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by David Altig and Alan C. Stockman

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SOURCES OF BUSINESS CYCLES

IN KOREA AND THE UNITED STATES

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INTRODUCTION

A central question of macroeconomics concerns the sources of business cycles, and the effects of various types of exogenous disturbances. Today, the answers remain elusive despite an enormous amount of research. A decade ago, Blanchard and Quah (1989) proposed a promising new method designed to provide the answers. They suggested statistical decomposition of fluctuations in aggregate variables into two types of disturbances: those that permanently affect real GDP and those that do not. They interpreted the first set of disturbances as reflecting changes in "supply," and the second set of disturbances as reflecting changes in "demand." Despite its promise, the identifying results of this framework are suspect. In an important contribution, Gali (1998) has recently modified the identifying assumption to estimate technology and demand shocks with this framework. This paper applies and extends Gali's contribution. We estimate common and nation-specific components of technology shocks, real demand shocks, and (combined common and nation-specific) monetary shocks using quarterly data for Korea and the United States. We attempt to contribute both to the fundamental macroeconomic issue of the sources of business cycles as well as issues of the international transmission of business cycles and the determination of exchange rates.

THE STANDARD BLANCHARD-QUAH STRUCTURAL VAR METHOD

A large literature has followed the pioneering contribution of Blanchard and Quah. Most papers have attempted to distinguish "supply" (or "technology") shocks from "demand" shocks by identifying supply shocks as those that have a long-run effect on real GDP, that is, by assuming that demand shocks do not affect real GDP in the long run. The procedure, which is attractive because it appears to use only uncontroversial long-run restrictions while allowing the data to show a wide variety of short-run dynamic patterns, works as follows.

Consider a vector $x_t = (y_t, z_t)$ where y_t is real GDP and z_t is another variable such as the price level. Assume the variables have already been transformed so that they are stationary. Assume that the structural, data-generating process is

$$x_t = \begin{bmatrix} C^{11}(L) & C^{12}(L) \\ C^{21}(L) & C^{22}(L) \end{bmatrix} \varepsilon_t = C(L)\,\varepsilon_t$$

where

$$\varepsilon_t = \begin{pmatrix} \varepsilon_t^S \\ \varepsilon_t^D \end{pmatrix}$$

is a vector whose first element is a "supply" or technology shock, and whose second element is a demand shock of some kind. We seek to estimate this structural process, but the model is not identified from the data. The typical application assumes that the two shocks are orthogonal. (This assumption is questionable, in our opinion, given their *interpretation* as aggregate supply and demand shocks; we discuss this issue later.) This assumption, combined with a scale normalization, implies that $E\varepsilon\varepsilon'=I$, the identity matrix. These two additional assumptions are still not quite enough to achieve identification, though, so the standard additional assumption asserts that demand shocks do not affect real GDP in the long run. This assumption implies that $C^{12}(1) = 0$, meaning that the sum of the C^{12} coefficients is zero. This makes the C(1) matrix lower triangular, and achieves exact identification of the structural model from the data.

Denote the reduced form VAR system as

$$B(L)x_t = \upsilon_t$$

where $B_0 = I$, $E\upsilon\upsilon' = \Sigma$, and $E\upsilon_t y_{t-i} = 0 \quad \forall i > 0$. The final assumption asserts that there exists a non-singular matrix S such that $\upsilon_t = S\varepsilon_t$. This assumption (which implies that the structural shocks are fundamental) implies that $B(L)x_t = S\varepsilon_t$. As a result, $x_t = B^{-1}(L)S\varepsilon_t = C(L)\varepsilon_t$, or $C(L) = B^{-1}(L)S$ so

$$S = C_0.$$

Also note that

$$E\upsilon\upsilon' = ES\varepsilon_t\varepsilon_t'S' = SS' = C_0C_0'.$$

These results will be used in the next paragraph.

From the data, we can estimate the reduced-form model to find estimates of $B(L)$ and Σ, and then compute $B^{-1}(L)$ and $B(1)$. Next, we can compute the lower-triangular Choleski decomposition matrix H such that $HH' = B^{-1}(1)\ \Sigma\ B(1)$. Use the facts that $B_0^{-1} = I$ and that $C(L) = B^{-1}(L)S$ to note that

$$B^{-1}(1) = B_0^{-1} + B_1^{-1} + \ldots = C_0C_0^{-1} + C_1C_0^{-1} + C_2C_0^{-1} + \ldots = C(1)C_0^{-1},$$

or $C_0 = B(1)C(1)$. Therefore $HH' = C(1)C_0^{-1}\ \Sigma\ C_0C(1)^{-1} = C(1)C(1)'$, so $C(1) = H$. As a result, $B^{-1}(1) = HC_0^{-1}$, and we can solve for

$$C_0 = B(1)H.$$

This gives the first matrix of the structural system. Finally, we can then use this estimate to solve for the entire set of matrices of the structural system,

$$C(L) = B^{-1}(L)\,B(1)H\ .$$

With estimates of every matrix of coefficients in the structural system, we can now solve that system for the time series of structural supply and demand shocks, ε_t .

PROBLEMS WITH THE STANDARD IDENTIFICATION ASSUMPTIONS

Blanchard and Quah, using this method, found that small fractions of the variance of real GDP are due to permanent shocks, identified above as technology or supply shocks. Instead, most of the variance of real GDP is attributable to transitory shocks, identified above as demand shocks. Similar findings appear in most subsequent work along these lines. However, the identification assumptions of these permanent and temporary shocks to real GDP as technology or demand shocks are troubling. First, some technology shocks may be temporary, particularly if one takes a broad view of technology shocks (as is common, appropriately or not, in the real-business-cycle literature). Second, not all permanent shocks need be technology shocks. Permanent real demand shocks originating in shocks to the level or composition of government spending, taxes, investment opportunities, or changes in tastes (or demographics) may have permanent effects on real GDP. Third, in an open economy (which characterizes, to varying degrees, *all* economies to which this procedure has been applied), a change in *relative* demand from the products of one country to the products of another country, holding fixed aggregate *world* demand, can change real GDP in both countries. (Such changes could result from changes in fiscal policies, government regulations, prospective returns from various investment projects, or changes in tastes or demographics.)

It might *appear* that this argument simply implies that standard models provide a downward bias to the fraction of variance of real GDP explained by demand shocks. After all, if some demand shocks permanently affect real GDP, then the standard identification method treats them incorrectly as supply shocks and thereby understates the importance of demand shocks. However, the implications of these criticisms are subtler than that argument would imply. When true demand shocks have permanent effects on real GDP, they create a correlation between the *conglomerate* shocks that the econometrician interprets as supply and demand shocks. This violates the model's assumption of orthogonality, with unknown effects on the model's estimated parameters and therefore estimates of shocks. Obviously, this problem also carries over to impulse response functions from the model. (The same problem obviously occurs when true temporary supply shocks occur without permanent effects.)

GALI'S CONTRIBUTION

Jordi Gali (1998) made an important contribution to this approach to structural VARs, which later sections of this paper will apply and extend. Gali's key new idea for identification of these models replaces the assumption that demand shocks have no long-run effects on real GDP with the alternative identifying assumption that demand shocks have no long-run effects on the average product of labor. This assumption follows from the underlying assumption of long-run constant returns to scale in production. This identifying assumption overcomes the major objections (to the standard assumption) outlined above. First, demand shocks due to changes in fiscal policies, investment demand, or consumer tastes may affect the long-run level of real GDP but are much less likely to affect the long-run average product of labor. Gali's identifying assumption is not perfect – changes in distorting taxes, for example, could affect both the gross and net-of-tax average products of labor – but it is satisfied in a far broader class of models than the standard identification assumption. Similarly, changes in relative demand for goods of one country versus those of another country would affect equilibrium relative prices and quantities, and therefore equilibrium real GDP in each country, but (in most standard models) would not affect the long-run average product of labor in either country. The criticism above regarding temporary technology shocks still applies – but if these are uncommon (which is more likely to be the case with a narrower view of technology shocks than the broader view criticized in Cochrane, 1994) – then this is not likely to create a major problem in estimation.

Gali estimated the structural system,

$$\begin{pmatrix} y/L \\ L \end{pmatrix}_t = \begin{bmatrix} a_{11}(L) & a_{12}(L) \\ a_{21}(L) & a_{22}(L) \end{bmatrix} \begin{pmatrix} \varepsilon^T \\ \varepsilon^D \end{pmatrix}_t$$

where y and L denote real GDP and total employment, the two shocks indicate technology shocks and demand shocks, and $a_{12}(1) = 0$. Gali estimated this model for the United States and for several other countries individually, and used his results to try to distinguish between real business cycle models and sticky-price monopolistic competition models of the kind proposed by Blanchard and Kiyotaki (1987). In particular, Gali notes that *conditional upon a technology shock*, real business cycle models imply a positive comovement of employment and labor productivity, while Blanchard-Kiyotaki models predict the opposite conditional correlation. In the latter models, output is constrained by the level of demand, so an advance in technology reduces the level of employment as it raises the labor productivity. Similarly, Gali's version of the Blanchard-Kiyotaki model, with variations in labor effort unobserved by the econometrician, predicts that demand shocks may generate a positive comovement of employment and labor productivity. This positive comovement can occur if increases in demand generate sufficiently large increases in unobserved labor effort that measured productivity rises along with employment. Finally, Gali argues that demand shocks, such as government-spending shocks, of the kind that Christiano and Eichenbaum have introduced into real business cycle models, generate negative comovements of employment and labor productivity. The reason for negative comovement is that these demand shocks shift the *supply* of labor along a fixed marginal-product-of-labor schedule. Christiano and Eichenbaum introduced aggregate demand shocks labor-supply shifters to reduce the strong *positive* correlation between employment and labor productivity predicted by the standard real-business cycle model, because such a prediction is strongly counterfactual, and shifts in labor supply could potentially combine with technology shocks to bring that correlation closer to its (approximately) zero level in the data.

Gali's structural VAR provides estimates of the time series of technology and demand shocks. These estimates allow him to calculate the correlations between employment and the average product of labor *conditional* on technology shocks and *conditional* on demand shocks. He concludes that in both cases the results are consistent with (his version of) the Blanchard-Kiyotaki model and inconsistent with the real business cycle model.

AN EXTENDED FRAMEWORK FOR IDENTIFYING SHOCKS

Gali's results include the peculiar discovery that demand shocks, which his model interprets as monetary shocks, have *permanent* effects on the levels of employment and real GDP, contrary to the predictions of the theoretical model. This discovery provides strong evidence *against* the standard identifying assumptions in most papers based on Blanchard-Quah methods (e.g. Clarida and Gali, 1994, who assume that even non-monetary demand shocks have zero long-run effects on real GDP, though they affect long-run real exchange rates). It also suggests the presence of permanent demand shocks with non-monetary origins. (Cochrane, 1994, notes that evidence suggests that neither monetary shocks nor technology shocks play strong roles in U.S. business cycles, suggesting that other non-monetary demand shocks may be at work.) Fiscal policies and changes in tastes provide two possible sources for shocks that might explain Gali's results.

We now examine this hypothesis by studying the additional implications of non-monetary demand shocks. In particular, consider a *pair* of *ex ante identical* countries.

Technology shocks that are common to the two countries would have no effect on the long-run exchange rate between the currencies of the two countries, but nation-specific technology shocks would affect the long-run exchange rate. (For evidence on the presence of such nation-specific shocks, see Stockman, 1988 and Costello, 1993.) Similarly, demand shocks that are common to the two countries would have no effect on the long-run exchange rate, but nation-specific demand shocks would affect it. Monetary shocks would not affect long-run levels of either employment or labor productivity in either country, but would affect the long-run exchange rate if idiosyncratic, though not if common to the two countries.[1]

The model developed by Blanchard and Kiyotaki (1987) forms the basis for most subsequent work on macroeconomic effects of sluggish nominal prices. Obstfeld and Rogoff (1995) placed their model in a two-country setting with purchasing power parity. Betts and Devereux (1996), and Chari, Kehoe, and McGrattan (1998) extended that model to include price discrimination across countries by the monopolistically-competitive firms, in an attempt to explain empirical evidence on "pricing to market" and deviations from purchasing power parity. We outline here (and the model is only outlined, not explicitly solved here) a combination of the Obstfeld-Rogoff and Chari-Kehoe-McGrattan models. The model is similar to the Chari-Kehoe-McGrattan model in that it includes capital – for analysis of long-run effects of demand and productivity shocks. It is similar to the Obstfeld-Rogoff in that we assume that each monopolistically-competitive producer sets a single price for all buyers (i.e. we rule out price discrimination across countries), and therefore we obtain the law of one price for each good as in their model.[2]

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[1] In future work, we plan to examine other related implications for the balance of international trade and for price levels.

[2] Although that assumption is not attractive on empirical grounds, we make it to avoid complications associated with determinacy of the *level* of the exchange rate in models, like those examined by Betts-Devereux and by Chari-Kehoe-McGrattan, in the presence of pricing to market.

Consider a world economy with two *ex ante* symmetric countries that have a continuum of individuals on [0,1], with identical preferences, who produce differentiated products (also on [0,1]). The home country consists of people in the interval [0,1/2]; the foreign country consists of people in the interval (1/2,1]. In all equations below, we suppress for simplicity the dependence of all variables on a state vector s_t (that is, the variables are functions of that state vector) listing current and past technologies, money supplies, and levels of government spending in each country.

Letting c(z) denoted a typical home person's consumption of good z (while c*(z) represents a foreign person's consumption), aggregate home consumption is

$$C = \left[\int_0^1 c(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}$$

for θ > 1, with a similar definition of C*. One could alter this consumption aggregator as in the and Chari-Kehoe-McGrattan model to add parameters that allow the model better to match features of the data, but that is not our purpose here. It is harmless to interpret the model in either of two ways: (1) consumers buy the intermediate goods and produce final consumption goods at home, or (2) firms buy the intermediate goods and produce final consumption goods that they sell to consumers. (In an extended version of the model with price discrimination for these intermediate goods, issues of tradability of the consumption good would arise.)

Besides consuming, people supply labor and own capital and money. The utility function is

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{\sigma}{\sigma-1} C_s^{\sigma-1/\sigma} + \frac{\chi}{1-\varepsilon} \left(\frac{M_s}{P_s} \right)^{1-\varepsilon} - \frac{\kappa}{\mu} (1-l)_s^{\mu} \right]$$

where $\beta \in (0,1)$ is the discount factor, $\mu > 1$ and $\sigma > 0$ and $\varepsilon > 0$ are other taste parameters, M is nominal money, P is an appropriately-defined price index for the consumption aggregator above, y(z) is output of good (z), and l is labor supply. Output of each intermediate good is described by a standard neoclassical production function of capital and labor, $y = Ak^{\alpha} l^{1-\alpha}$. The law of one price holds for each good (as there are no distorting taxes or other natural or government-imposed impediments to trade in the model). Therefore

$$p(z) = ep^*(z),$$

which implies a similar relationship between aggregate consumption price indexes:

$$P = eP^*.$$

Individuals face a standard budget constraint of the form,

$$PF + (q+\delta) f + M = P(1+r_{t-1})F_{t-1} + q_{t-1} f_{t-1} + M_{t-1} + p(z)y(z) - PC - PT,$$

where all variables (except the index, z) without explicit time subscripts implicitly take the time subscript, t. In this budget constraint, *f* denotes a vector of financial assets other than money and nominal bonds. Assets in the vector *f* pay dividend vector δ and have ex-dividend price vector *q*. In general, a complete-markets version of the model would permit any other asset to enter the vector *f*; while an incomplete-markets model would restrict that vector. In addition, F denotes one-period foreign nominal bonds that pay nominal interest rate i* and real interest rate r where

$$(1+r_{t,t+1}) = \frac{P_t}{P_{t+1}}(1+i_{t,t+1}),$$
$$(1+i_{t,t+1}) = \frac{e_{t+1}}{e_t}(1+i*_{t,t+1});$$

M denotes holdings of nominal money; and T denotes real lump-sum tax payments by the representative home individual. A similar maximization problem characterizes the representative foreign individual.[3]

This model, generates simple demand functions,

$$\frac{c_t(z)}{C_t} = \left(\frac{p_t(z)}{P_t}\right)^{-\theta}.$$

We are interested in the implications of the sticky-price version of this model in which nominal prices are predetermined one period ahead in the producer's own currency. (Notice that this makes nominal prices if imported goods flexible to the extent the exchange rate changes.) Because each producer is monopolistically competitive, facing the (downward-sloping) demand curve for a differentiated product, we assume that each producer sets a nominal home-currency price to maximize expected profit, and price therefore exceeds expected marginal cost.

[3] In the Betts-Devereux and Chari-Kehoe-McGrattan models, sellers of each intermediate good can price discriminate by setting different prices to buyers in the two countries. As a result, the law-of-one-price condition that ties down the level of the exchange rate in the Obstfeld-Rogoff model does not hold. Instead, both the Betts-Devereux and Chari-Kehoe-McGrattan papers use these asset-pricing conditions, which are first-order difference equations, to solve for the exchange rate. However, while those equations determine the *expected rate of change* of the exchange rate, the *level* of the exchange rate requires some additional element of the model. See Duarte and Stockman (1998) for a related model that avoids this problem and provides a unique equilibrium; that model is based on the explicit transactions-cost analysis of Uppal (1993), Uppal, Sercu, and van Hulle (1995), and Ohanian and Stockman (1997).

Conditional on the predetermined nominal price, a (small) increase in demand raises output because marginal revenue (which equals the predetermined price) exceeds marginal cost. With predetermined prices, an unexpected increase in the home nominal money supply raises home aggregate demand, and given the demand functions above, this increase in home demand falls on all products. As a result, unexpected expansion of the home money supply raises home output. The short-run responses of real GDP and the exchange rate are tied together in a simple way:

$$y\exists - y\exists\ * = \theta e\exists$$

In the long run, a monetary shock has no effects on real variables, but affects the nominal exchange rate.[4]

Now consider real demand shocks. It is easy to show that in this model a permanent increase in government spending by an equal amount in each country – financed by lump-sum taxes and falling on home and foreign goods in the same proportions as private spending – raises real GDP and employment in each country, but leaves long-run labor productivity unaffected. Finally, it is easy to show that common technology shocks affect levels of real GDP, employment, and labor productivity identically in both countries in the long run, though not the exchange rate. Nation-specific technology shocks affect levels of real GDP, employment, and labor productivity differently in the two countries in the long run, and affect the long-run exchange rate.

AN EMPIRICAL MODEL

We extend the empirical model estimated by Gali to a two-country setting and we

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[4] Notice that the model predicts a tight relation between the difference in the responses of real GDP in each country and the real exchange rate (in both the short run and the long run). Given the level of technology, this implies a relation between the long-run responses of employment in each country and the real exchange rate. While Stockman (1998) and Leonard and Stockman (1998) provide empirical evidence that supports *some* relation between these variables, the evidence strongly contradicts the model's implication in the absence of nation-specific technology shocks. This provides an additional reason to estimate the multi-shock system we consider below.

include the exchange rate. This system, unlike Gali's model, takes into account correlations of technology shocks across countries. Also, unlike his system, it takes into account correlations of demand shocks across countries. It also takes into account the different effects on the exchange rate of nation-specific shocks to technology or demand. Finally, it separates the effects of permanent real demand shocks (whether common or nation-specific) from monetary demand shocks, which affect only nominal variables in the long run.

We estimate, for a pair of countries, the following structural VAR (in which *e* denotes the exchange rate):

$$x_t = \begin{pmatrix} y/L \\ \dfrac{y/L}{y^*/L^*} \\ L \\ \dfrac{L}{L^*} \\ e \end{pmatrix}_t = A(L) \begin{pmatrix} \varepsilon_T^W \\ \varepsilon_T^R \\ \varepsilon_D^W \\ \varepsilon_D^R \\ \varepsilon_M \end{pmatrix}_t = A(L)\varepsilon_t$$

The elements of ε_t are, in order, (1) a world technology shock (common to both countries); (2) a *relative* technology shock that raises the ratio of long-run labor productivity in the home and foreign countries without affecting its level in the home country (that is, this shock reduces the labor productivity in the foreign country alone); (3) a world demand shock (common to both countries) that is "real" in the sense that (unlike a monetary shock) it affects long-run employment and GDP (though not labor productivity); (4) a *relative* demand shock; and (5) a *monetary* demand shock that combines both common and nation-specific elements.

The identifying assumptions impose a set of zero restrictions on the matrix of long-run responses:

$$A(1) = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix}.$$

These restrictions on $A(1)$ incorporate (a) a straightforward extension of Gali's identifying assumptions -- only technology shocks affect either the level of labor productivity at home or its ratio across countries; and (b) the assumption that *monetary* demand shocks have no long-run effects on real variables (but may on nominal variables, depending upon the monetary system and behavior of monetary authorities). The diagonal, recursive structure of the long-run response matrix ensures that this model is just identified.[5]

Because this system incorporates information on whether productivity and real demand shocks are common or nation-specific, and separately identifies monetary shocks from real demand shocks, it allows us to undertake several interesting exercises. First, we re-evaluate the results obtained by Gali on the conditional correlations of employment and labor productivity. Because Gali shows that those conditional correlations can help distinguish between the rather different implications of Blanchard-Kiyotaki type models and real business cycle models, that exercise is important.

Second, we re-evaluate the findings of Clarida and Gali that technology shocks play almost no role in explaining variation in exchange rates, and that demand shocks and monetary shocks play about equally important roles in explaining the short-run variation of exchange rates. Our estimates allow us to examine this result while using a more believable set of identification

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[5] One potential problem with our model concerns the assumption that monetary shocks are independent of other demand shocks, and independent of technology shocks. Clearly the shock that we *label* a monetary shock actually includes only the orthogonal component of that shock, that is, the part that does not affect real variables in the long run. As a result, our estimation could understate the importance of monetary shocks in a variance decomposition. This problem is not unique to our model; the same problem

assumptions (restrictions that, unlike theirs, are consistent with Gali's later empirical results indicating that demand shocks *do* have long-run effects on real GDP). We conduct an analysis of variance to examine what fraction of the short-run variances of employment, productivity, real GDP, and the exchange rate are due to each type of productivity shock (common versus nation-specific), each type of real demand shock, and to monetary shocks. This also allows us to re-evaluate the some of the conclusions summarized in Cochrane (1994) about the inability of either technology or monetary shocks to explain much of the variation in U.S. real GDP.

Third, we compare our impulse response functions with those of Eichenbaum and Evans (1995) for U.S. monetary shocks. Eichenbaum and Evans estimated a reduced-form VAR for U.S. data with three exogenous indicators of monetary shocks in the United States (the federal fund rate, the nonborrowed reserve ratio, and the Romer-Romer index). They found results partially, but not wholly, consistent with a model with short-run price stickiness. However, although they used an explicit indicator of monetary shocks, their method did not allow them to control for common versus idiosyncratic real demand shocks or common versus idiosyncratic technology shocks. Because their results indicate a very high degree of persistence in the response of the real exchange rate to monetary shocks (which appears to be inconsistent with theoretical models), there is room for suspicion that they shocks they identified as monetary shocks may in fact contain some strong elements of real shocks, and that those real shocks are responsible for the long-lived effects on the exchange rate. By examining impulse responses to monetary shocks and various real shocks in our model, we shed additional light on these questions.

RESULTS

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appears in applications of Blanchard-Quah methodology, e.g. Clarida and Gali.

We estimate our model with quarterly data for Korea and the United States (treating the United States as the foreign country) from 1969:2 to 1998:1. Figure 1 shows variance decompositions of forecast error variances at various horizons, up to 3 years. World productivity is explained mostly by shocks to itself at all horizons. Nation-specific productivity, however, is determined by all five factors, with about two-thirds of its variance accounted for by nation-specific productivity and nation-specific demand shocks. This suggests that while demand shocks have little effect on average world productivity, they affect nation-specific components of productivity. Of course, our identifying assumption does not permit long-run effects of demand on productivity, so these results reflect short-run impacts of demand on labor productivity.

The variance of world aggregate demand is explained mostly by real shocks to world and nation-specific demand, with monetary shocks playing virtually no role at any horizon. Productivity shocks play little role at short horizons, but account for about one-third of the variation in demand at longer horizons (which may reflect lags in the general-equilibrium responses of demand to increases in income brought about by technology shocks. The variance of nation-specific aggregate demand, however, is explained mostly by a combination of nation-specific real demand shocks and monetary shocks, each explaining about 40 percent of the variance of nation-specific demand. Finally, monetary shocks account for about half the variation of the exchange rate at all horizons. Real demand shocks account for about 40 percent of the variation of the exchange rate at short horizons (split roughly equally between worldwide and nation-specific demand shocks). Productivity shocks play little role in explaining the exchange rate. They explain less than 5 percent of the variation in exchange rates at short horizons and about 15 percent at longer horizons (possibly reflecting a Balassa-Samuelson effect).

Figures 2-6 show impulse response functions from our estimates. Figures 2a-2e show the estimated effects over three years of a one-standard-deviation shock to world productivity on world productivity, nation-specific productivity, world demand, nation-specific demand, and the nominal exchange rate. As indicated above, world productivity shocks affect world demand with a lag because its effects accumulate the first 1-1/2 years. Figures 3a-3e show the effects of a one-standard-deviation shock to nation-specific productivity on world productivity, nation-specific productivity, world demand, nation-specific demand, and the nominal exchange rate. Figures 4a-4e show the effects of shocks to world demand; note that world demand shocks raise productivity for about 6 quarters; nation-specific demand shocks also raise productivity for about that length of time, following a negative impact effect. Figures 5a-5e show the effects of shocks to nation-specific demand; Figures 6a-6e show the effects of nominal shocks. Notice that monetary shocks raise world demand for about a year, and begin to reduce world demand after that. Monetary shocks affect the exchange rate on impact, although the effects continue to accumulate so that the peak effect on the exchange rate occurs after about 2-1/2 years; our estimates show no evidence of exchange-rate overshooting in response to monetary shocks.

Our results conflict with Gali's finding that shocks to productivity reduce employment in the short run, as a monopolistic-competition model with sticky prices implies. As Figures 3c and 3d show, shocks to nation-specific productivity raise employment even in the short run. Shocks to world productivity also raise world employment, as Figure 2c shows, although Figure 2d shows a long-lived negative effect of world productivity shocks on Korean employment relative to U.S. employment.

Our results show a second source of conflict with Gali's results for the United States. As Gali argues, researchers have added real demand shocks to real business cycle models as a source of *negative* comovement between employment and labor productivity; in contrast, Gali's version of the sticky-price monopolistic-competition model can produce a postive conditional comovement, which he finds for the United States. Our estimates show partial conflict with his results: Figure 4 shows that world demand shocks generate opposite short-run movements in country-specific labor productivity and employment, although (consistent with Gali's results) they generate a positive comovement between world labor productivity and world employment. Figure 5 shows that country-specific demand shocks generate a strong negative comovement between country-specific labor productivity and employment in the short run, in contrast to Gali's results for the United States.

We examine this issue further by estimating bivariate vector autoregressions for Korea and the United States separately, with only the productivity and employment variables included. Not surprisingly, variance decompositions show that the variance each variable is primarily accounted for shocks to itself.

Our estimates conflict with Gali's results for the United States. Figure 7 shows that productivity shocks in Korea raise employment along with productivity in the short run. This pattern of estimates for Korea, conditional on a productivity shock, is not consistent with the monopolistic-competition model with sticky prices. Our estimates for Korea are also inconsistent with that model when we condition on demand shocks. In contrast to Gali's estimates for the United States, we find that demand shocks reduce labor productivity in the short run.

To shed additional light on this issue, we re-estimated Gali's model for the United States with the shorter sample period for which we have data on both Korea and the U.S. (In contrast, Gali's sample period for the United States included the 1950s and 1960s, and ended before our sample ends.) Figure 8 shows our estimated impulse response functions for productivity shocks. We find a zero impact effect of productivity shocks on employment, followed by positive effects after a 1-quarter lag. We conclude that Gali's results are not robust to his sample period; essentially, excluding the 1950s from the sample removes his evidence in favor of the sticky-price monopolistic competition model for the United States.

Our impulse response functions are somewhat similar to those estimated by Eichenbaum and Evans for U.S. monetary shocks. Figure 6e shows that monetary shocks have a long-lived effect on the nominal exchange rate, with the effect building slightly over time. Interestingly, we find the same pattern of response in the exchange rate to real demand shocks. Figure 4e shows that world real demand shocks have a long-lived effect on the exchange rate that builds to a peak after 4 or 5 quarters before declining slightly. Figure 5e shows the same pattern of response for a nation-specific real demand shock. Because Eichenbaum and Evans estimated a small VAR that did not allow them to distinguish real demand shocks from nominal shocks and productivity shocks, there is a possibility that they misinterpret their results. If their measures of monetary shocks reflect partly real demand shocks (including possible Federal Reserve reactions to such shocks), then their results on the effects of monetary shocks may include the effects of both monetary shocks *and* real demand shocks. Our results show that real demand shocks play an important role in explaining exchange-rate variation, and that their effects are persistent.

CONCLUSIONS AND EXTENSIONS

Despite considerable research, the central macroeconomic questions of the sources of business cycles, and the effects of various types of exogenous disturbances, remain unanswered. Recently, some signs of progress have appeared, particularly Gali's important contribution extending the Blanchard-Quah model provides a promising new method for seeking the answers. Our paper applies Gali’s contribution to a multi-country system, introducing some extensions along the way. We estimate world and nation-specific components of technology shocks, real demand shocks, and (combined common and nation-specific) monetary shocks, using quarterly data for Korea and the United States.

Our results shed light on the sources of business cycles and sources of variation in exchange rates. In particular, using Gali's method of examining separately the comovements of labor productivity and employment, conditional on productivity shocks and conditional on demand shocks, our estimates for Korea and the United States are *not* consistent with the sticky-price monopolistic-competition model.

We find that real demand shocks have little effect on average world productivity, though they affect idiosyncratic, nation-specific productivity. We find that neither monetary shocks nor productivity shocks play important roles in explaining the variance of *world* demand (though productivity shocks explain about one-third of variation in demand at longer horizons). Instead, the variance of world demand is mostly accounted for by *real* demand shocks. In contrast, monetary shocks do play an important role, along with nation-specific real demand shocks, in explaining the variance of *nation-specific* employment and output. We also find that monetary shocks explain about half of the variation of the exchange rate, with real demand shocks accounting for another 40 percent of the variation of the exchange rate and productivity shocks playing little role. Like Eichenbaum and Evans, our estimates show no evidence of exchange-rate overshooting in response to monetary shocks. In addition, we find a similar pattern of exchange-rate response to both world and nation-specific *real* demand shocks.

One shortcoming of our work in this paper lies in our inability to distinguish between (a) world monetary shocks, (b) relative monetary shocks, and (c) some "other" shock with a long-run effect on the exchange rate but without long-run effects on nominal price levels, labor productivities, or aggregate employment. That third shock may reflect, for example, speculation in financial markets that affects the exchange rate. In future work, we plan to add home and foreign price levels to our vector autoregression.[6] In particular, consider extending the system estimated here to the 7-dimensional system:

[6] We also plan to examine the effects of other variables such as innovations to world oil prices and to world interest rates.

$$
\begin{pmatrix} y/L \\ y/L \Big/ y^{*}/L \\ L \\ L \Big/ L^{*} \\ e \\ P \\ P \Big/ P^{*} \end{pmatrix} = A(L) \begin{pmatrix} \varepsilon_T^W \\ \varepsilon_T^R \\ \varepsilon_D^W \\ \varepsilon_D^R \\ \varepsilon^{other} \\ \varepsilon_M^W \\ \varepsilon_M^R \end{pmatrix}
$$

where the last two elements of the structural disturbance vector are separate common and relative (nation-specific) monetary shocks, and the third-to-last element of the structural disturbance vector is some other shock that affects real exchange rates in the long run. The standard assumptions that monetary disturbances have no long-run effects on real variables leads to a large number of overidentifying restrictions, which we plan to test. This system will also allow us to gauge the importance of shocks to exchange rates that are not associated with long-run changes in *any* other variables in the system, and to examine the short-run real and nominal effects on other variables of such shocks. Such shocks may include speculative elements in foreign exchange markets – which have received little attention in formal empirical studies, except in cases of speculative attacks under pegged-rate systems.

References

Catherine Betts and Michael B. Devereux, "The Exchange Rate in a Model of Pricing to Market," European Economic Review 40, 1996, 1007-1021

Olivier Blanchard (1989), “A Traditional Interpretation of Macroeconomic Fluctuations,” *American Economic Review* 79 no. 5, 1146-64

______ and Nobuhiro Kiyotaki, "Monopolistic Competition and the Effects of Aggregate Demand," *American Economic Review* 77 (September, 1987): 647-66.

______ and Danny Quah (1989), “The Dynamic Effects of Aggregate Supply and Demand Disturbances,” *American Economic Review* 79, no. 5, 654-73.

Chari, V.V., Pat Kehoe, and Ellen McGrattan, "Monetary Shocks and Real Exchange Rates in Sticky Price Models of International Business Cycle," Federal Reserve Bank of Minnesota Staff Report 223, revised January 1998.

Richard Clarida and Jordi Gali, "Sources of Real Exchange Rate Fluctuations: How Important are Nominal Shocks?” in Allan H. Meltzer and Charles I. Plosser (eds.) *Carnegie-Rochester Conference Series* 41, December 1994, 1-56.

John H. Cochrane (1994), “Shocks,” in Allan H. Meltzer and Charles I. Plosser (eds.) *Carnegie-Rochester Conference Series* 41, December 1994, 295-365.

Thomas F. Cooley and Mark Dwyer, "Business Cycle Analysis Without Much Theory: A Look at Structural VARs," *Journal of Econometrics*, forthcoming, 1998.

Donna Costello (1993), “A Cross-Country, Cross-Industry Comparison of Productivity Growth,” *Journal of Political Economy* 101 no. 2, 207-22.

Margarida Duarte and Alan C. Stockman, 1998, "Exchange Rates and Business Cycles with Arbitrage Costs in Product Markets," unpublished, University of Rochester, 1998.

Martin Eichenbaum and Charles Evans, "Some Empirical Evidence on the Effects of Monetary Policy Shocks on Exchange Rates," *Quarterly Journal of Economics* 110, November 1995, 975-1009.

Jordi Galí, "Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?” *American Economic Review*, 1998.

Edward N. Gamber and Frederick L. Joutz (1993), “The Dynamic Effects of Aggregate Supply and Demand Disturbances: A Comment” *American Economic Review* 83, no. 5, 1387-93.

Gregory Leonard and Alan C. Stockman, 1998, "Are Exchange Rates Cyclical, as Most Models Imply?" unpublished, University of Rochester, 1998

Maurice Obstfeld and Kenneth Rogoff, "Exchange Rate Dynamics Redux, *Journal of Political Economy* 103, June 1995, 624-60.

Lee E. Ohanian and Alan C. Stockman, " Arbitrage Costs and Exchange Rates," University of Rochester, unpublished, 1997.

Matthew Shapiro and Mark Watson (1988), "Sources of Business Cycle Fluctuations," in S. Fischer (ed.), *NBER Macroeconomics Annual 1988*, 111-48.

Alan C. Stockman, "Sectoral and National Aggregate Disturbances to Industrial Output in Seven European Countries," *Journal of Monetary Economics*, March/May, 1988, 387-410.

_______ "New Evidence Connecting Exchange Rates to Business Cycles," *Economic Quarterly*, Federal Reserve Bank of Richmond, 1998.

Raman Uppal, "A General Equilibrium Model of International Portfolio Choice," *Journal of Finance*, Vol. 48.2, June 1993, 529-553.

_______, P. Sercu and C. Van Hulle, "The Exchange Rate in the Presence of Transaction Costs: Implications for Tests of Purchasing Power Parity," *Journal of Finance*, Vol. 50.4, September 1995, 1309-1319.

Forecast-Error Variance Decomposition for Nominal Exchange Rate: United States and Korea

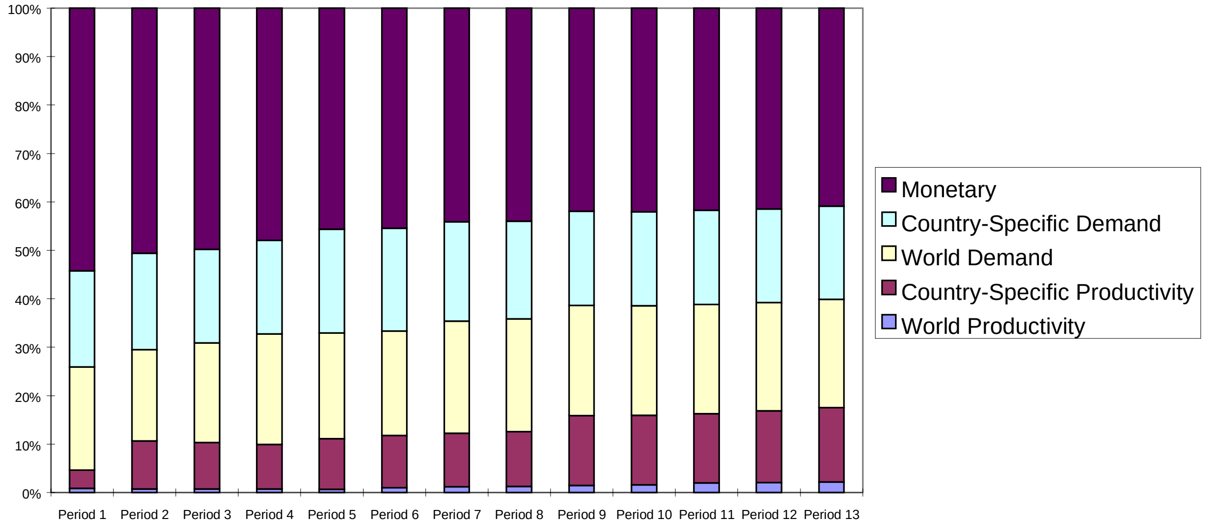
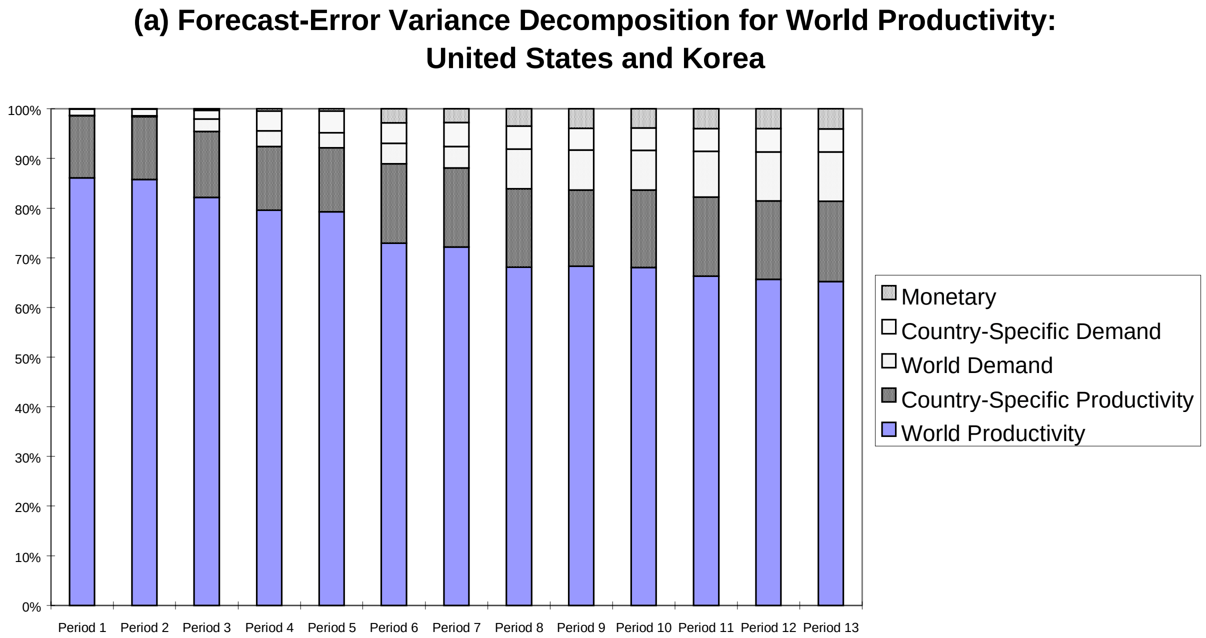
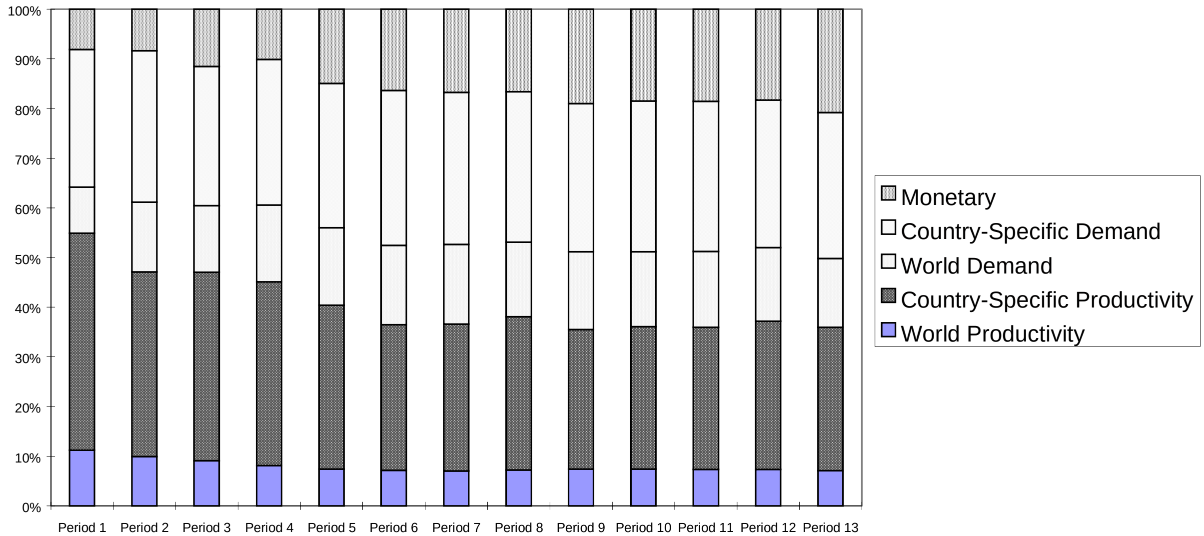


Figure 1: Variance Decompositions: Korea-U.S



(b) Forecast-Error Variance Decomposition for Country-Specific Productivity: United States and Korea



(c) Forecast-Error Variance Decomposition for World Demand United States and Korea

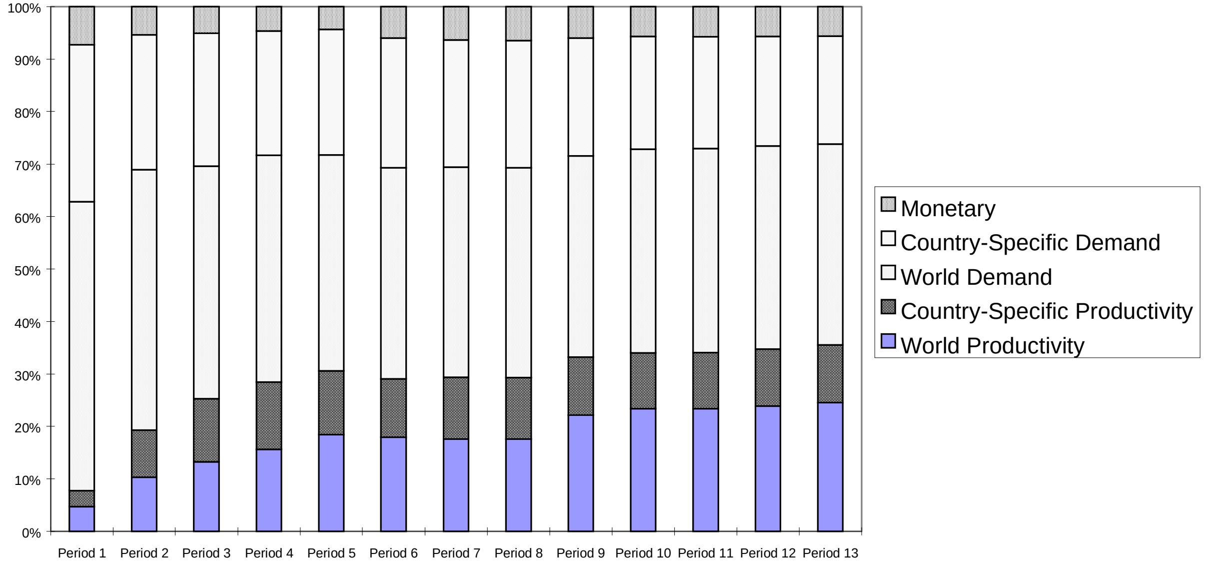
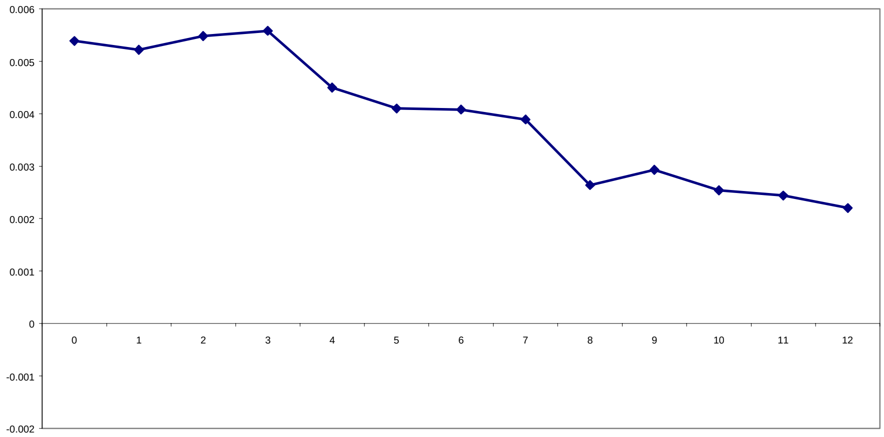
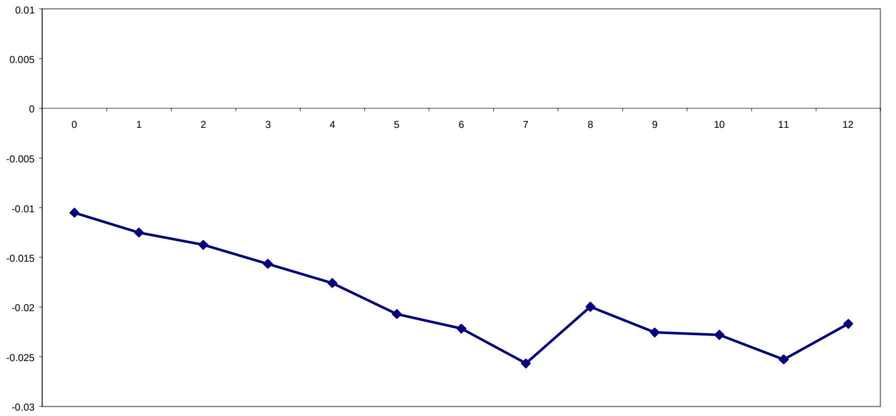


Figure 2 Effects of World Productivity Shocks

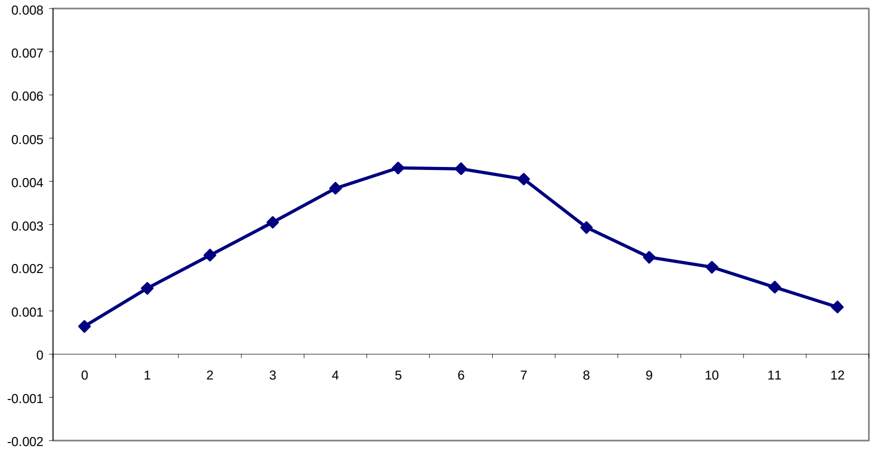
(a) Effects of World Productivity Shock on Itself



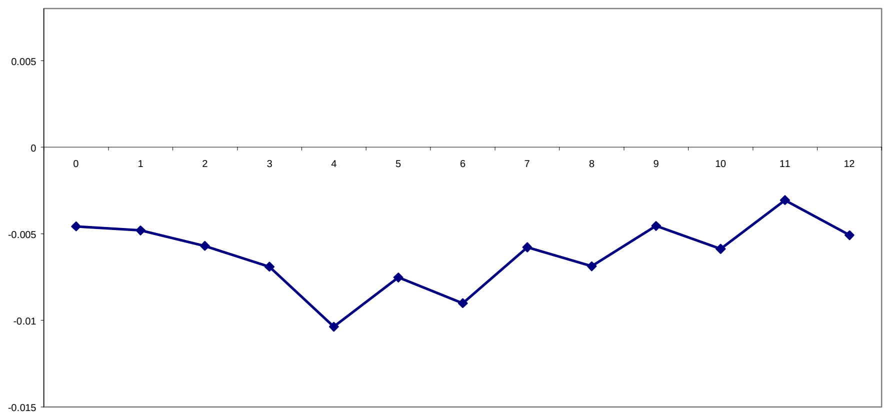
(b) Effects of World Productivity Shock on Country-Specific Productivity



(c) Effects of World Productivity Shock on World Demand



(d) Effects of World Productivity Shock on Country-Specific Demand



(e) Effects of World Productivity Shock on Exchange Rate

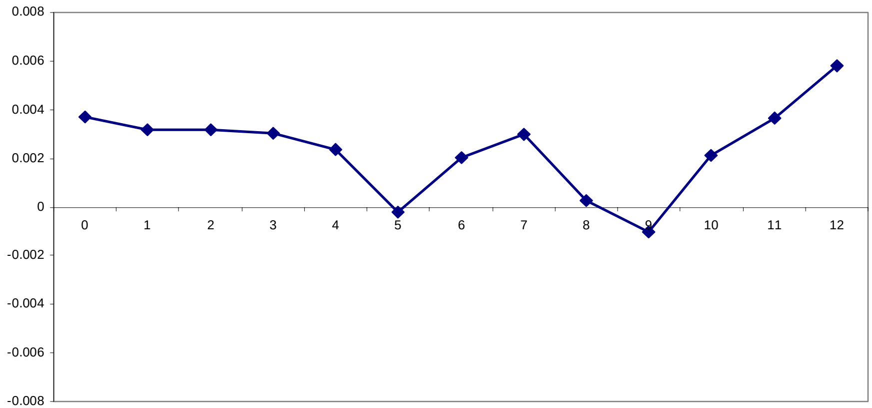
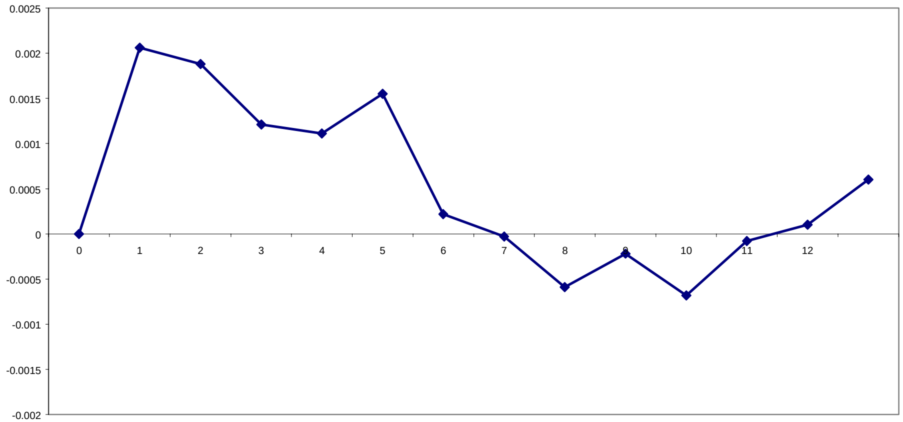
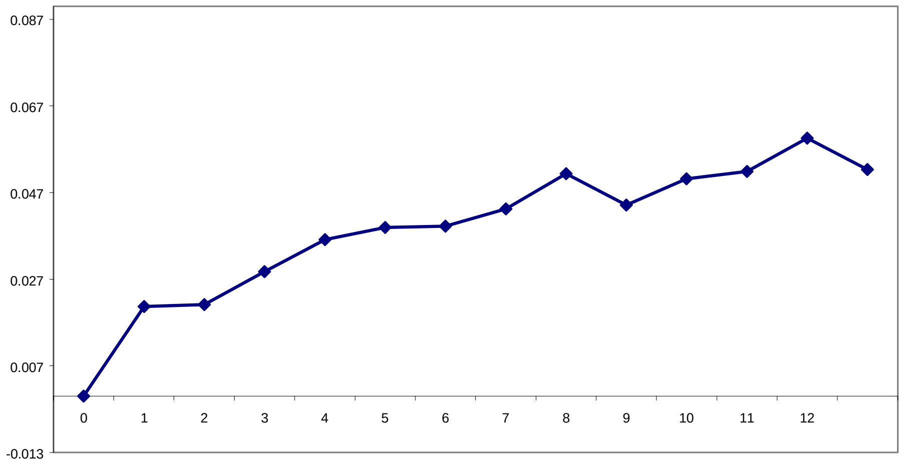


Figure 3 Effects of Country-Specific Productivity Shocks

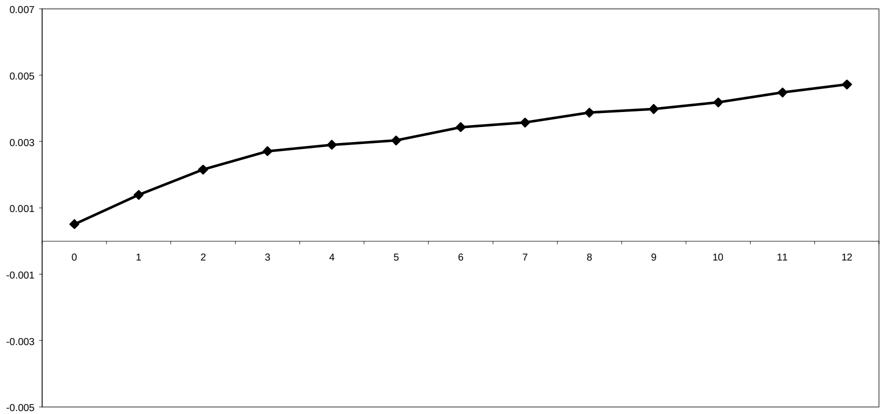
(a) Effects of Country-Specific Productivity Shock on World Productivity



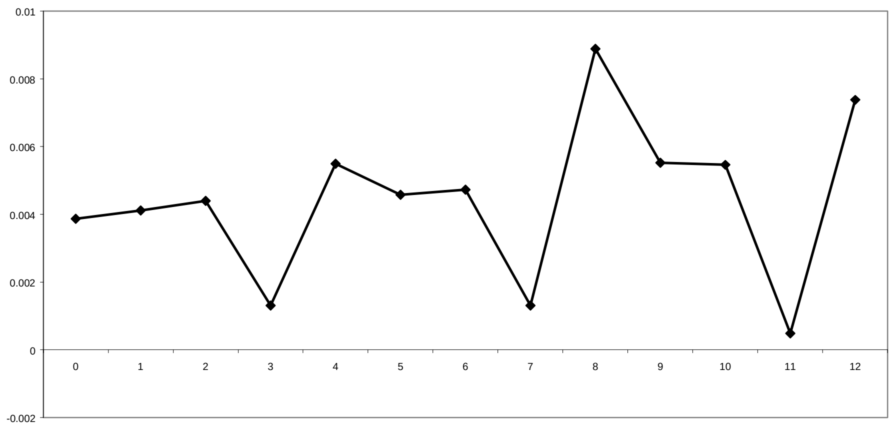
(b)Effects of Country-Specific Productivity on Itself



(c) Effects of Country-Specific Productivity on World Demand



(d) Effects of Country-Specific Productivity on Country-Specific Demand



(e) Effects of Country-Specific Productivity on the Exchange Rate

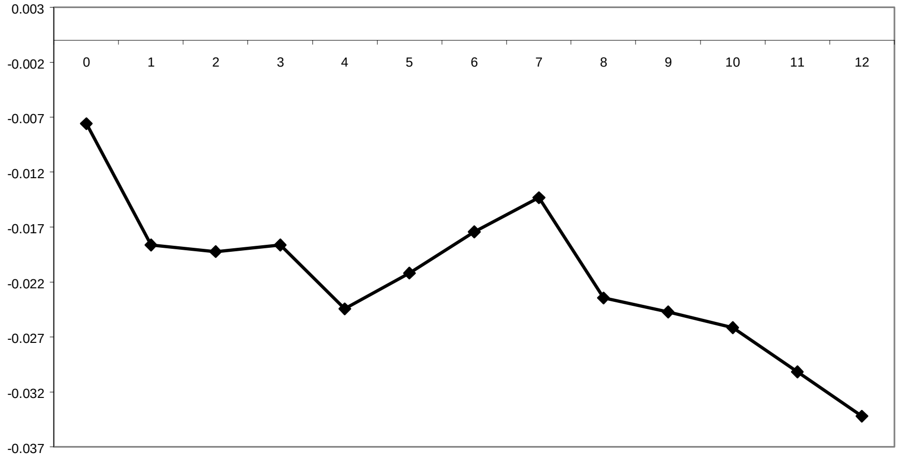
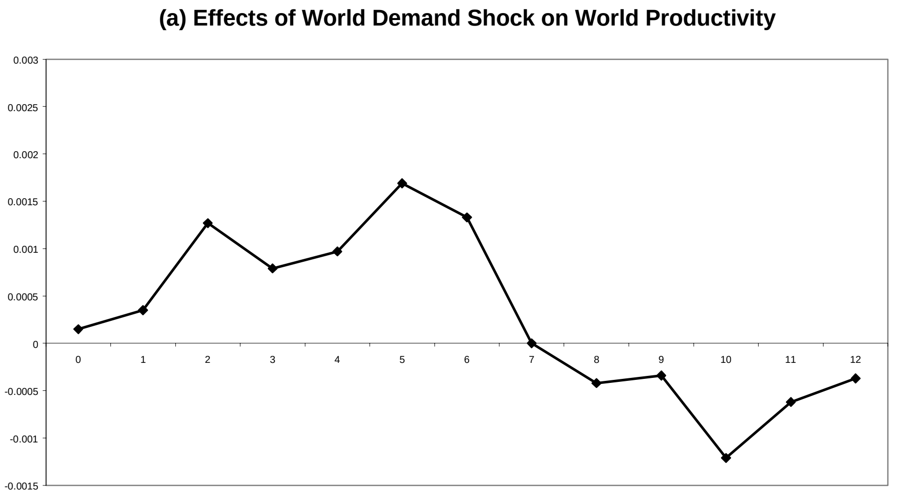
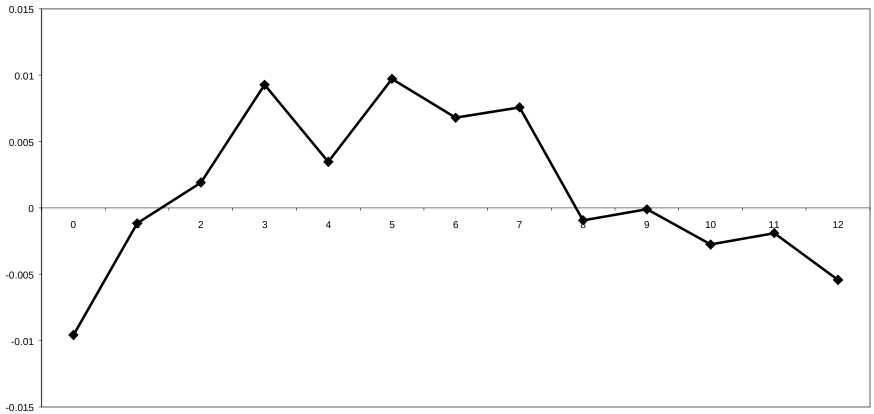


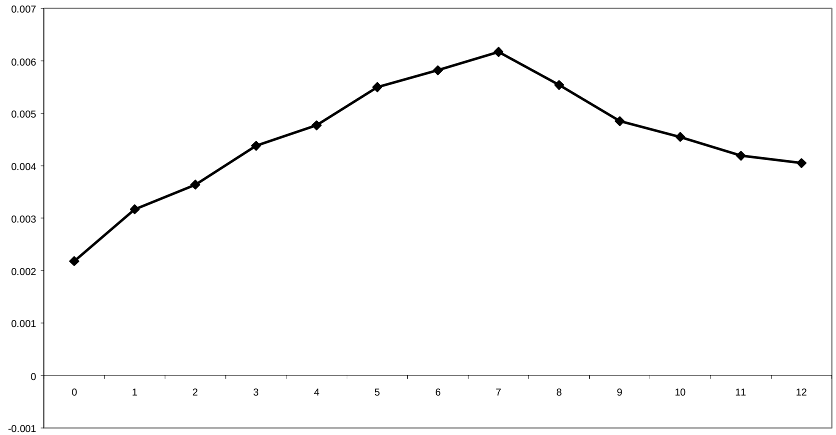
Figure 4 Effects of World Real Demand Shocks



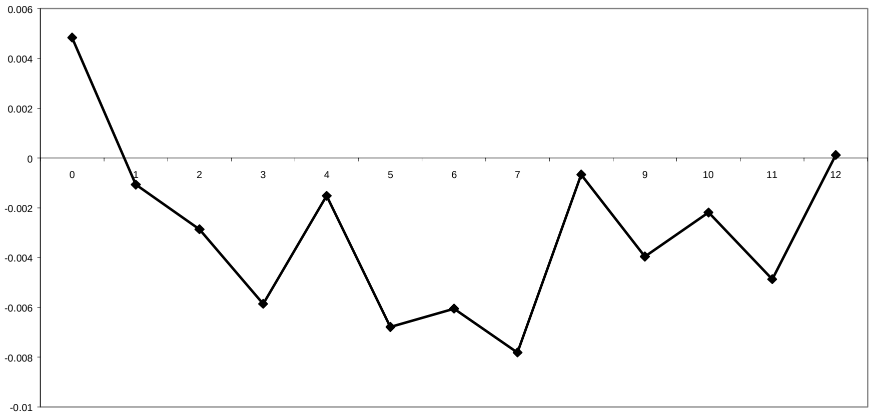
(b) Effects of World Demand Shock on Country-Specific Productivity



(c) Effects of World Demand Shock on World Demand



(d) Effects of World Demand Shock on Country-Specific Demand



(e) Effects of World Demand Shock on Exchange Rate

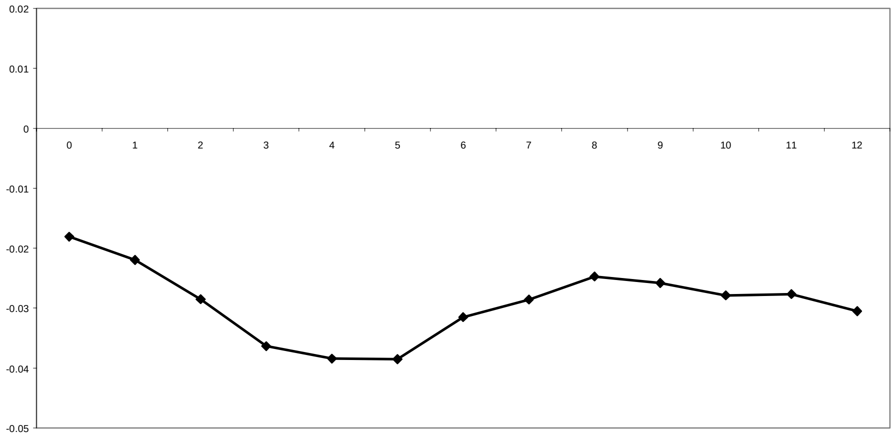
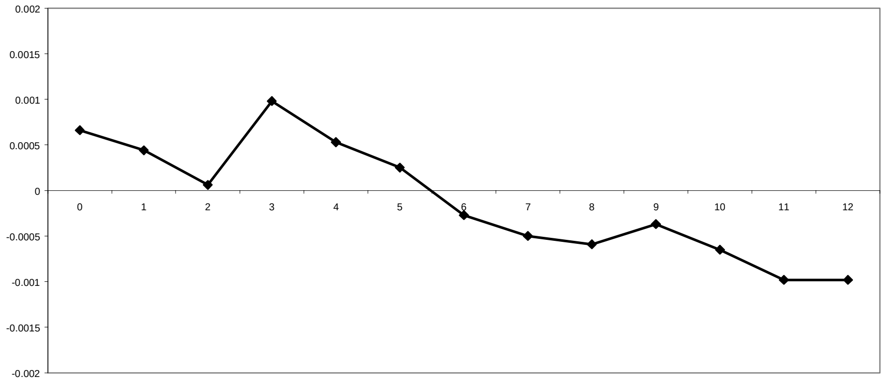
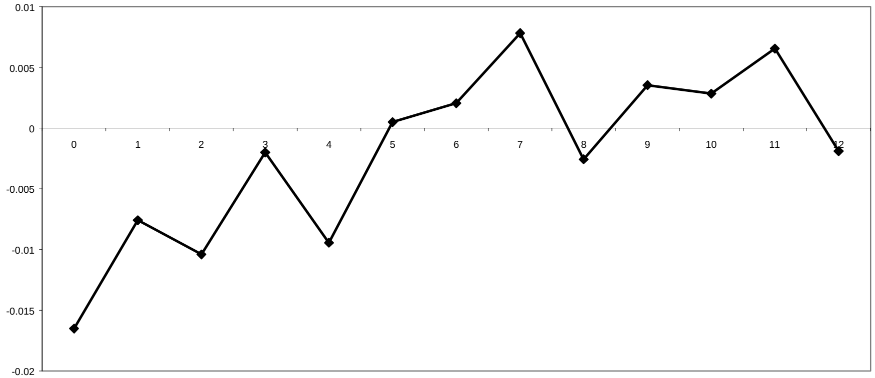


Figure 5 Effects of Country-Specific Real Demand Shocks

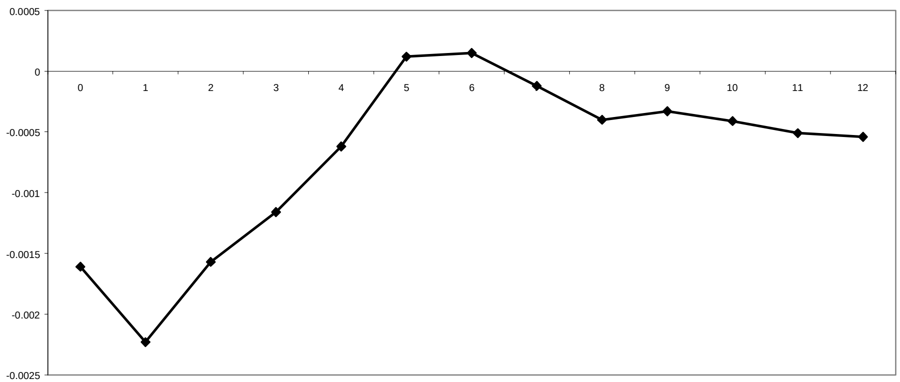
Effects of a Country-Specific Demand Shock on World Productivity



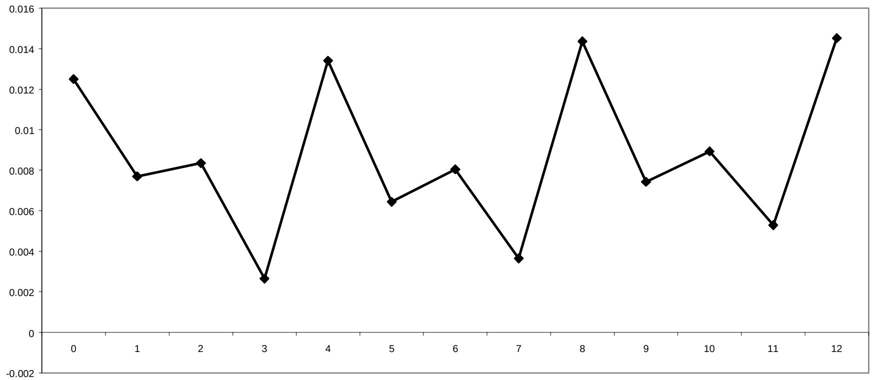
(b) Effects of a Country-Specific Demand Shock on Country-Specific Productivity



(c) Effects of a Country-Specific Demand Shock on World Demand



(d) Effects of a Country-Specific Demand Shock on Country-Specific Demand



Effects of a Country-Specific Demand Shock on the Exchange Rate

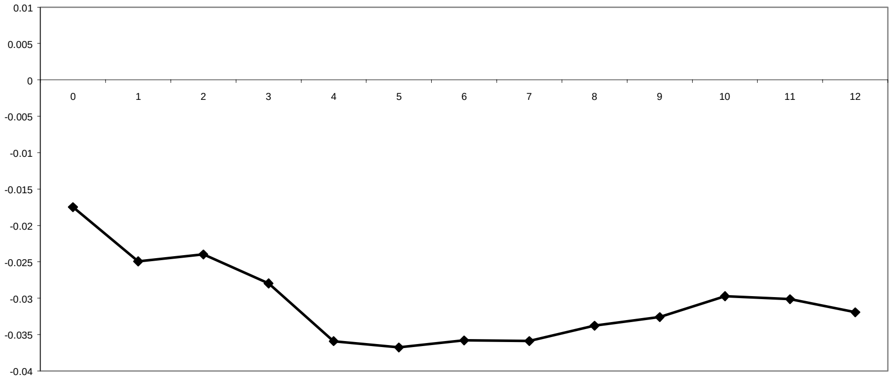
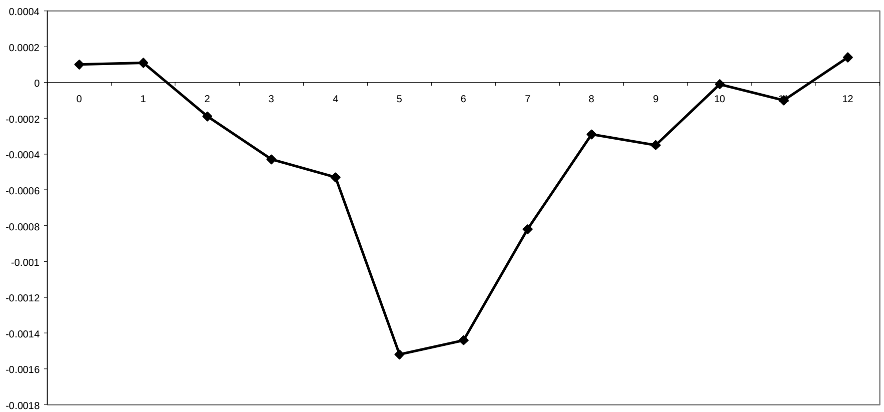
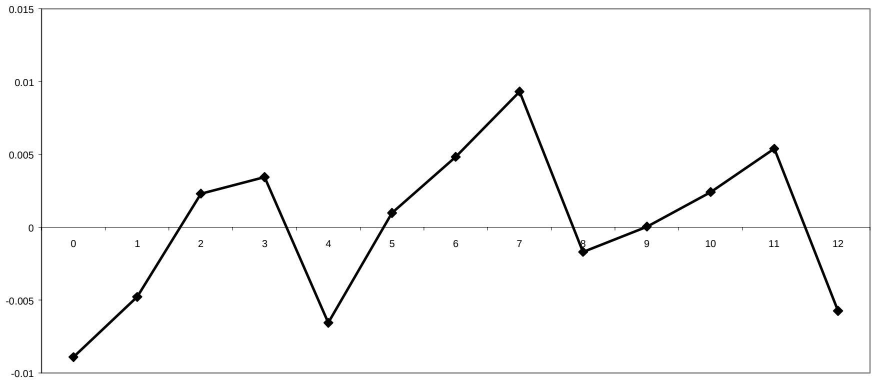


Figure 6 Effects of Monetary (Nominal Exchange Rate) Shocks

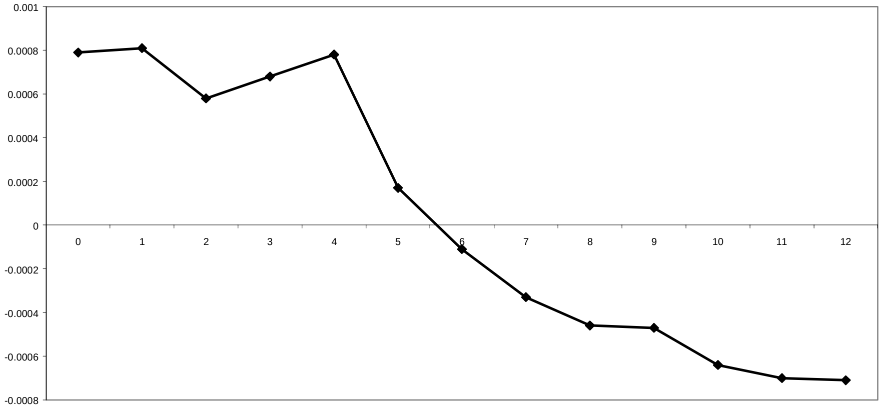
(a) Effects of Monetary Shock on World Productivity



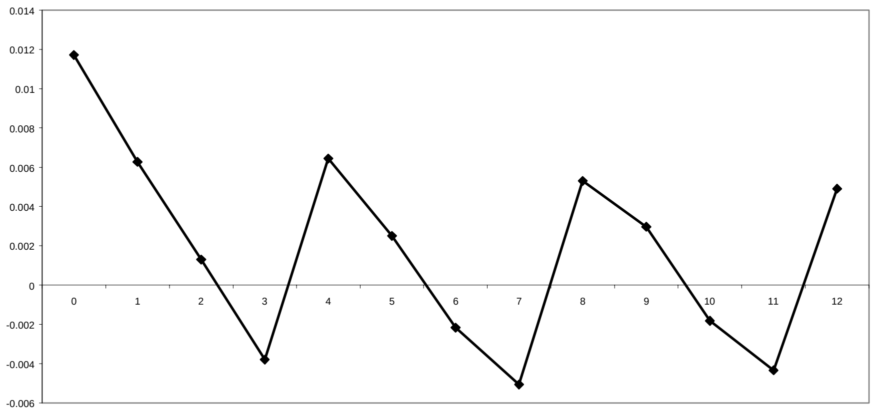
(b) Effects of Monetary Shock on Country-Specific Productivity



(c) Effects of Monetary Shock on World Demand



(d) Effects of Monetary Shock on Country-Specific Demand



(e) Effects of Monetary Shock on Exchange Rate

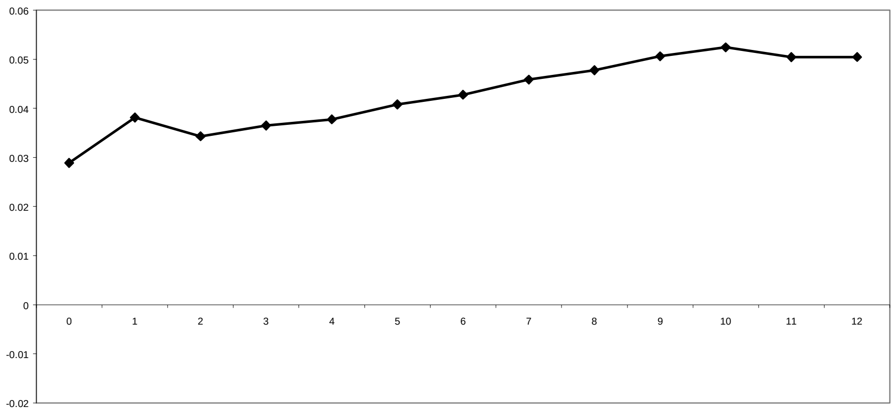
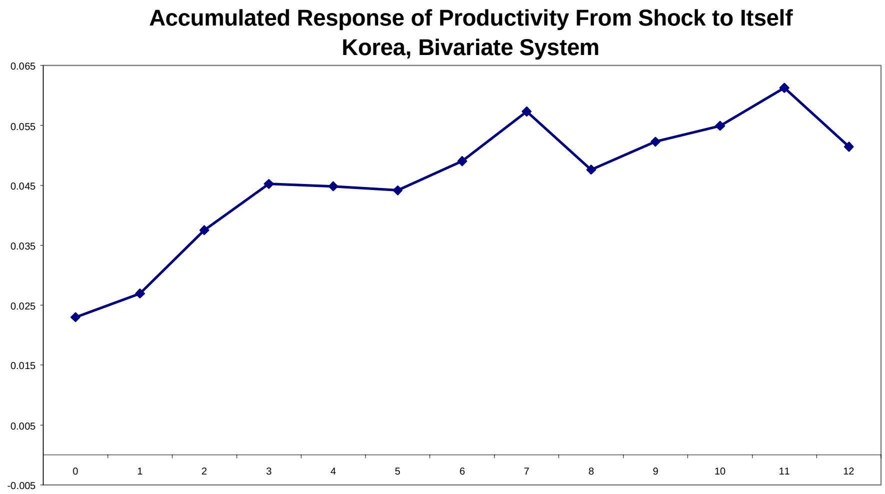


Figure 7 Shocks to Productivity in Bivariate Korean Model



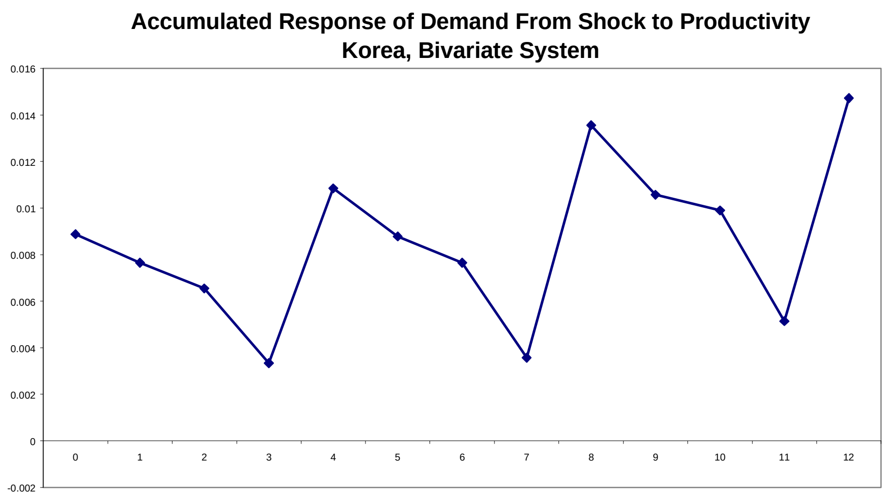
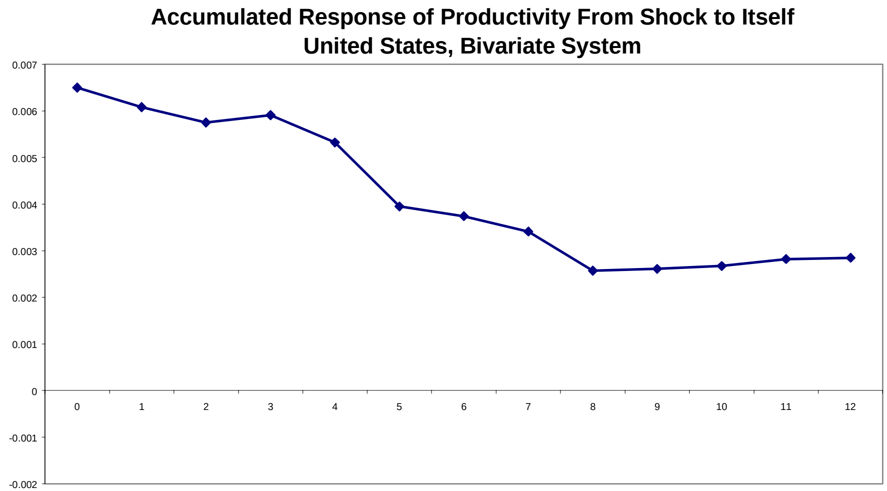
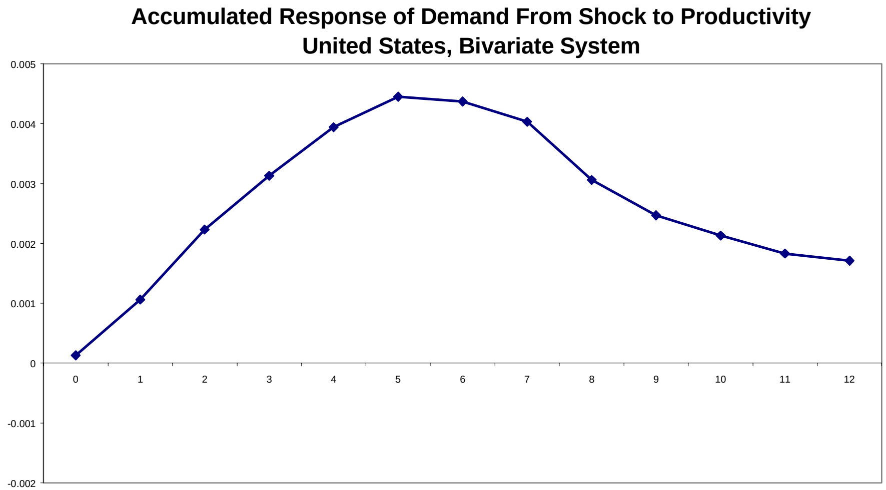


FIGURE 8 Shocks to Productivity in Bivariate Model for the United States




Accumulated Response of Demand From Shock to Productivity
United States, Bivariate System
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
0
1
2
3
4
5
6
7
8
9
10
11
12