstrate this in two ways.

First, we use a small open economy model to match national business cycle moments (excluding international comovement) in our cross-section and find the permanent shocks must account for twice as much of output growth for developing countries compared to developed countries, which is even more skewed in the direction of AG's earlier findings. This demonstrates that our results using the same modeling approach as AG also imply a dominant role for permanent shocks in developing countries. The even larger roll of the permanent shock may be a consequence of the Great Recession.

Second, shocks to the exogenous interest rate play a non-trivial role, accounting for about 25% of output growth variation in the average country (both developing and developed). Since the real interest rate is stationary in the model, it is impossible to determine the role of permanent and transitory shocks in accounting for real interest rate fluctuations without a general equilibrium model. To demonstrate the identification issue, when we incorporate the international spillovers of productivity estimated from the general equilibrium model, the real interest rate plays almost no role in the small open economy version despite the fact that the small open economy with spillovers of productivity produces virtually the same variance decomposition as the general equilibrium model with spillovers.

The lessons here are stark. The logical contradiction of the small open economy approach is that any comovement of business cycles through productivity transmission (or endogenous

[3] Consistent with the partial equilibrium approach, there are no productivity spillovers from the small countries to the large countries: a block-exogeneity assumption.

propagation) must be attributed to domestic productivity or the "world" interest rate. Any yet, the world interest rate is not determined by the business cycle of the small open economy leading to a fundamental issue of identification and mis-specification of the variance decomposition.

2 The one-sector stochastic growth model

Our use of the basic one-sector, two-country stochastic growth model is motivated by two objectives. The first is to stay as close as possible to the model specification utilized by AG. The second is to ensure that the general equilibrium and partial equilibrium versions of the model are structurally compatible. Three sources of novelty are introduced into these otherwise standard models. First, careful attention is given to international productivity spillovers from the large G-8 block to each individual nation. Second, the cross-section of countries is comprehensive. Third, general equilibrium and partial equilibrium models are explicitly compared. The general equilibrium model is the one-sector, two country, DSGE model developed by Baxter and Crucini (1995). The partial equilibrium version of this model omits the world goods market clearing condition and adds a stochastic process to capture the evolution of the world interest rate.[4] This section begins by quickly reviewing common features of these two versions of the one-sector model and concludes with a discussion of the differences.

2.1 Preferences and technology

Individuals in each country have Cobb-Douglas preferences over consumption and leisure

$$U(C_{jt}, L_{jt}) = \beta^t \frac{1}{1-\sigma}[C_{jt}^{\theta} L_{jt}^{1-\theta}]^{1-\sigma}, \quad (1)$$

where parameter $\theta \in (0,1)$, and the inter-temporal elasticity of substitution is $1/\sigma$.

[4] AG incorporate a domestic interest rate response to home debt relative to productivity, but this plays a minor quantitative role in their exercise.

The final good is produced using capital and labor. The production function is Cobb-Douglas and each country experiences stochastic fluctuations in the level of factor productivity, A_{jt},

$$Y_{jt} = A_{jt} K_{jt}^{1-\alpha} {N_{jt}}^{\alpha} \ . \tag{2}$$

The stochastic processes for productivity will involve both permanent and transitory components each potentially with a component common G-8 (world) component and an idiosyncratic or nation-specific component. These stochastic processes are described in more detail below.

The capital stock in each country, depreciates at the rate δ and is costly to adjust:

$$K_{jt+1} = (1 - \delta) K_{jt} + \phi(I_{jt}/K_{jt}) K_{jt}, \tag{3}$$

where $\phi(\cdot)$ is the adjustment cost function. As in Baxter and Crucini (1995), adjustment costs have the following properties: i) at the steady-state, $\phi(I/K) = I/K$ and $\phi'(I/K) = 1$ so that in the deterministic solution to the model the steady state with and without adjustment costs are the same and ii) $\phi' > 0$, $\phi'' < 0$.

2.2 Closing the model

Following Baxter and Crucini (1995), the two country general equilibrium model is closed by imposing one intertemporal budget constraint and world goods market clearing. The intertemporal budget constraint is:

$$P_t^B B_{jt+1} - B_{jt} = Y_{jt} - C_{jt} - I_{jt} \tag{4}$$

where B_{jt+1} denotes the quantity of bonds purchased in period t by country j. P_t^B is the price of a bond purchased in period t and maturing in period $t+1$. The bond is not state-contingent, it pays one physical unit of consumption in all states of the world. Implicitly this defines, r_t, the real rate of return for the bond (i.e., $P_t^B \equiv (1 + r_t)^{-1} < 1$). The price of this bond is endogenous in the two-country equilibrium model, determined by the market-clearing condition in the world bond market.

The world goods market clearing condition is:

$$\pi_0(Y_{0t} - C_{0t} - I_{0t}) + \pi_j(Y_{jt} - C_{jt} - I_{jt}) = 0, \tag{5}$$

where π_j denotes the fraction of world GDP produced by country j. These weights are necessary to define market clearing because the quantities in the constraint are in domestic per capita terms.

The small open economy is closed with an inter-temporal budget constraint identical to (4). However, the discount rate follows an exogenous stochastic process describe below. In addition, the following boundary condition is imposed:

$$\lim_{t \to \infty} \beta^t p_{jt} B_{jt+1} = 0,$$

where p_{jt} is the multiplier on the inter-temporal budget constraint of the representative agent in country j.

Parameterization of tastes and technology are set to values commonly used in the literature. The value of β is set to be 0.954, so that the annual real interest rate is 6.5%. The parameter of relative risk aversion σ is 2 and labor's share α in the production function is 0.58. In the Cobb-Douglas preference function, $\theta = 0.233$. The depreciation rate of capital, δ, is assigned a value of 0.10. The elasticity of the investment-capital ratio with respect to Tobin's Q is $\eta = -(\phi'/\phi'') \div (i/k) = 15$.

2.3 Exogenous shocks

Moving from theory to quantitative implications requires estimation of the stochastic process for productivity in each country. Partial equilibrium models require specification of stochastic processes for home country productivity and the domestic interest rate. General equilibrium models require the estimation of stochastic processes for both home and foreign productivity since the interest rate is endogenous. Our specification and estimation method for each of these stochastic processes is discussed in turn below.

2.3.1 Total factor productivity

Beginning with the G-8 aggregate, indexed by 0, the logarithm of productivity is the sum of a non-stationary and a stationary component, $\ln A_{0t} = \ln A^P_{0t} + \ln A^T_{0t}$. The non-stationary component follows a pure random walk,

$$\ln A^P_{0t} = \ln A^P_{0t-1} + \ln \varepsilon^P_{0t} \ , \tag{6}$$

and the stationary component follows an AR(1) process:

$$\ln A^T_{0t} = \rho_0 \ln A^T_{0t-1} + \ln \varepsilon^T_{0t} \ . \tag{7}$$

The innovations are drawn from independent normal distributions with different standard deviations: $\varepsilon^T_{0t} \sim N(0, \sigma^T_0)$, $\varepsilon^P_{0t} \sim N(0, \sigma^P_0)$.

As the G-8 is by far the largest region and we assume that productivity spillovers are from the G-8 to each nation of the G-60 and not the reverse. Simulations of the closed economy version of the benchmark model are used to estimate the parameters of the productivity components of the G-8 (effectively this involves setting $\pi = 1$ in the general equilibrium model described earlier). Inputs into the estimation are G-8 aggregates, constructed as country-size-weighted averages of output growth, consumption growth and the logarithm of the consumption-output ratio.

Productivity parameters are chosen to match the observed sample variances of these three key macroeconomic variables. The outcome of the moment-matching exercise is reported in Table 1. The average difference (across countries) between the moments from the data and from the model simulation, reported in the upper panel of the table, is less than 10% in all cases. The estimated persistence of the stationary component of productivity is 0.90, which, when converted to a quarterly estimate matches closely the existing closed economy real business cycle literature that focuses exclusively on persistent, but transitory shocks and output fluctuations at business cycle frequencies. It is interesting that the innovations to the permanent and transitory components are of the same order of magnitude, with standard deviations of 0.9 and 1.2, respectively. When combined with the estimated persistence of the stationary component, the implication is that the unconditional variance of the transitory shock adds about 16% *more* to the variance of productivity growth than the permanent shock.

The specification of total factor productivity of the small open economies (nations outside of the G-8 block) is more novel. We have a no–spillover case and a spillover case. In the no-spillover case, the structure is analogous to the G-8 specification:

$$\ln A_{jt} = \ln A_{jt}^P + \ln A_{jt}^T \ .$$

The permanent component of TFP in country j is,

$$\ln A_{jt}^P = \ln A_{jt-1}^P + \ln \varepsilon_{jt}^P \ , \tag{8}$$

and the stationary component is an AR(1) process :

$$\ln A_{jt}^T = \rho_j \ln A_{jt-1}^T + \ln \varepsilon_{jt}^T \ . \tag{9}$$

As was the case of innovations to the components of TFP of the G-8, ε_{jt}^P, ε_{jt}^T, are *i.i.d.* draws from normal distributions both with mean zero, but different standard deviations. For expositional convenience, the distributions are expressed as: $\varepsilon_{jt}^T \sim N(0, v_j^T \sigma_0^T)$, $\varepsilon_{jt}^P \sim N(0, v_j^P \sigma_0^P)$. Thus, v_j^P and v_j^T, are the standard deviations of the innovations to the permanent and temporary components of productivity in country j *relative* to their counterparts in the G-8, estimated earlier. For purposes of parsimony and tractability, the persistence of the transitory component of TFP in all countries is set equal to its G-8 counterpart: $\rho_j = \widehat{\rho}_0 = 0.90 \ \forall j$.[5]

[5]While this choice of persistence for the stationary component is based on maintaining some aspects of

The second specification of total factor productivity is the correctly specified one in the sense that it is estimated by simulating the two country general equilibrium model. Specifically, with the G-8 productivity processes estimated from the closed economy general equilibrium model, the stochastic process for TFP in the small open economy in the two-country general equilibrium model is specified as: $\ln A_{jt} = \ln A_{jt}^P + \ln A_{jt}^T + \omega_j^P \ln A_{0t}^P + \omega_j^T \ln A_{0t}^T$. The parameters ω_j^P and ω_j^T are factor loadings capturing non-stationary and stationary productivity spillovers from the G-8 to country j. These spillovers are necessary to match international business cycle comovement patterns across the G-8 and individual small open economies in our panel data.

Thus, the correct structural model is taken to be the two-country general equilibrium model with a block-recursive bivariate model for TFP of country j and the G-8 ($j = 0$):

$$\begin{bmatrix} \ln A_{jt} \\ \ln A_{0t} \end{bmatrix} = \begin{bmatrix} 1 & 1 & \omega_j^P & \omega_j^T \\ 0 & 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} \ln A_{jt}^P \\ \ln A_{jt}^T \\ \ln A_{0t}^P \\ \ln A_{0t}^T \end{bmatrix}.$$

As a matter of accounting, the true productivity process of the small open economy is the sum of four terms, the first two terms are permanent and temporary components coming from domestic productivity and the second two terms are permanent and temporary productivity spillovers from the G-8.

Naturally, the response of an open economy to a permanent or temporary productivity shock will depend on whether the shock is of home or foreign origin. As we shall see, the spillovers are necessary to match the international correlation of business cycles, which are absent from the set of moments available using the partial equilibrium approach. This is what distinguishes general equilibrium analysis from partial equilibrium analysis of interna-

tractability and symmetry across countries, it turns out this is equivalent to a quarterly persistence of 0.96 and thus consistent with the findings of Aguiar and Gopinath (2007). They estimated persistence of their transitory component of productivity at the quarterly frequency of 0.97 for Canada and 0.95 for Mexico, respectively. Moreover, they find this value is close to what the persistence of transitory component of productivity equals for a number of other developed countries.

tional business cycles.

To estimate the nation-specific factor loadings on G-8 productivity components, ω_j^P and ω_j^T, and the *relative* standard deviations of nation-specific productivity innovations, v_j^T and v_j^P, the general equilibrium open economy model is used. Specifically, in each simulation, the G-8 takes the role of the home economy and nation j (a nation outside the G-8) takes the role of the foreign economy in the model. The relative size of the small country is set to the fraction of world GDP that country produces, on average, over the sample period of observation. The model is simulated for a range of values for the innovation variance of the permanent and transitory shock to the small country relative to the G-8 value (keeping the G-8 processes as previously estimated) to match: i) the variance of GDP growth of country j; ii) the variance of consumption growth of country j; iii) the correlation of GDP growth between the G-8 and country j. and iv) the correlation of consumption growth between the G-8 and country j.

The heterogeneity of business cycles across developing and developed countries is stark (see Table 2). The standard deviation of output growth is almost twice as high in developing countries compared to developed countries, 4.93 versus 2.60. Notice also that the standard deviation of consumption is higher than that of output in developing countries (5.93 versus 4.93) while it is lower in developed countries (2.12 versus 2.60). Recall that the permanent income reasoning of AG plays a key role in their attributing a dominant role for permanent shocks in developing countries to match this ranking. The additional moments to be matched in the general equilibrium model are the international comovement of consumption growth and output growth. These correlations are also quite distinct across the two groups with strong positive comovement of income growth (0.62) between the median developed economy and the G-8 and positive, but lower consumption growth correlations (0.47). In contrast, the median developing country has a near zero correlation with the G-8 business cycle by either measure (output or consumption growth).[6]

[6] Backus, Kehoe and Kydland (1992) coined the phrase '*international comovement puzzle*' in recognition that models featuring complete financial markets predict consumption growth correlations be near unity, bounding the output correlation from above. There work focused on developed nations within the G-8 block. The puzzle is preserved in the developed nations sample and the puzzle worsens dramatically when the sample is extended to developing countries.

The stochastic processes for productivity, by allowing for both idiosyncratic and common components to permanent and transitory movements in national productivity is able to capture both the standard deviation patterns of income and consumption growth in each nation as well as the correlation of business cycles between each nation and the G-8 block. It is not surprising, for example, that the standard deviation of productivity innovations are estimated to be much higher in developing countries. Less obvious and more interesting is a comparison of the two components that determine country-specific component of national productivity: the innovations to the permanent component to productivity has a standard deviation three times that of the G-8 (3.13) and that stationary component has a standard deviation of twice that of the G-8 (1.98). In contrast, the country specific components of national productivity are relatively smooth for the developed countries: the permanent component has a standard deviation of innovations 0.61 times that of the G-8 and the stationary component is 0.78 times that of the G-8.

Turning to the factor loadings linking national productivity to the G-8 productivity levels, the spillover from G-8 productivity shocks to productivity level in the developed world is positive for both permanent and transitory shocks, but the permanent shock has a factor loading of 1.83, almost three times that of the transitory component (0.67). The factor loadings for developing countries are both smaller and the loading on the permanent G-8 shock is actually negative. This pattern of spillovers are required to match the low correlation of output growth (0.09) and negative correlation of consumption growth (-0.08) between the G-8 and developing countries. This is where the general equilibrium incomplete markets model is particularly useful. Essentially, what matters for consumption comovement is the correlation of wealth in each country with that of the G-8 block. The negative factor loading on the permanent G-8 shock for developing countries shifts output and particularly consumption comovement toward zero for that group of nations.

2.3.2 Interest rate shocks

In the SOE model, domestic productivity shocks play a central role as they should, just as is the case in the general equilibrium model. However, unlike the general equilibrium model, foreign productivity shocks are not explicitly included in the set of exogenous shocks faced by small open economies and interest rate shocks are intended to summarize the relevant international business cycle spillovers. As there has not been any systematic research into the ability of interest rate disturbances to capture the response of a small open economy to anything other than an an unexpected change in the interest rate itself, it seems essential to elucidate the issue.

To explore the implications of exogenously specified interest rates we assume as Mendoza (1991) did that the discount rate follows an AR(1) process:

$$\ln P_{jt}^{B} = \gamma_j \ln P_{jt}^{B} + \ln \varepsilon_{jt}^{B}, \tag{10}$$

where $0 < \gamma_j < 1$ denotes the persistence of the logarithm of the bond price, and ε_{jt}^{B} is an *iid* draw from a normal distribution with zero mean and standard deviation σ_j^{PB}.[7]

From a general equilibrium perspective, the bond price is redundant as it is determined almost entirely by G-8 productivity when the model is closed. When added as a separate forcing process in the small open economy model along with the productivity processes, some of the variance of output and consumption that should be attributable to domestic or foreign productivity is incorrectly attributed to the real interest rate. Turning to the results, Table 3 reports the persistence and innovation variance of the bond price for the two groups of countries for two parameterizations. The column labeled "Yes" is the case in which G-8 productivity spillovers are included and the case labeled "No" are the case in which these spillovers are absent. The contrast of these cases is intended to explore the consequences of

[7]Recent extensions of this basic approach allow for a differential to arise between the domestic interest rate and the world interest rate and for that differential to be a function of domestic productivity, as Uribe and Yue (2006). The latter formulation is intended to allow for the possibility that changes in domestic productivity change the probability of default and this feeds back into banks willingness to lend. While this is an important extension of the basic framework, this formulation, once again, abstracts from the differential response of a country to a home and global productivity change.

ignoring international business cycle comovement in the moment matching exercise.

Beginning with the no-spillover case, which is most relevant to partial equilibrium calibration, the persistence averages 0.54 for developing countries and 0.69 for developed countries while the standard deviation averages about 5.5 basis points. Including spillovers from the G-8 significantly reduces the role of interest rate shocks by: reducing the persistence needed for both groups of countries and, particularly for the developing countries while cutting the innovation variance in half. The diminished role of the interest rate shocks when spillovers are included goes in the right direction in terms of general equilibrium reasoning, but a more direct evaluation is to examine the output variance decomposition across the model variants, to which we now turn.

3 Variance Decomposition

With the calibration of the DGSE and SOE models complete, we are in a position to compute variance decomposition of output growth into the underlying exogenous sources of variation under the null and alternative model. Recall, the null model is the two-country general equilibrium model with international productivity spillovers.

Table 4 reports the results using the small open economy model without spillovers as this corresponds most closely to the analysis of AG. Beginning with the pooled results for all countries the permanent and transitory shocks account for virtually identical fractions of output growth fluctuations, 37% (74% combined). The world interest rate accounts for the remaining 26%. However, these averages obscure heterogeneity in the cross-section. Dividing the sample into developing and developed countries the asymmetry point out by AG shows up vividly: the permanent shock accounting for about 43% of the variance in developing countries compared to 23% in the case of developed economies. The interest rate plays a relative minor role in both cases, but is more important for the developed economies than the developing economies.

This no-spillover benchmark is even more stark in amplifying the role of permanent shocks in developing countries than the original AG result. The result is sensitive to the sample of countries. Using 20 countries that are common across our study and theirs, the permanent shock accounts for 30% for developing countries and 22% in developed countries. The sensitivity to countries included in the analysis reflects substantial differences in business cycle variability within each group, an issue we address below.

Turning to Table 5, the result when the simulation model is correctly specified as a two country general equilibrium model with productivity spillovers, the asymmetry in the contribution of permanent and transitory shocks across the country groups is now the reverse of what AG found. That is, the permanent shocks now play a relatively more important role in the case of the developed countries, 51% versus 45% for developing countries. Notably this tendency is even more pronounced in the narrower sample used by AG (51% versus 35%). The right-most panel uses the partial equilibrium model with spillovers to show that when the productivity processes of correctly specified, the partial equilibrium approach gives quantitatively similar results. However, this should not be construed as indicating the potential for the partial equilibrium model to correctly identify the relevant business cycle shocks. Recall, the spillover case was based upon the general equilibrium simulations that also matched international business cycle comovement.

Further problems of identification are evident in the lower panel of Table 5, which breaks the permanent and transitory components into the contributions of home productivity and G8 spillovers. In particular, the small open economy model does not reproduce the correct decomposition of the permanent and temporary components into home and foreign (spillovers). For example, in the case of developed countries, the correct decomposition of the permanent shocks is to assign 42.7% of the variation to a spillover from the G-8. The small open economy model assigns 30.9% to this spillover. The reason the prediction is so far off is that the small open economy predicts that agents will respond in the same fashion to shocks of domestic or foreign origin provided they have the same stochastic properties (i.e. permanent or transitory) whereas this is obviously not the case in a general equilibrium context where the source of the shock is of paramount importance in determining the quantitative response and often the sign of the response.

The results are even more apparent at the country level since the specification errors tend to highly skewed. Figure 2 depicts the fraction of output growth variance attributable to the permanent shocks (home and G-8 spillover) predicted by the general equilibrium and partial equilibrium models. Since the interest rate is endogenous in the general equilibrium model, the fraction of variance attributed to productivity is typically an upper envelope of that predicted by the small open economy. The reader is reminded that in this exercise the spillovers estimated using the general equilibrium model are included in the partial equilibrium simulations in this comparison to give the partial equilibrium model the best chance of matching the general equilibrium null model. Since the spillovers are not identified in the partial equilibrium model these comparisons should be viewed as lower bounds on the errors: only if the productivity processes could be directly observed would this small open economy specification be feasible to simulate and compare to the small open economy results in Figure 2.

Figure 3 presents a more pragmatic comparison. It contrasts the small open economy approach under the correct specification with productivity spillovers from G-8 and the more common practice (as in AG) where the small open economy model is simulated with only domestic permanent and transitory shocks. Note that the small open economy approach gets the correct variance decomposition on average (across countries) even when spillovers are ignored. However, the errors of variance accounting country-by-country are obviously very substantial and not randomly distributed in the cross-section. The role of permanent shocks is underestimated when spillovers are ignored for developed economies, but overestimated when spillovers are ignored in the case of developing countries.

4 Concluding remarks

In this paper we have compared the performance of a standard SOE model with an analytically comparable two-country DSGE model. We conducted variance decomposition for 58 small economies using both models. We find that the main limitation of the SOE model is that it cannot capture the role of TFP spillovers from the G-8 since it ignores international business cycle correlation in the moment-matching exercise. This result is robust in the entire cross-section of nations, but is more quantitatively important for small developed countries, who share more of a stochastic trend in productivity with the G-8 than do developing countries.

The exercise shows that is simply not true that the small open economy framework is justifiable on the grounds that small economies do not affect the world interest rate. The practical difficulty with the small open economy approach is that is greatly limits the ability of researchers to capture the differential national responses of internationally integrated economies to common and idiosyncratic shocks, be they permanent or transitory in nature. What matters is not just how persistence the shocks are, but also how idiosyncratic they are.

Our paper has provided a methodology that allows researchers to study economic interactions of a large number of heterogeneous and small open economies in general equilibrium without exploding the dimensionality of the state space. Essentially it boils down to modeling a large aggregate economic region in general equilibrium with a small open economy. One limitation of way this approach is developed here is that it abstracts from the possibility that shocks outside of the G-8 are large enough to alter the world interest rate. With the emergence of the BRICs, for example, it seems important to extend the approach to allow for more than one block of nations to alter the equilibrium dynamics of the smaller economies that comprise the rest of the world. We leave this extension to future work.

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TABLE 1 – ESTIMATES of G-8 PRODUCTIVITY PROCESSES

	Data	Model
Standard deviation of:		
GDP growth	1.78	1.80
Consumption growth	1.14	1.14
Consumption-GDP ratio	1.22	1.20
G-8 productivity parameters		
Std. dev. of permanent innovation	0.9	
Persistence	0.90	
Std. dev. of transitory innovation	1.2	

Notes: The upper panel reports the moments of G-8 data in the first column that are matched with the model simulations reported in the second column. The closed economy version of the model is simulated 2,700 times with the range of parameters as follows: $\widehat{\rho}_0 \in [0.40, 0.95]$, $\widehat{\sigma}_0^T \in [0.006, 0.02]$ and $\widehat{\sigma}_0^p \in [0.006, 0.02]$. The parameters that best fit the model to the data are reported in the lower panel.

TABLE 2 – ESTIMATES of G-60 PRODUCTIVITY PROCESSES

	Developing		Developed	
	Data	Model	Data	Model
Std. Dev. of GDP	4.93	5.51	2.60	2.87
Std. Dev. of consumption	5.93	5.61	2.12	2.46
Corr. with G-8 GDP	0.09	0.09	0.62	0.61
Corr. with G-8 consumption	-0.08	-0.06	0.47	0.37
Innovation standard deviations relative to G-8 counterparts				
$v_j^P \in [0.1, 15]$	3.13		0.61	
$v_j^T \in [0.1, 15]$	1.98		0.78	
Factor loadings on G-8 spillovers				
$\omega_j^P \in [-15, 15]$	-0.53		1.83	
$\omega_j^T \in [-15, 15]$	0.40		0.67	

TABLE 3 – BOND PRICE SHOCK PARAMETERS

	Developing		Developed	
Spillovers	Yes	No	Yes	No
Persistence	0.30	0.54	0.24	0.69
Innovation standard deviations	0.003	0.006	0.004	0.005

TABLE 4. OUTPUT VARIANCE DECOMPOSITIONS, SMALL OPEN ECONOMY MODEL

	Variance Decomposition				Number	Std. dev.
Source of shock	Home	Home	World	Total	of	of
Type of shock	Permanent	Transitory	Interest rate		Countries	Output
All Countries	36.93	36.97	26.10	100	58	4.3
Developing	43.13	30.51	26.37	100	40	4.9
Developed	23.15	51.34	25.51	100	18	2.8
AG Sample	25.70	46.72	27.58	100	20	3.1
Developing	29.97	43.03	27.00	100	9	4.0
Developed	21.81	50.07	18.12	100	11	2.3

Notes:Productivity spillovers are abstracted from in this specification because they would not be identified using the small open economy model.

TABLE 5. OUTPUT VARIANCE DECOMPOSITIONS, MODEL COMPARISONS

Model	DSGE		SOE		
Source of shock	Home + G8	Home + G8	Home + G8	Home + G8	Interest
Type of shock	Permanent	Transitory	Permanent	Transitory	rate
All Countries	46.9	53.1	41.3	53.2	5.4
Developing	45.2	54.8	42.8	54.4	2.7
Developed	50.8	49.2	38.0	50.5	11.5
Aguiar and Gopinath	43.3	56.7	32.6	57.0	10.4
Developing	34.9	65.1	30.2	64.0	5.8
Developed	51.0	49.0	34.8	50.8	14.4

Source of shock	Home	G8	Home	G8	Home	G8	Home	G8	Interest
Type of shock	P	P	T	T	P	P	T	T	rate
All Countries	23.6	23.4	38.5	14.6	22.5	18.8	37.9	15.3	5.4
Developing	30.6	14.6	44.2	10.6	29.5	13.4	43.6	10.8	2.7
Developed	8.1	42.7	25.8	23.4	7.1	30.9	25.3	25.2	11.5

Figure 1. International Business Cycles

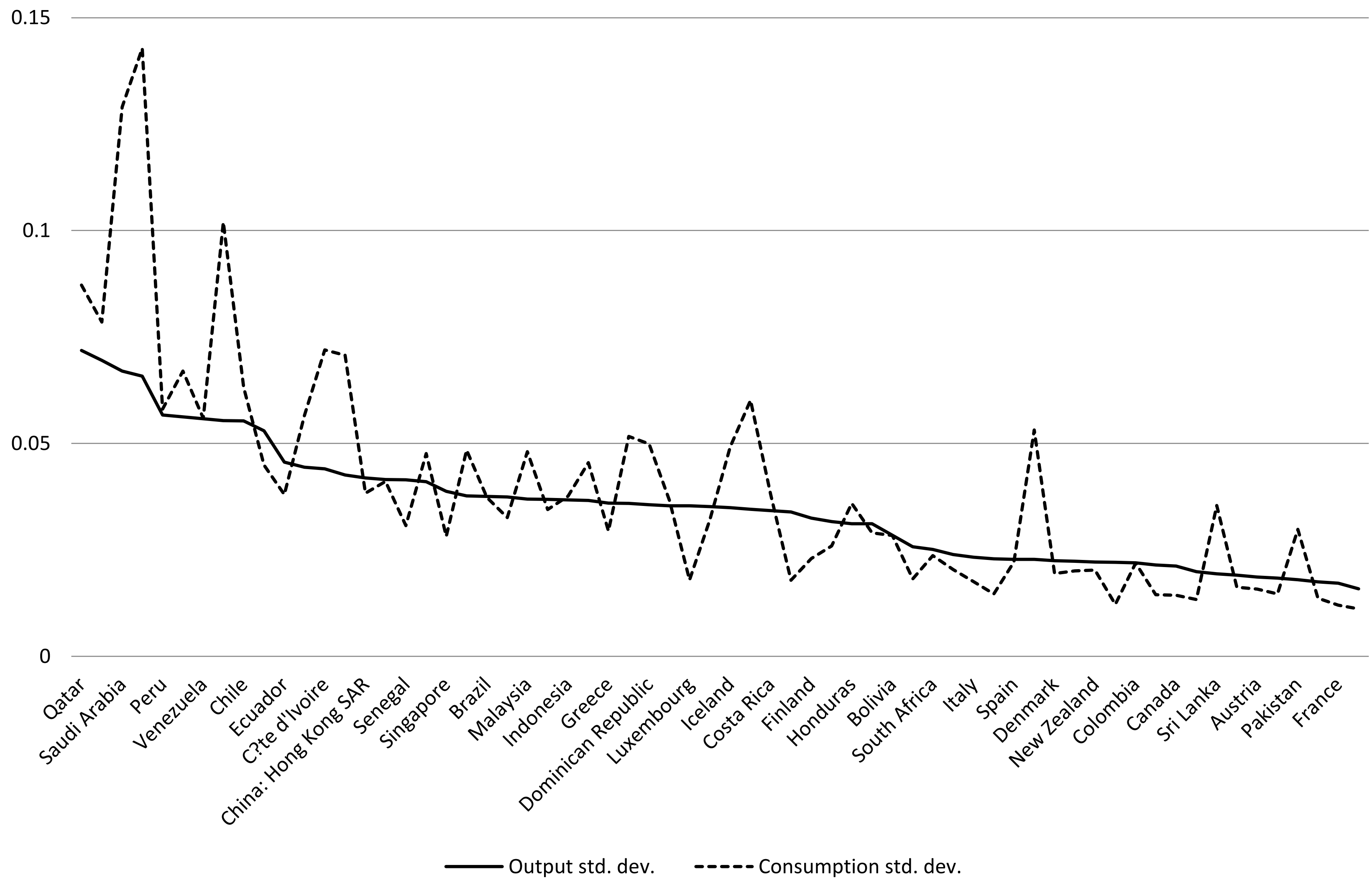

Figure 2. Proportion of output growth variance accounted for by permanent shocks:
Comparison of DSGE model and SOE with productivity spillovers

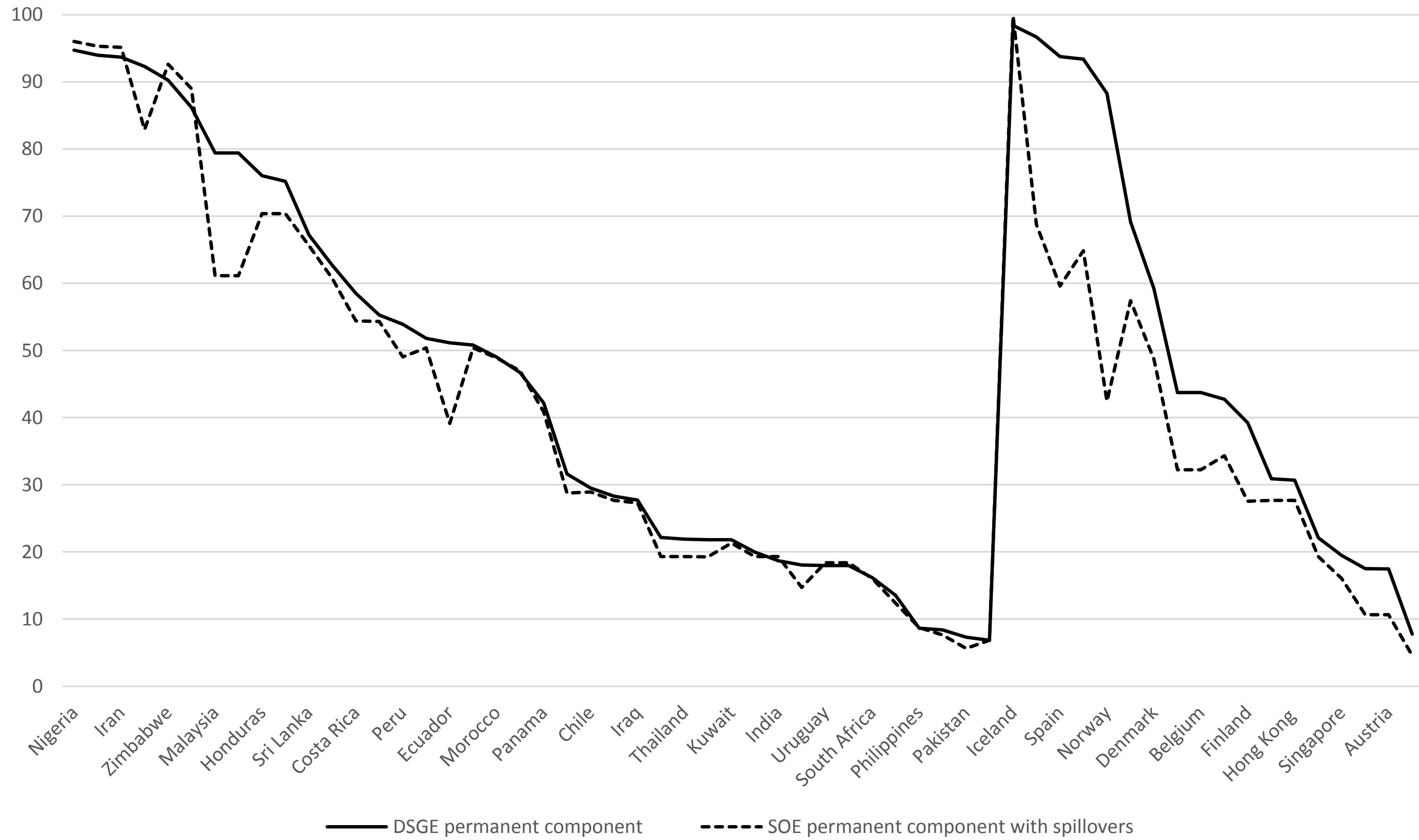

Figure 3. Proportion of output growth variance accounted by permanent shocks:

Comparison of SOE model with productivity spillovers to SOE model without spillovers