The Effects of News About Future Productivity on International Relative Prices: An Empirical Investigation[*]

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Abstract

In this paper, we find that expected (news) and unexpected (contemporaneous) components of productivity changes have opposite effects on the US real exchange rate. Following Barsky and Sims' (2010) identification method, we decompose US total factor productivity (TFP) into news and contemporaneous productivity changes. The US real exchange rate appreciates following a favorable news shock to TFP, while it depreciates in response to a positive contemporaneous shock. In addition, the identified news TFP shocks play a much more important role than the identified contemporaneous TFP shocks in driving the US real exchange rate. These findings provide empirical guidance to important international macroeconomic issues, such as the international transmission of productivity shocks and the modeling of exchange rate volatility.

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1 Introduction

In this paper, we empirically study the effects of expected and unexpected changes in productivity on the real exchange rate. It has long been recognized that changes in expectations about the future path of productivity may be an important source of economic fluctuations. Recently, there has been a revived interest of studying the role of expected changes in productivity, known as news shocks to productivity in the literature, in explaining business cycles. For instance, see Cochrane (1994), Beaudry and Portier (2004, 2006, and 2007), Jaimovich and Rebelo (2009), and Schmitt-Grohe and Uribe (2009), among others. In particular, there is a large body of literature suggesting that changes in expectations about future fundamentals are important in driving asset prices. Fama (1990) and Schwert (1990) find that stock returns are highly correlated with future production growth rates. More recently, Beaudry and Portier (2006) argue that asset prices, such as stock prices, are likely a good measure of any changes in market expectations about future economic conditions. They identify news shocks as innovations in stock prices, which are orthogonal to innovations in some measures of productivity. The identified news shocks predict productivity several years into the future.

On the other hand, some recent research supports that exchange rates behave like the prices of financial assets. Engel and West (2005) show that existing exchange rate models can be written in a present-value asset-pricing format. In these models, exchange rates are determined not only by current fundamentals, but also by expectations of future fundamentals. When the discount factor is close to unity, exchange rate movements are primarily driven by changes in expectations about future economic fundamentals, rather than by changes in current fundamentals. Engel and West (2005) and Chen, Rogoff, and Rossi (2010) find empirical evidence that exchange rates are helpful in forecasting fundamentals. These findings are consistent with exchange rates being determined by fundamentals as in a linear prevent-value asset-pricing model.

The findings that news shocks are important in driving asset prices and that exchange rates behave like asset prices motivate our study of the effects of news shocks to productivity on the real exchange rate. Our paper is also motivated by a discrepancy between model predictions and the data, which is documented in recent studies on the international transmission of productivity shocks. The effect of productivity changes on international relative prices, such as the real exchange rate and the terms of trade, is an important channel for the international transmission of productivity shocks. Standard international macroeconomic models (e.g., Backus, Kehoe, and Kydland, 1992) predict that a country's terms of trade and real exchange rate deteriorate when its productivity increases relative to the rest of the world. Such models imply a positive spillover of productivity gains from one country to another. As a result, additional gains from international risk sharing through financial markets or international policy coordination may be quite limited. For instance, see Cole

and Obstfeld (1991) and Obstfeld an Rogoff (2002). However, recent empirical studies document that the terms of trade and the real exchange rate of the US appreciate, rather than depreciate, when its labor productivity increases relative to the rest of the world. For instance, see Corsetti, Dedola, and Leduc (2006, 2009), Enders and Muller (2009), and Enders, Muller, and Scholl (forthcoming).

Several studies propose theories to reconcile model predictions with these empirical findings. Corsetti, Dedola, and Leduc (2008) and Enders and Muller (2009) emphasize the wealth effect of productivity shocks in driving the terms of trade and the real exchange rate. They show that the responses of the real exchange rate and the terms of trade to productivity changes depend on the extent of home bias in consumption, the substitutability between home and foreign goods, and the persistence of productivity shocks. Corsetti, Martin, and Pesenti (2007) argue that the correlation between labor productivity and international relative prices may also depend on the nature of productivity gains. They consider two types of productivity gains: the first reduces the cost of producing existing products, while the second reduces the cost of creating new firms and new product varieties. In a model with both internal and external margins of international trade, they show that the second type of productivity gains can improve the terms of trade while the first type deteriorates the terms of trade.

Nam and Wang (2010) explore the role of news about future total factor productivity (TFP) in driving international relative prices. An important feature of the news shock is its impact on present variables through the wealth effect. When expecting an increase of productivity in the future, households increase consumption immediately, even if present TFP remains constant. When consumption is biased towards home goods, the increase in aggregate consumption falls disproportionately on home goods, therefore raising home goods prices relative to foreign goods prices. In a dynamic stochastic general equilibrium (DSGE) model modified with news shocks to TFP and variable capital utilization, Nam and Wang (2010) show that the terms of trade and the real exchange rate appreciate and labor productivity increases following a positive news shock. The appreciation of the terms of trade is due to the wealth effect described above and the increase in labor productivity is due to the increase in capital utilization following good news about future productivity.

In this paper, we decompose the variation in US productivity into news and contemporaneous shocks following the method proposed in Barsky and Sims (2010). Their method is highly flexible and only imposes a minimum of restrictions based on the definition of news shocks: news shocks only change future productivity and are orthogonal to contemporaneous shocks that affect productivity immediately. We then study the effects of news and contemporaneous shocks to productivity on the US real exchange rate and the relative importance of these two shocks in driving the US real exchange rate at different horizons. Findings in this

paper can help us evaluate the empirical relevance of news shocks to TFP in Nam and Wang (2010) as an explanation of the discrepancy documented in studies of the international transmission of productivity shocks. In addition, they can shed some light on the importance of news shocks in modeling exchange rate volatility.

We include in our benchmark vector error correction model (VECM) the utilization-adjusted TFP series in Basu, Fernald, and Kimball (2006), as well as measures of per capita output, consumption, investment, hours worked, and the real exchange rate. It is crucial that the measure of productivity must be adjusted for the utilization rate because news shocks can change capital utilization and increase measured productivity immediately if it is not adjusted. The unadjusted measure of productivity invalidates Barsky and Sims' (2010) identification assumption that news shocks have no immediate effect on productivity. We find that the US real exchange rate appreciates in response to a positive news shock to TFP, while it depreciates in response to a positive contemporaneous shock. The finding that news and contemporaneous shocks to TFP have opposite effects on the US real exchange rate is consistent with the theoretical predictions in Nam and Wang (2010).

In addition, the identified news shocks to TFP play a much more important role than the identified contemporaneous shocks in driving the US real exchange rate. The identified news shocks to TFP explain between 30-50% of the forecast error variance of the US real exchange rate at horizons of 4 quarters and less. At horizons of 8 quarters and more, they explain about 60% of the the forecast error variance. In contrast, the identified contemporaneous shocks to TFP explain almost none of the forecast error variance of the US real exchange rate at horizons of 4 quarters and less, and only about 15% at horizons of 8 quarters and more. This finding suggests that anticipated changes in future productivity are more important than current productivity in determining the US real exchange rate, providing support to the literature of studying exchange rates as asset prices. Given that news shocks to TFP are important in driving exchange rate movements in the data and a positive news TFP shock can simultaneously produce an appreciation of the real exchange rate and an increase in labor productivity as shown in Nam and Wang (2010), it may not be surprising to find an appreciation of the real exchange rate following an increase in labor productivity in empirical studies that do not differentiate contemporaneous and news shocks to productivity.

The real exchange rate is much more volatile than output in the data and it is difficult to generate this relative volatility in standard international macroeconomic models. For instance, see Chari, Kehoe, and McGrattan (2002) and Devereux and Engel (2002), among others. Matsumoto, Cova, Pisaniz, and Rebucci (2010) argue that the high volatility of asset prices in the data may be a result of news shocks to fundamentals. They show that introducing news shocks to a canonical DSGE model can increase the

volatility of asset prices. Nam and Wang (2010) report similar results for the real exchange rate in the simulated data of a DSGE model with news shocks to TFP. In this paper, we find that the relative volatility of the US real exchange rate conditional on news shocks to TFP is about twice as volatile as that conditional on contemporaneous shocks to TFP. This finding provides empirical support to theoretical studies that use news shocks to generate exchange rate volatility in international macro models.

Our empirical findings are robust to systems that are either larger or smaller than our benchmark specification, to the corresponding VAR specifications when all variables are in their levels, and to the case of using cross-country differences of the data instead of US data as in our benchmark model. Similar results also hold when we replace the real exchange rate with the terms of trade in our empirical models. In addition, we extend our study to several other countries: Australia, Japan, New Zealand, Norway, and the UK. Utilization-adjusted TFP is not available for these countries, however. In response, we apply the shape restrictions identification method in Barsky and Sims (2010) to estimate the impulse response functions to news productivity shocks in these countries. Except in Japan, there is no strong evidence that the real exchange rate and the terms of trade appreciate following a positive news shock to productivity. Besides the data issue, other factors may have caused the heterogeneity across countries including the extent of home bias in consumption, the length of news shocks, and the availability of financial credit to finance increases in consumption from good news about future productivity.

The remainder of the paper is arranged as follows. Section 2 describes our empirical strategy and the data. Sections 3 and 4 present our main empirical findings in the US and other countries, respectively. Section 5 concludes and discusses directions for future research.

2 Empirical Strategy and Data

2.1 Identification Strategy

In this section, we give a brief description of Barsky and Sims' (2010) identification method. See Beaudry and Portier (2006), Beaudry, Dupaigne, and Portier (2008), and Beaudry and Lucke (2009) for examples of other identification strategies for news shocks to productivity.

In Barsky and Sims (2010), it is assumed that variation in TFP is fully explained by two distinct shocks: one that has an immediate effect on TFP (called the contemporaneous shock) and the other that only affects future TFP (called the news shock). The contemporaneous shock is identified as reduced form innovations in TFP from a VAR or VECM. Given the restriction that the news shock has no immediate effect on TFP,

it is identified as a structural shock that is orthogonal to the contemporaneous shock and can account for as much variation in observed future TFP as possible.

For any VAR or VECM, the reduced form moving average representation for an $N \times 1$ vector of variables, Y_t, can be expressed as:

$$Y_t = B(L) u_t,$$

where $B(0) = I_N$ and u_t is reduced form innovations with a variance-covariance matrix of Σ_u. The relationship between reduced form innovations u_t and structural shocks ϵ_t is $u_t = A_0 \epsilon_t$, where $A_0 A_0' = \Sigma_u$ and the variances of structural shocks are normalized to be unity. Note that A_0 is not unique. Let $\widetilde{A}_0$ denote an arbitrary orthogonalization of Σ_u (e.g., $\widetilde{A}_0$ is the Cholesky decomposition of Σ_u such that $\widetilde{A}_0 \widetilde{A}_0' = \Sigma_u$) and D denote an orthonormal matrix of conformable size (i.e., $DD' = I_N$). Then, the matrix $\widetilde{A}_0 D$ spans the space of possible orthogonalizations of Σ_u. That is, $u_t = A_0 \epsilon_t = \widetilde{A}_0 D \epsilon_t$.

The h-step ahead forecast error of Y_{t+h}, in terms of the structural shocks over the space of possible orthogonalizations, is:

$$Y_{t+h} - E_{t-1}[Y_{t+h}] = \sum_{\tau=0}^{h} B_\tau \widetilde{A}_0 D \epsilon_{t+h-\tau},$$

where $B_\tau \widetilde{A}_0 D$ is the coefficient matrix of the structural moving average representation at horizon τ. Then, the share of the forecast error variance of variable i attributable to structural shock j at horizon h is:

$$\Omega_{i,j}(h) = \frac{\mathbf{e}_i' \left(\sum_{\tau=0}^{h} B_\tau \widetilde{A}_0 D \mathbf{e}_j \mathbf{e}_j' D' \widetilde{A}_0' B_\tau' \right) \mathbf{e}_i}{\mathbf{e}_i' \left(\sum_{\tau=0}^{h} B_\tau \Sigma_u B_\tau' \right) \mathbf{e}_i} = \frac{\left(\sum_{\tau=0}^{h} \mathbf{B}_{i,\tau} \widetilde{A}_0 \gamma_j \gamma_j' \widetilde{A}_0' \mathbf{B}_{i,\tau}' \right)}{\left(\sum_{\tau=0}^{h} \mathbf{B}_{i,\tau} \Sigma_u \mathbf{B}_{i,\tau}' \right)},$$

where $\mathbf{e}_k$ $(k = i, j)$ is the selection vector, $\mathbf{B}_{i,\tau}$ is the ith row of B_τ, and γ_j is the jth column of D. Note that $var\left(\widetilde{A}_0 D \epsilon_t \right) = var(u_t) = \Sigma_u$ for any t and $\widetilde{A}_0 \gamma_j$ is an $N \times 1$ vector corresponding to the jth column of a possible orthogonalizing matrix (i.e., the jth column of A_0).

Without loss of generality, let the contemporaneous and news shocks be the first and second structural shocks, $\epsilon_{1,t}$ and $\epsilon_{2,t}$. In this case, the first element of Y_t is a measure of TFP. The assumption that the news and contemporaneous shocks account for all variation in TFP at all horizons implies that:

$$\Omega_{1,1}(h) + \Omega_{1,2}(h) = 1 \quad \forall\, h.$$

The news and contemporaneous shocks are identified by choosing the elements of A_0 such that the above condition holds as closely as possible. With the contemporaneous shock being identified as innovations in

TFP, the share of the forecast error variance of TFP attributable to the contemporaneous shock (i.e., $\Omega_{1,1}(h)$) will be invariant to all alternative identifications of the other $N-1$ structural shocks at all horizons. As a result, the above problem is equivalent to maximizing the contribution of the news shock to the variation in TFP, $\Omega_{1,2}(h)$, over time horizon h.[1] This is similar to the maximum forecast error variance strategy proposed in Francis, Owyang, and Roush (2007). We leave the details of this optimization problem to the appendix.

2.2 Data and Empirical Models

Our empirical study uses quarterly US data over the post-Bretton Woods period from 1973:Q1 to 2007:Q4. The ending date of our sample is chosen to avoid the effects of the recent global financial crisis on exchange rates. Exchange rates during the global financial crisis are driven by factors not captured by conventional economic fundamentals, such as productivity. For instance, flight to quality usually plays an important role in driving exchange rate movements during financial crises. Engel and West (2010) find that most of the strength of the US dollar in 2008 and 2009 is mainly driven by the change in the risk premium. As a result, we end our sample in the last quarter of 2007.

In our benchmark model, we estimate a vector error correction model (VECM) with six variables: total factor productivity (TFP), output per capita, consumption per capita, investment per capita, hours worked per capita, and the real exchange rate. As a robustness check, we also consider a larger system that includes two additional variables – inflation and nominal interest rates.

TFP is measured by the quarterly utilization-adjusted TFP series provided by Fernald (2009).[2] The news shock to productivity is identified in our empirical study with the restriction that it has no immediate effect on productivity and only affects future productivity. In Nam and Wang (2010), however, they show, in a model with variable capital utilization, that a positive news shock to TFP, like a positive contemporaneous shock, can also increase labor productivity immediately because it raises the capital utilization rate. The utilization-adjusted TFP series helps us distinguish news and contemporaneous shocks better than the labor productivity series that is not adjusted for capital utilization. We retrieve real output and total hours worked in the non-farm business sector from the US Bureau of Labor Statistics (BLS). Real personal consumption expenditures of nondurable goods and services and real gross private domestic investment are obtained from the US Bureau of Economic Analysis (BEA) as our measures of consumption and investment, respectively.

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[1] In our empirical study, we maximize $\sum_{h=0}^{H} \Omega_{1,2}(h)$, where the truncation horizon H is set to 40.

[2] Utilization-adjusted TFP data are obtained from John Fernald's website. The series is provided in terms of annualized percentage changes (i.e., 400 times changes in the logarithms of quarterly data). The quarterly series in level is recovered by dividing the original data by 400 and then cumulating it.

We divide these four series by the population (civilian non-institutional population aged sixteen and over from BLS) to convert them into per capita values. All series are then logged. In a robustness check, we also use labor productivity as a measure of TFP. Labor productivity is measured by output per hour in the non-farm business sector, obtained from BLS.

The real exchange rate is defined as the foreign price divided by the price in the US. As a result, an increase in the real exchange rate indicates a depreciation of the US dollar. We use the log of the inverse of the US trade-weighted real exchange rate as our measure of the real exchange. The nominal interest rate is measured by the effective federal funds rate. Both series are taken from the Federal Reserve database. The inflation rate is measured by CPI inflation for all urban consumers and all items, which is obtained from BLS.

Using the unit root test proposed in Elliott, Rothenberg, and Stock (1996), we fail to reject unit roots at a 10% significance level for TFP, per capita output, consumption, investment, and labor productivity. In all model specifications considered below, these variables are assumed to be I(1) variables. Remaining variables, including hours worked, the real exchange rate, the inflation rate, and the interest rate are assumed to be stationary.[3]

Based on the properties of the data described above, the following VECM is employed in our empirical study:

$$\Delta Y_t = C + \Phi Y_{t-1}^N + \Gamma_1 \Delta Y_{t-1} + \cdots + \Gamma_p \Delta Y_{t-p} + u_t,$$

where $\Delta Y_t = (\Delta Y_t^N \quad Y_t^S)'$. Y_t^N is the vector containing all nonstationary variables and Y_t^S is the vector containing all stationary variables. Depending on model specifications, Y_t^N and Y_t^S may contain different variables.

3   Empirical Results

This section reports the results using US data. In the benchmark specification, we estimate a VECM of six variables in the US: TFP, output per capita, consumption per capita, investment per capita, hours worked per capita, and the real exchange rate. As mentioned in the last section, hours worked and the real exchange rate are treated as stationary variables and the remaining variables are I(1). We assume there are three cointegrating relationships among nonstationary variables and the number of lags in the VECM, p, is set to

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[3]The results of unit root tests are available upon request.

3. Changing the number of cointegrating relationships and the number of lags does not change our main results qualitatively. As a robustness check, we estimate a VAR with all variables in their levels. The VAR estimation produces consistent estimates of the impulse response functions and is robust to the form of cointegration. Our main findings hold up well in the estimation of the VAR.[4]

There are two sets of main results. First, we show with impulse response functions that the US real exchange rate appreciates in response to a positive news shock to TFP, while it depreciates following a positive contemporaneous shock to TFP. In both cases, the real exchange rate exhibits hump-shaped (delayed overshooting) impulse response functions. Next, we use several variance decompositions to show that news shocks to TFP are more important than contemporaneous shocks to TFP in driving the US real exchange rate.

As robustness checks, we also report the results for two alternative specifications. The first one is a smaller system with only four variables: TFP, output per capita, consumption per capita, and the real exchange rate. The second is a larger system with eight variables: the six variables included in our benchmark specification plus the inflation rate and the nominal interest rate. Following Enders and Muller (2009), these two nominal variables are included to control for the potential effects of monetary policy and price rigidities on the transmission of productivity shocks.

3.1 Impulse Response Functions

Before presenting our results for contemporaneous and news shocks to TFP, we first show that our data can replicate the appreciation of the US real exchange rate following a positive productivity shock identified by the long-run restrictions method as in Corsetti, Dedola, and Leduc (2008) and Enders and Muller (2009). Figure 1 shows the impulse response functions to a positive productivity shock where productivity shocks are identified by assuming that only these shocks affect productivity in the long run, as in Gali (1999). In Sub-figures 1(a) and 1(b), productivity is measured by utilization-adjusted TFP and output per hour, respectively. In both cases, the US real exchange rate appreciates following a positive shock to productivity. The impulse response functions of all variables are similar to those in previous empirical studies. It is unlikely that there is something special in our data sample that drives the empirical findings reported next.

Figure 2 presents the estimated impulse response functions under our benchmark specification. Sub-figures 2(a) and 2(b) display impulse response functions with respect to a favorable news and contemporaneous TFP shock, respectively. The circles in these charts are point estimates and the shaded areas are one-standard-error bands obtained by bootstrap sampling with 2000 replications. Following a favorable news

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[4]Results of the VAR and the VECM with different cointegrating relationships and lags are available upon request.

shock, TFP, output, consumption, and investment all rise and then converge to their new long-run levels, indicating the news TFP shock has a permanent effect on these variables. Hours worked decline on the impact of the news shock and exhibit a hump-shaped response. The decline of hours worked on impact of the shock is due to the wealth effect of good news about future productivity. Households decrease the supply of labor, in other words, increase the consumption of leisure when expecting an increase in productivity in the future. Similar results are also documented in Barsky and Sims (2010).

Following a favorable contemporaneous shock, TFP, output, consumption, investment, and hours worked all increase on impact and then revert back to their initial levels, indicating that the contemporaneous TFP shock has mainly transitory effects. The identification strategy of Barsky and Sims (2010) places no ex ante restriction on the long-run effects of news and contemporaneous shocks. Instead, the data will decide if each shock has a transitory or permanent effect on each variable. Our finding is consistent with Barsky and Sims' (2010) result that news shocks to TFP account for a large fraction of low frequency variation in technology, while contemporaneous shocks are mainly transitory, but persistent. The simultaneous increase in macroeconomic aggregates following a favorable contemporaneous TFP shock is also consistent with the aggregate co-movement features documented in previous empirical studies of real business cycles (RBC) and the predictions of standard RBC models.

The most striking observation in our results is that news and contemporaneous shocks to TFP have opposite effects on the US real exchange rate. The impulse response functions of the real exchange rate are shown in the last chart of Sub-figures 2(a) and 2(b). By definition, an increase in the real exchange rate indicates a real depreciation of the US dollar. The US real exchange rate appreciates following a positive news TFP shock, while it depreciates after a positive contemporaneous TFP shock. The real exchange rate appreciates immediately following a positive news shock and remains in the appreciative territory in the following periods. In contrast, the response of the real exchange rate after a positive contemporaneous shock is nearly zero on impact. However, the real exchange rate depreciates significantly and exhibits a hump-shaped response over the following periods. In both cases, the real exchange rate converges back to its initial level, indicating that both shocks have no long-run effect on the real exchange rate.

The estimated impulse response functions of the US real exchange rate exhibit delayed overshooting for both news and contemporaneous TFP shocks. The real exchange rate continues to appreciate or depreciate for about 8 quarters after the shock in these two cases. Our finding of delayed overshooting is consistent with previous studies in the literature. For instance, see Corsetti, Dedola, and Leduc (2006), Enders and Muller (2009) for examples of using the long-run restrictions method in SVAR models, or Steinsson (2008) for a univariate example.

The real appreciation following a positive news TFP shock could be caused by an increase in nontradable goods prices relative to tradable goods prices (the Balassa-Samuelson effect). However, when we replace the real exchange rate with the terms of trade in our empirical exercises, the estimated responses of the terms of trade exhibit similar patterns as those of the real exchange rate in Figure 2. This finding suggests that our results for the real exchange rate are not mainly driven by the Balassa-Samuelson effect.

Our empirical finding that news and contemporaneous shocks to TFP have opposite effects on the real exchange rate and the terms of trade is consistent with model predictions in Nam and Wang (2010). In that paper, they show in a two-country DSGE model that the wealth effect of good news about future productivity increases consumption. When there is a home bias in consumption, the increase in aggregate consumption falls disproportionately on home goods, therefore raising home goods prices relative to foreign goods prices. A positive contemporaneous TFP shock has a similar wealth effect. However, the contemporaneous shock also raises TFP immediately and therefore the supply of home goods. This supply effect tends to decrease home goods prices relative to foreign goods prices. In standard open-economy macroeconomic models (e.g., Backus, Kehoe, and Kydland, 1992), the supply effect dominates the wealth effect. As a result, the real exchange rate and the terms of trade depreciate following a positive contemporaneous shock to TFP, but appreciate following a positive news shock in Nam and Wang (2010). The findings in this paper provide empirical support to Nam and Wang (2010).

An important parameter affecting Nam and Wang's (2010) results is the length of the news shock, in other words, the interval between the arrival of the news and the actual change in TFP the news forecasts. In their benchmark model, Nam and Wang (2010) show that the real exchange rate appreciates on the impact of a favorable news TFP shock if the length of the news shock is 8 quarters or more. In addition, when the elasticity of substitution between home and foreign goods is set to a level commonly used in the trade literature, 4, a length of 4 quarters is sufficient to generate an appreciation of the real exchange rate after a favorable news shock. In general, the greater the length of the news shock, the stronger the appreciation of the real exchange rate following a positive news shock. In Figure 2(a), TFP does not rise significantly above zero until 6 quarters after the shock at a one standard-error band level, and 10 quarters at a 90% confidence level. This result suggests that good news about future productivity may not materialize until 6 or more periods later, indicating a length of 6 or more quarters for the news shock. A similar length for the news shock is also found in Beaudry and Portier (2006), though Barsky and Sims (2010) find a shorter length.

3.2   Variance Decompositions

In this subsection, we present three sets of results: a decomposition of the forecast error variance, a historical decomposition of real exchange rate movements, and a decomposition of business cycle variance. All of these results provide evidence that the news shock to TFP plays an important role in driving the US real exchange rate.

3.2.1   Decomposition of the Forecast Error Variance

Table 1 reports the shares of the forecast error variance (FEV) that are attributed to news and contemporaneous TFP shocks, respectively, at various horizons for each variable in our benchmark model. The lower panel of Table 1 reports the sum of the shares of the FEV attributed to these two shocks.

At short horizons, the FEV of TFP comes mainly from the contemporaneous shock. The news shock accounts for less than 5% of the FEV of TFP for forecast horizons less than 8 quarters. In contrast, the contemporaneous shock accounts for more than 85% of the FEV of TFP for forecast horizons of 8 quarters and less. With the increase in the forecast horizon, the share of the FEV attributed to the news shock rises. The news shock accounts for a larger portion of TFP forecast error variance than the contemporaneous shock at horizons of 24 quarters and more. In total, the contemporaneous and news shocks account for more than 90% of the FEV of TFP at all horizons equal to or less than 40 quarters. This is consistent with the identification assumption that all variation in TFP can be explained by the contemporaneous and news TFP shocks.

The news shock explains a small share of the FEV of output, consumption and investment at short horizons, but a relatively large share at long horizons. The contemporaneous shock, however, exhibits the opposite pattern for these variables. For instance, the share of the news shock in the FEV of output increases from 1% at horizon zero to 38% at horizon 40. In contrast, the share of the contemporaneous shock in the FEV of output declines from 70% at horizon zero to 9% at horizon 40. On the other hand, the contribution of the news shock to the FEV of hours worked is larger at short horizons (e.g., 27% at horizon zero) than at medium and long horizons (e.g., 10% at horizon 40). The contribution of the contemporaneous shock to the FEV of hours worked is almost zero at all horizons. Overall, the news shock contributes more than contemporaneous shocks to the FEV of consumption and hours worked at both short and long horizons. In general, our results of FEV decomposition for these variables are similar to those in Barsky and Sims (2010).

The most interesting observation of our FEV decomposition results comes from the real exchange rate. The news TFP shock plays a much more important role than the contemporaneous TFP shock in explaining

the FEV of the real exchange rate at all horizons. At horizon zero, the news shock accounts for 32% of the FEV of the real exchange rate, while the contemporaneous shock accounts for almost none of the FEV of the real exchange rate. This difference becomes more pronounced at longer horizons. For instance, at horizon 40, the news shock accounts for 57% of the real exchange rate FEV, while the contemporaneous shock accounts for only 16%. Our finding that news shocks are more important than contemporaneous shocks in driving the US real exchange rate provides empirical support to the argument that exchange rate movements are mainly driven by changes in expectations of future fundamentals rather than current fundamentals (e.g., Engel and West, 2005).

In total, these two shocks to TFP account for a large portion (about 70%) of the FEV of the US real exchange rate at long horizons (8 quarters or more). At short horizons (4 quarters or less), however, these two shocks only explain at most half of the FEV of the US real exchange rate. This suggests that other shocks, such as demand, monetary policy, or financial market shocks, may also play an important role for fluctuations in the US real exchange rate in the short run. For instance, Clarida and Gali (1994) find that demand shocks explain a large portion of variation in the US real exchange rate. Chadha and Prasad (1997) find that both demand and productivity shocks are important in explaining the Japanese yen-US dollar exchange rate. Farrant and Peersman (2006) find that nominal shocks, such as monetary policy shocks, play an important role in driving the exchange rate, although Faust and Rogers (2003) find only a minor role for monetary policy shocks in exchange rate volatility.

3.2.2 Historical Decomposition of the Real Exchange Rate

Figure 3 plots the cumulative effects of the identified news and contemporaneous shocks to TFP on the US real exchange rate during our sample period (the solid lines). The cumulative effect of each shock in these plots is the fitted value of the real exchange rate (in the log level) conditional on that shock. For the purpose of comparison, the de-meaned actual log real exchange rate series (the dashed line) is also plotted. Sub-figures 3(a) and 3(b) show the cumulative effects of the news and contemporaneous TFP shocks, respectively. Historically, these charts indicate that both news and contemporaneous shocks to TFP have made fairly significant contributions to the fluctuations of the US real exchange rate. Overall, the real exchange rate conditional on the news TFP shock traces the actual real exchange rate more closely than that conditional on the contemporaneous TFP shock, suggesting the news shock accounts for a larger portion of the variation in the US real exchange than the contemporaneous shock.

In addition, the share of US real exchange rate fluctuations attributed to the contemporaneous TFP shock, relative to the share attributed to the news TFP shock, seems to have declined since the late 1980s.

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After 1985, the cumulative effect of the news shock on the real exchange rate in Sub-figure 3(a) traces the actual real exchange rate very closely, while the cumulative effect of the contemporaneous shock stays relatively flat during this period. This could be a result of the news shock becoming more important than the contemporaneous shock in driving TFP during this period. Jaimovich and Rebelo (2009) argue that news about future productivity becomes increasingly available after 1985 due to the rapid progress made in the information technology industry. According to their argument, news shocks to TFP become relatively more important in driving business cycles, which partially contributed the Great Moderation after the mid 1980s.

Figure 4 displays the time series plots of identified news and contemporaneous shocks to TFP. The time series are expressed as a four-quarter moving average to smooth out noises in the series and make the charts easier to read. Sub-figures 4(a) and 4(b) show the plots of the news and contemporaneous shocks, respectively. We divide the sample into two sub-samples – before and after 1985, and calculate the standard deviation of the news shock relative to the standard deviation of the contemporaneous shock in each sub-sample. The relative standard deviation of the news shock increases from 0.89 in the sub-sample before 1985 to 1.09 in the sub-sample after 1985. This finding supports the argument that the size of the news TFP shock relative to the contemporaneous TFP shock becomes larger after 1985.

The economic boom of the late 1990s and the subsequent slowdown are considered as good examples of expectations-driven business cycles. For instance, Jaimovich and Rebelo (2009) show that investment of companies in the Standard & Poor's 500 is positively correlated with forecasts of these companies' earnings, but negatively correlated with realized earnings during this period. One plausible interpretation is that high expectations of future earnings driven by the prospects of technology improvement lead to an increase in investment. However, when realized technology improvements failed to live up to expectations, investment fell. In Figure 4(a), there is a series of large positive news shocks to US TFP from the late 1990s to the early 2000s. Meanwhile, there are several large negative contemporaneous TFP shocks around 2000. This pattern of news and contemporaneous shocks is consistent with the above story of expectations-driven economic boom and bust during this period. We acknowledge, however, that studying whether US business cycles are in general driven by news shocks to TFP is out of the scope of this paper. Nevertheless, it is very interesting to note in Figure 3 that the news TFP shock contributed significantly to the initial strong appreciation and the subsequent depreciation of the US real exchange rate during this period.

3.2.3 Decomposition of Business Cycle Variance

In this subsection, we compare the relative importance of the news and contemporaneous TFP shocks at business-cycle frequencies. First, we apply the Hodrick-Prescott (HP) filter to the actual and counterfactual data with a smoothing parameter of 1600. Each series of the counterfactual data contains fitted values for a variable in our benchmark VECM conditional on only one identified shock. If a shock is important in driving the actual data, the counterfactual data conditional on that shock should be highly correlated with the actual data. Therefore, we initially investigate conditioning on which shock (the news or contemporaneous shock) the counterfactual data are more correlated with the actual data. However, a high correlation itself is not enough: the shock that the counterfactual data are conditional on may still have a limited role in explaining variation in the actual data if the counterfactual data are much less volatile than the actual data. To address this issue, we also evaluate the contributions of news and contemporaneous TFP shocks to the volatility of variables in our benchmark VECM using the business cycle variance decomposition in Enders and Muller (2009).

Table 2 reports the correlation between the actual and counterfactual data conditional on the news and contemporaneous shocks. All variables are logged and HP filtered before we calculate correlations. In the right panel of Table 2, we also try a different de-trending method by taking the first difference (instead of using the HP filter) of nonstationary variables (output, consumption, and investment). Hours worked and the real exchange rate are not de-trended in this case because unit root tests suggest that they are stationary in our sample.

The HP-filtered actual and counterfactual US real exchange rate series are much more correlated when conditional on the news TFP shock than when conditional on the contemporaneous TFP shock. The correlation is 0.63 when conditional on the news shock and only 0.34 when conditional on the contemporaneous shock. The difference is more pronounced if we do not HP filter the counterfactual and actual real exchange rate series. In this case, the correlation conditional on the news shock is 0.86 and only 0.22 conditional on the contemporaneous shock. This is consistent with our finding that the news TFP shock is more important than the contemporaneous TFP shock in explaining the FEV of the US real exchange rate at lower frequencies.

Note that other macroeconomic variables in our model exhibit the opposite pattern. The correlation between the actual and counterfactual series when conditional on the news TFP shock is generally smaller than the correlation conditional on the contemporaneous TFP shock. For instance, the correlation for output is 0.48 conditional on the news shock and 0.65 conditional on the contemporaneous shock. However, the difference between the conditional correlations is usually smaller for these macroeconomic variables than for

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the real exchange rate. For instance, the correlation conditional on the news shock is about twice as large as that conditional on the contemporaneous shock for the real exchange rate in the HP-filtered data. For other variables, the difference is much smaller.

We then compare the contributions of news and contemporaneous TFP shocks to volatility of the US real exchange rate at business-cycle frequencies. The left panel of Table 3 reports the standard deviation of each variable in our benchmark specification relative to the standard deviation of output. The first column reports the statistics calculated using actual data, while the second and third columns use counterfactual data conditional on news and contemporaneous TFP shocks, respectively. Note that the standard deviations of consumption, investment, and hours worked relative to the standard deviation of output conditional on the news shock have almost the same size as those conditional on the contemporaneous shock. However, the relative volatility of the real exchange rate is much higher when conditional on the news shock than conditional on the contemporaneous shock. The standard deviation of the real exchange rate is about two and half times as large as the standard deviation of output when conditional on the news shock. The relative standard deviation of the real exchange rate is only 1.32, however, when conditional on the contemporaneous shock. In other words, the relative volatility of the real exchange rate conditional on the news shock is about twice as large as that conditional on the contemporaneous shock. This is very similar to Nam and Wang's (2010) finding using data simulated from their benchmark DSGE model with news shocks to TFP. Matsumoto, Cova, Pisaniz, and Rebucci (2010) show that introducing news shocks to a canonical DSGE model can increase the volatility of asset prices, although the introduction of news about future cash flows in partial equilibrium present-value asset-pricing models always reduces asset price volatility as shown in West (1988). Standard international macroeconomic models usually have to use exogenous exchange rate shocks to replicate the exchange rate volatility documented in the data. For instance, see Devereux and Engel (2002) and Wang (2010).[5] Our empirical results suggest that incorporating news shocks to TFP may be a promising and empirically relevant avenue for international macroeconomic models to replicate the exchange rate volatility in the data.

The right panel of Table 3 displays the ratio of the variance of counterfactual data conditional on each shock to the variance of actual data. Following Enders and Muller (2009), we use this as an exercise to assess the contributions of news and contemporaneous TFP shocks to the volatility of the US real exchange rate. The first and second columns of the right panel report the results for news and contemporaneous shocks, respectively. In general, the contribution of the news TFP shock to business cycle variance of the variables in

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[5]See Chari, Kehoe, McGrattan (2002), Heathcote and Perri (2002), and Corsetti, Dedola, and Leduc (2008) for examples of endogenously generating exchange rate volatility in international macro models.

our benchmark specification exceeds that of the contemporaneous TFP shock except for the case of output. In particular, the contribution of the news shock to real exchange rate fluctuations (0.55) is much larger than that of the contemporaneous shock (0.17), indicating that the new shock is more important than the contemporaneous shock in explaining observed volatility of the US real exchange rate.

To sum up, empirical evidence based on our business cycle correlation exercise and our business cycle variance decomposition exercise supports that the news TFP shock is more important than the contemporaneous TFP shock in explaining fluctuations of the US real exchange rate at business-cycle frequencies. The results concerning the relative importance of news and contemporaneous TFP shocks for other macroeconomic variables, such as US output, investment, and hours, however, are mixed. The counterfactual data conditional on contemporaneous shocks are more correlated with the actual data than when conditional on news shocks. This finding is consistent with Barsky and Sims' (2010) result that the news TFP shock fails to account for US output fluctuations at business-cycle frequencies, although it is important at medium to low frequencies. However, we also find that the contemporaneous TFP shock contributes less than the news TFP shock to the volatility of these variables in our sample.

3.3   Robustness Checks

In this subsection, we report results of three robustness exercises. First, we show that our findings are robust when different variables are included in the VECM. Two alternative models are considered: one is larger and another smaller than our benchmark specification. The smaller model excludes hours worked and investment from the benchmark specification and includes only TFP, output, consumption, and the real exchange rate. The larger model adds two additional variables to our benchmark model: the inflation rate and the nominal interest rate. In the second robustness check, we use a different measure of productivity. The TFP series in our benchmark model is replaced with labor productivity, which is measured by output per hour. In the last robustness check, we use the relative variables between the US and the rest of the world.

Figure 5 shows the results of the smaller model. Sub-figures 5(a) and 5(b) display the estimated impulse response functions to a favorable news shock and a favorable contemporaneous shock to TFP, respectively.[6] The results are very similar to those of the benchmark model. The real exchange rate appreciates immediately on impact of a favorable news shock and stays in the appreciative territory for more than 35 periods following the shock. In response to a positive contemporaneous shock, the real exchange rate depreciates gradually and exhibits a humped shape, which peaks 20 periods after the shock. Compared to the benchmark results,

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[6]We estimate the VECM with three lags beyond the error correction term and an unrestricted constant term, assuming that there are two cointegrating relationships among TFP, output, and consumption.

the only difference is that the delayed overshooting of the real exchange rate following a news shock is less pronounced in the smaller model.

Figure 6 shows the results of the lager model. Sub-figures 6(a) and 6(b) display the estimated impulse response functions to a favorable news shock and a favorable contemporaneous shock to TFP, respectively.[7] The real exchange rate appreciates strongly following a favorable news shock and exhibits a delayed overshooting in the following periods as in the benchmark specification. In response to a positive contemporaneous shock, the real exchange rate appreciate slightly on impact of the shock, then depreciates gradually in the following periods as in the benchmark specification.

Figure 7 displays the estimated impulse response functions to a favorable news shock when utilization-adjusted TFP is replaced with labor productivity. Labor productivity is measured by output per hour. To avoid collinearity, hours worked is withdrawn leaving only five variables in the system. Other model specifications are identical to those in the benchmark model. The responses of the US real exchange rate and other variables to the identified news shock are very similar to those in the benchmark specification. Note that labor productivity increases above zero faster than utilization-adjusted TFP in our benchmark specification. This result is not surprising. Labor productivity is measured by output per hour and is not adjusted for the capital utilization rate. As a result, output per hour can increase immediately following a positive news shock to TFP because of an increase in capital utilization, even if TFP remains constant. For instance, Nam and Wang (2010) show this result in a DSGE model with news shocks to TFP, in which capital utilization is endogenously determined. This finding suggests that empirical studies based on productivity measures not adjusted for utilization can underestimate the length of news shocks.

Barsky and Sims' (2010) identification strategy assumes that the news shock does not affect productivity on impact. As we have just discussed, this assumption is invalid when the measure of productivity is not adjusted for utilization. Barsky and Sims (2010) also propose an identification approach based on shape restrictions, which is more appropriate when the measure of productivity is not adjusted for utilization. See Barsky and Sims (2010) for details about this approach. Figure 8 shows the impulse response functions to a positive news shock estimated with the shape restrictions method. The blue line with circles represents the median response and the asterisks represent the 16th and 84th percentiles of the distribution of impulse response functions. Again, the results are very similar to those in our benchmark model. The real exchange rate appreciates strongly following a positive news shock. Note that labor productivity, in this case, remains statistically indifferent from zero for more periods following the news productivity shock than in Figure 7.

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[7]The inflation rate and the nominal interest rate enter the model in levels as suggested by our unit root tests. Other specifications of the VECM are the same as in the benchmark model.

We also use the relative variables between the US and the rest of world (ROW) in our empirical study. Following Enders and Muller (2009), our data include the following variables: US utilization-adjusted TFP, US-ROW relative output per capita, relative consumption per capita, relative investment per capita, the relative CPI inflation rate, the relative short-term (3-month) interest rate, the oil price inflation rate, and the US real exchange rate.[8] Following Enders and Muller (2009), ROW data are aggregates of Canada, the euro area, Japan, and the UK. See the appendix for details about ROW data. There is no particular reason to believe that the cross-country relative variables are cointegrated with US TFP. As a result, we estimate a VAR model with the above eight variables rather than the VECM used in the benchmark specification. Unit root tests suggest that relative output, relative consumption, and relative investment are non-stationary and the relative inflation rate, the relative interest rate and the oil price inflation rate are stationary. Therefore, we estimate a VAR with a constant term and four lags, where US TFP and the other three nonstationary variables are first-differenced and the remaining four variables are in levels. Our results are also robust when all variables are in levels and when different numbers of lags are used in the VAR model.[9]

Figure 9 shows the impulse response functions for the US-ROW data. Our main finding that the US real exchange rate appreciates following a positive news shock to TFP, but depreciates following a positive contemporaneous shock to TFP holds up in this case as well. In addition, we find similar results for the terms of trade when we replace the US real exchange rate with the terms of trade and re-estimate the model.[10] The impulse response function of the terms of trade is included in Figure 9 as well. In Sub-figure 9(a), we also plot the point estimates of the impulse response functions (lines with squares) to a positive TFP shock identified with the long-run restrictions method. It is interesting to note that the impulse response functions of the real exchange rate and the terms of trade to a positive TFP shock identified with the long-run restrictions method are very similar to the impulse response functions to a positive news TFP shock. This similarity highlights that the results of empirical studies without differentiating the news and contemporaneous TFP shocks may just reflect the effects of the news TFP shock on the real exchange rate and the terms of trade. Impulse response functions of other variables such as relative output and relative consumption, to the news TFP shock and the TFP shock identified with the long-run restrictions method, differs more than those of the real exchange rate. This is consistent with our finding that the news TFP shock is relatively less important in driving other variables than the real exchange rate.

We did the same variance decomposition exercises in Section 3.2 for the US-ROW data. Our main

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[8]Ideally, it would be better to replace US TFP with cross-country relative TFP. However, utilization-adjusted TFP is not available for the ROW data.

[9]Results of these robustness checks are available upon request.

[10]The US terms of trade are calculated from the export and import price indexes that we obtain from BEA.

findings in that section do not change qualitatively.[11] We confirm in the US-ROW data that the news TFP shock is much more important than the contemporaneous TFP shock in driving the US real exchange rate and the terms of trade.

Table 4 reports unconditional correlations between the US real exchange rate and other variables in our US-ROW dataset. The table also shows the correlations conditional on the identified news and contemporaneous TFP shocks. In addition, we include the correlations conditional on the TFP shock identified with the long-run restrictions method for the purpose of comparison. All series are logged and HP filtered before we calculate correlations. The real exchange rate and cross-country relative consumption are negatively correlated in our sample (-0.29), although standard international macroeconomic models predict a positive correlation. This finding confirms the well-known Backus-Smith puzzle in the literature. Note that conditional on the news TFP shock, the correlation of the real exchange rate and relative consumption is highly negative in our US-ROW data, indicating that the news shock to TFP has contributed to the puzzle. This result is consistent with the theoretical prediction in Opazo (2006) and Nam and Wang (2010). As we have mentioned, the real exchange rate can appreciate following a positive news TFP shock in an international macroeconomic model. Home consumption also increases relative to foreign consumption in such a model following good news in the home country about future productivity gains, generating a negative correlation between the real exchange rate and cross-country relative consumption. However, the news shock itself cannot fully explain the Backus-Smith puzzle: the real exchange rate and relative consumption are also negatively correlated even conditional on the contemporaneous TFP shock in our US-ROW data. This reflects the fact that the US real exchange appreciates slightly on impact of the contemporaneous TFP shock in Sub-figure 9(b), although it depreciates in the following periods.

Note in Table 4 that sizable differences exist between the correlations conditional on the news shock and those conditional on the TFP shock identified with the long-run restrictions, although the responses of the real exchange rate to these two shocks are similar. This result indicates that the news TFP shock and the TFP shock identified with the long-run restrictions have different effects on business cycle fluctuations in the real exchange rate and other variables.[12]

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[11]Results are available upon request.

[12]Significant differences exist between these two shocks when we apply the variance decomposition exercises in Section 3.2 to the US-ROW data. Results are available upon request.

4 Cross-country Comparisons

We find, in US data, that the real exchange rate exhibits a persistent appreciation following a favorable news shock to productivity, while it depreciates in response to a favorable contemporaneous shock to productivity. In this section, we investigate whether similar patterns exist in other countries. A couple of data-related problems arise for our empirical study outside the US. First, utilization-adjusted TFP series are not available in other countries. As mentioned before, the identification assumption that the news shock has no immediate effect on productivity is invalid if the measure of productivity is not adjusted for the utilization rate. We address this issue by employing the identification method with shape restrictions previously used in Section 3. Another caveat related to data outside the US concerns the measurement of labor productivity. Labor productivity in these countries is measured by output per employment, which is less accurate than output per hour because it does not take into account the variation of hours worked per employee during business cycles. As a result, we need to be careful in interpreting our results in these countries.

We include labor productivity (measured by output per employment), GDP, consumption, and the real exchange rate in a VECM to estimate impulse response functions to a favorable news productivity shock, using the shape restrictions method in Barsky and Sims (2010).[13] As a robustness check, we also replace the real exchange rate with the terms of trade. Figure 10 displays the estimated impulse responses of the real exchange rate and the terms of trade to a favorable news shock for Australia, Japan, New Zealand, Norway, the UK, and the US. The choice of these countries is dictated by data availability in Haver Analytics' G10 dataset.[14]

Except in Japan, there is no strong evidence for other countries in our sample that the real exchange rate and the terms of trade appreciate in response to a favorable news shock to productivity. Other than the data issues we mentioned above, a few other factors may have potentially caused these differences across countries. Corsetti, Dedola, and Leduc (2006) emphasize the importance of home bias in consumption in driving heterogeneous responses of the real exchange rate to technology shocks. When home bias is higher, the increase in aggregate consumption falls more disproportionately on home goods. As a result, home goods prices rise more relative to foreign goods prices. Our findings that the terms of trade and the real exchange rate in large closed economies, such as the US and Japan, appreciate in response to a favorable news productivity shock is consistent with this argument. In addition, Nam and Wang (2010) find that the

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[13]Two cointegrating relationships among labor productivity, GDP, and consumption are assumed, and an unrestricted constant and three lags beyond the error correction term are included.

[14]We use the same sample period (from 1989:Q1 to 2007:Q4) for all countries to facilitate the cross-country comparison of our results. Some countries have data that go back to earlier dates (e.g., the 1970s). The results in Figure 10 do not change qualitatively if we use all available data for these countries.

length of the news shock to productivity is also important for responses of the terms of trade and the real exchange rate. In their model, when the length of the news productivity shock is short, for instance two quarters or less, the real exchange rate and the terms of trade depreciate following a positive news TFP shock. There may be heterogeneity among countries in the availability of news about future productivity. Another potential factor could be the availability of the financial credit. Households may need to borrow to finance increases in their consumption when expecting an increase in future productivity. The lack of financing in some countries may have dampened the increase in consumption from the wealth effect of a favorable news productivity shock.

5   Conclusion

In this paper, we empirically investigate the effects of news about future productivity on the US real exchange rate. Employing Barsky and Sims' (2010) methodology, we identify news and contemporaneous shocks to US TFP. The US real exchange rate appreciates in response to a positive news shock, while it depreciates in response to a positive contemporaneous shock. Similar findings are also found for the US terms of trade. These findings are consistent with the theoretical predictions in Nam and Wang (2010). We also find in the data that news about future productivity plays a more important role than contemporaneous innovations in productivity in driving the US real exchange rate. Our findings hold up qualitatively well in various robustness checks.

Our empirical findings provide important empirical guidance to theoretical studies on several important issues in international macroeconomics. International relative prices, such as the real exchange rate and the terms of trade, are important transmission channels of shocks across countries. Our finding that news and contemporaneous productivity shocks have opposite effects on international relative prices suggests that it is important to distinguish these two shocks when studying the international transmission of shocks both empirically and theoretically.

Our finding that news about future productivity is more important than current productivity for exchange rate fluctuations is consistent with several recent studies. If exchange rate movements contain information about future fundamentals, the exchange rate should be able to forecast the fundamentals. Engel and West (2005) find empirical evidence that the exchange rate is useful in forecasting macroeconomic fundamentals such as relative output. Chen, Rogoff, and Rossi (2010) also document that the exchange rate can forecast commodity prices. Future research along this line may be fruitful.

We also find that the volatility (relative to output) of the real exchange rate is higher conditional on news

TFP shocks than conditional on contemporaneous TFP shocks. This finding provides support to a recent theoretical study by Matsumoto, Cova, Pisaniz, and Rebucci (2010), who argue that high volatility of asset prices in the data may be a result of news shocks to fundamentals. Our results suggest that news shocks to TFP may be an important candidate for international macroeconomic models to replicate exchange rate volatility in the data.

Although we find that news and contemporaneous TFP shocks account for a large share of fluctuations in the US real exchange rate at medium and long horizons (e.g., 4 and more quarters), they account for relatively small share (30%) at short horizons. Shocks from other resources, such as demand, monetary policy, and financial markets, must have also played important roles in driving exchange rate fluctuations in the short run. It may be of interest to study the effects of news and contemporaneous components of these shocks on the exchange rate. We think it is of interest to study the effects of the news and contemporaneous components of these shocks on other macroeconomic variables as well. For instance, Christiano, Ilut, Motto, and Rostagno (2008) fit a Bayesian DSGE model to US data and find that anticipations about the future monetary policy are important to business cycle dynamics. We leave these studies for the future research.

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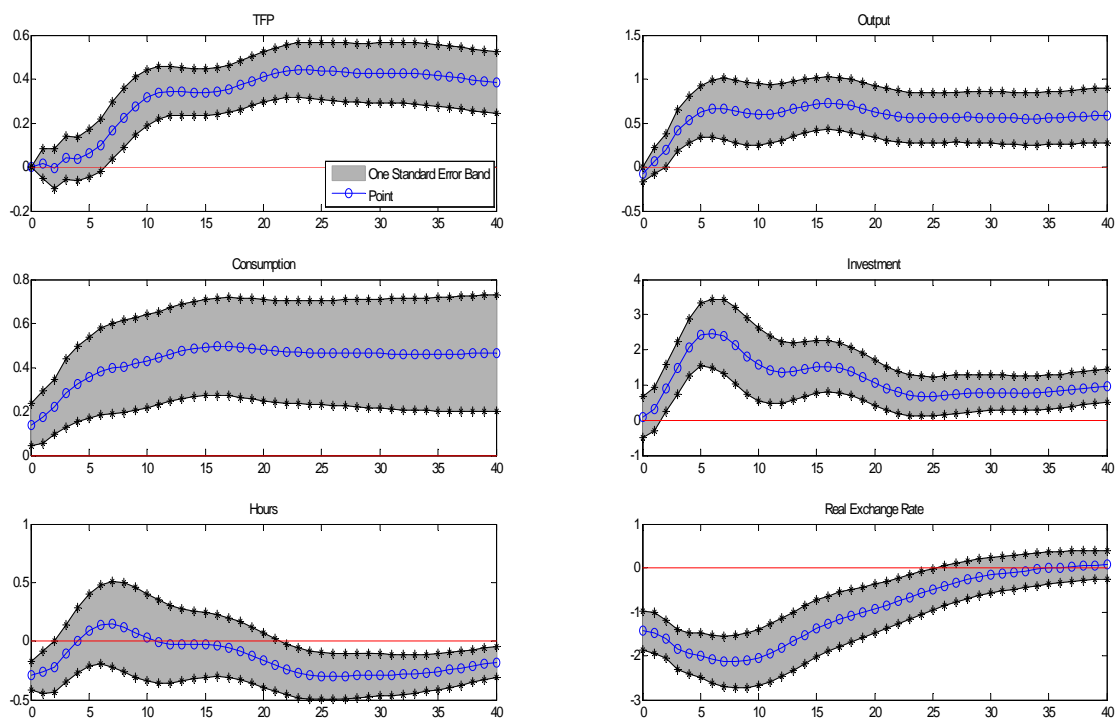Figure 1: Impulse Response Functions: Long-run Restrictions Method
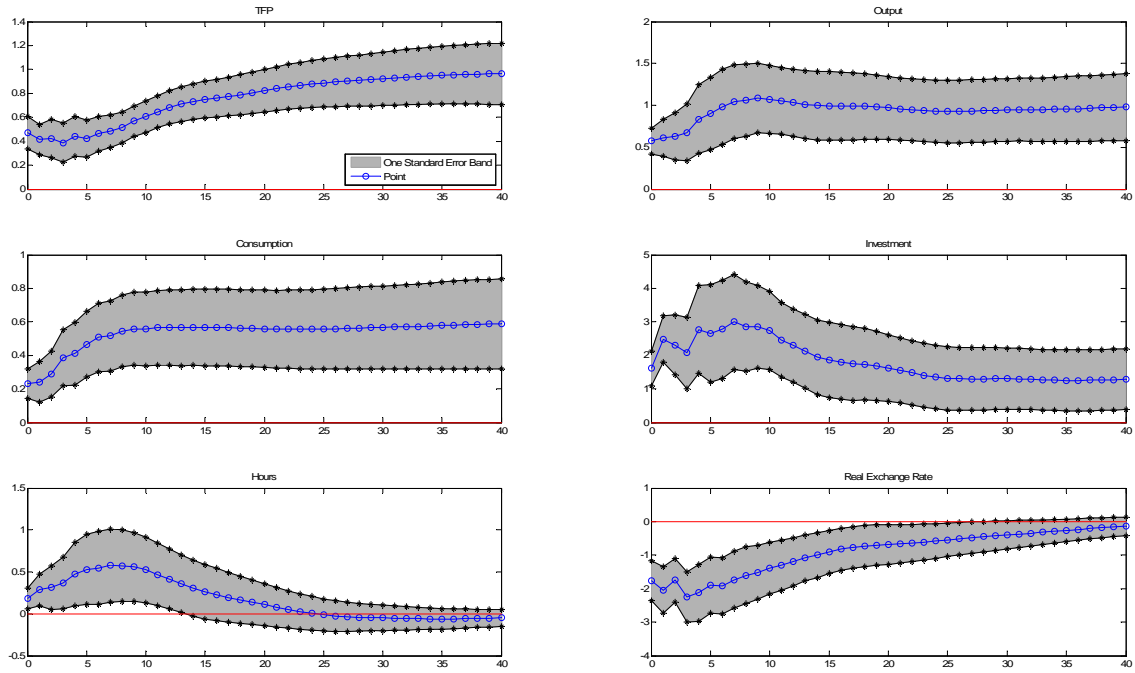
(a) Utilization-adjusted TFP as the measure of productivity
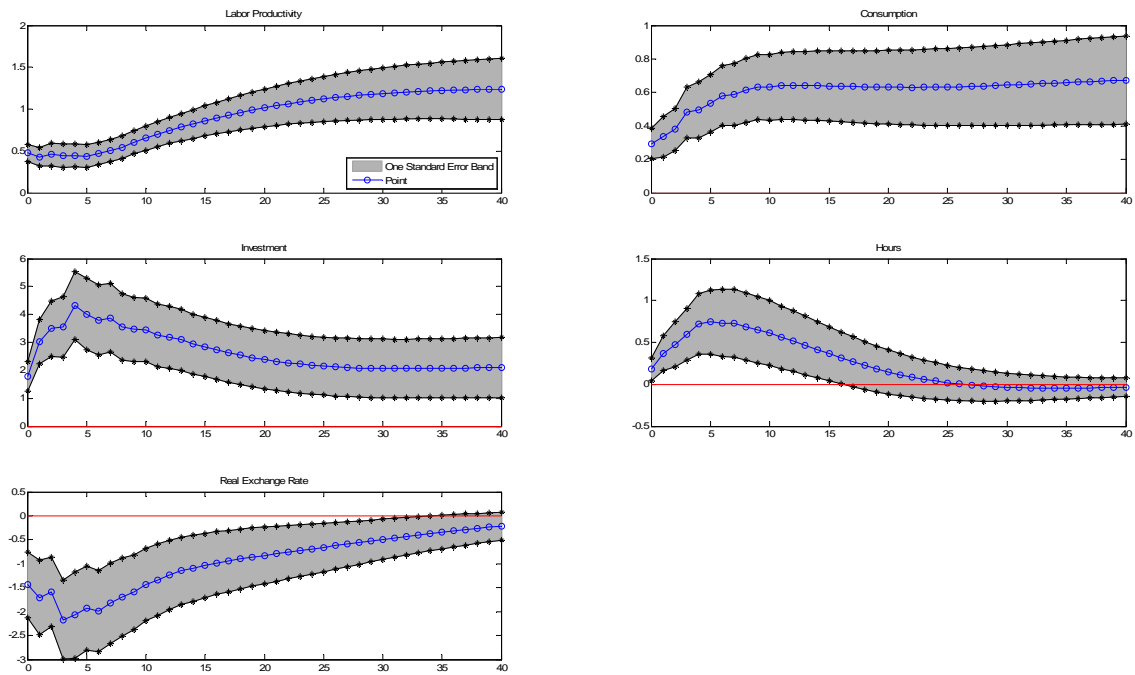
(b) Labor productivity (output per hour) as the measure of productivity

Figure 2: Impulse Response Functions: Benchmark Specification

(a) News Shock

(b) Contemporaneous Shock

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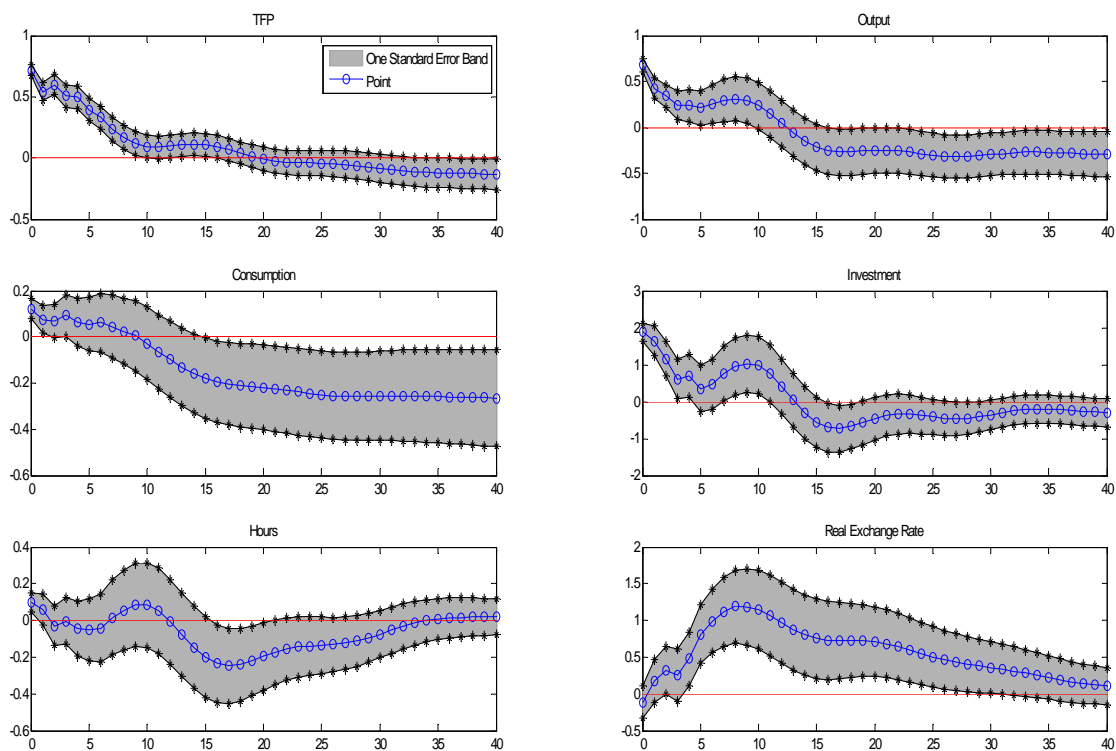
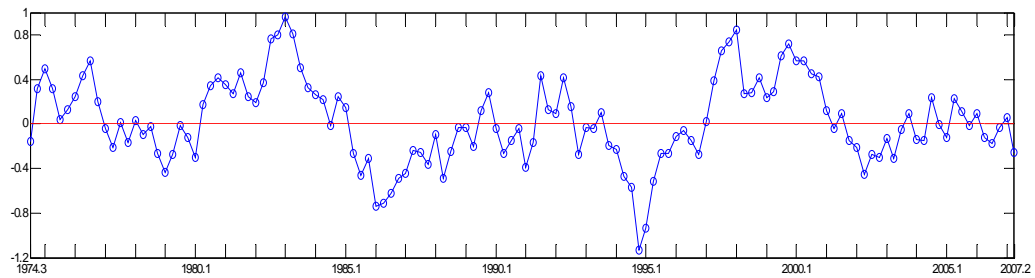Figure 3: Cumulative Effects of News and Contemporaneous Shocks on the Real Exchange Rate
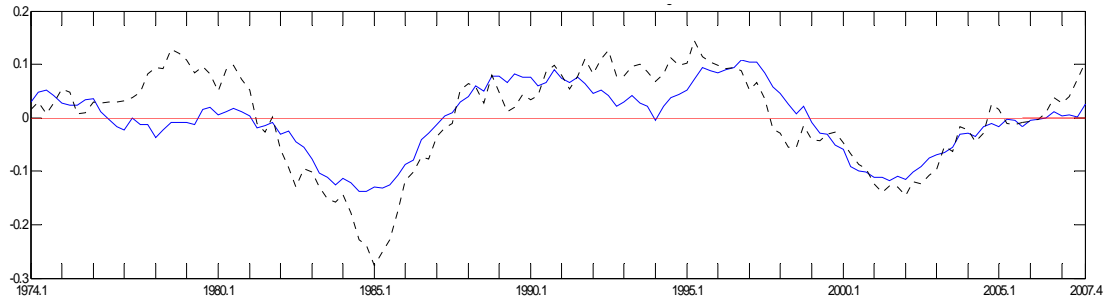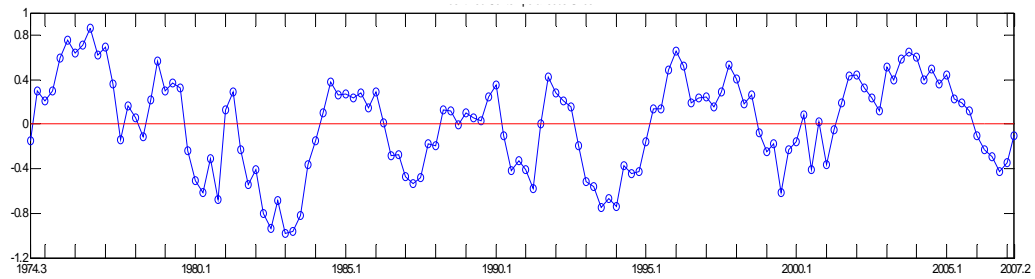

(a) News Shock
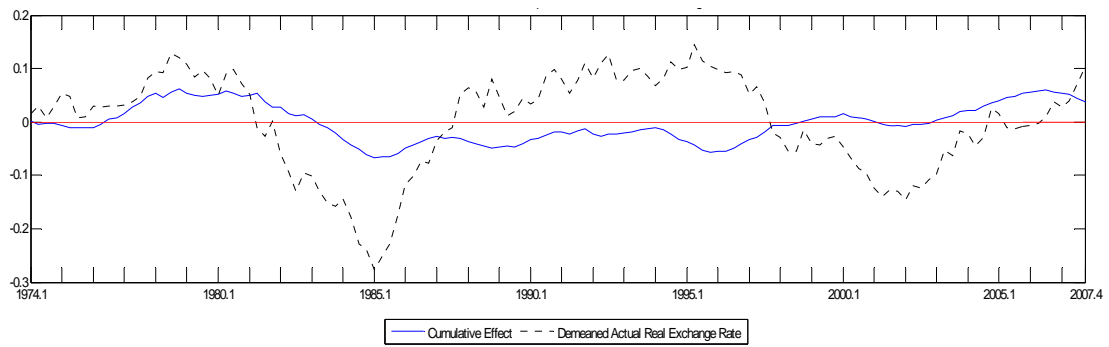
(b) Contemporaneous Shock

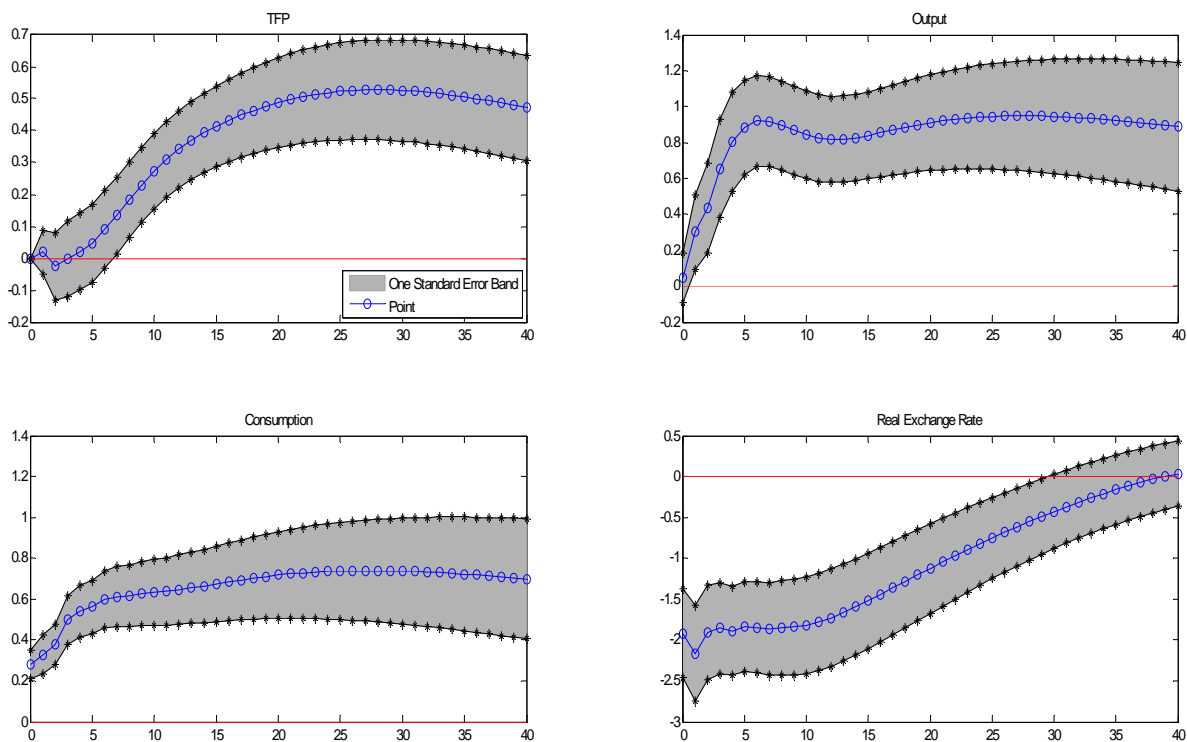Figure 4: Time Paths of News and Contemporaneous Shocks (4-quarter Moving Average)
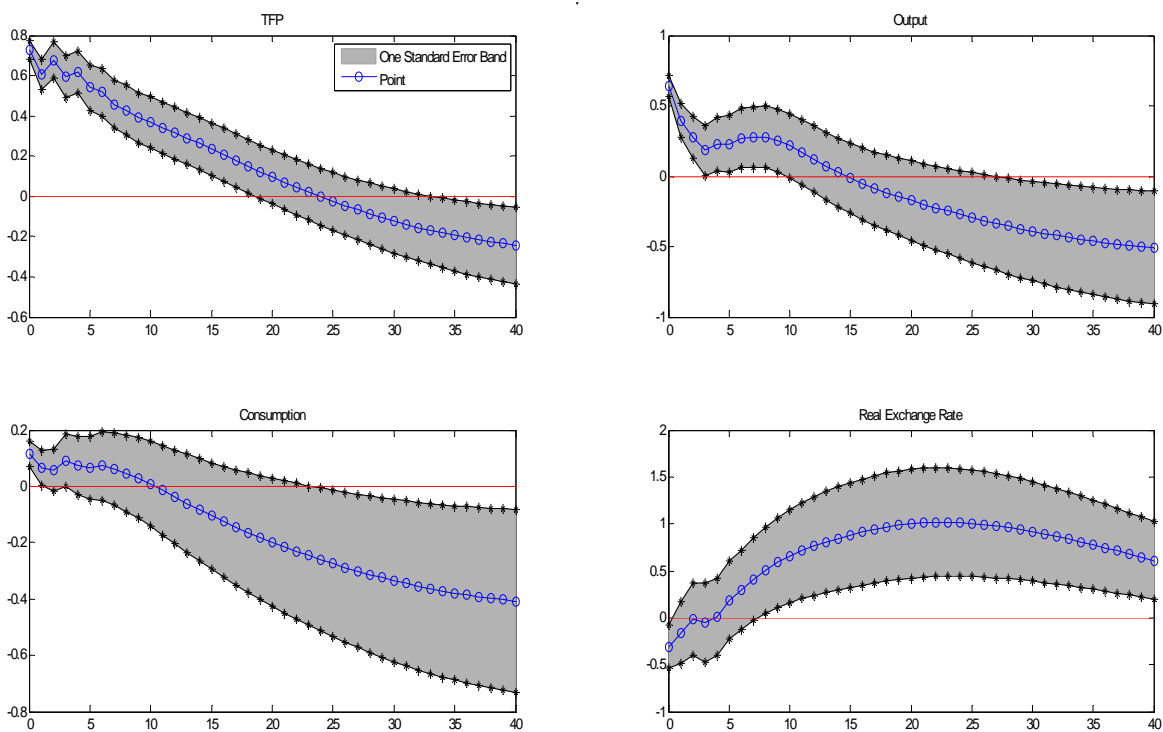

(a) News Shock

(b) Contemporaneous Shock

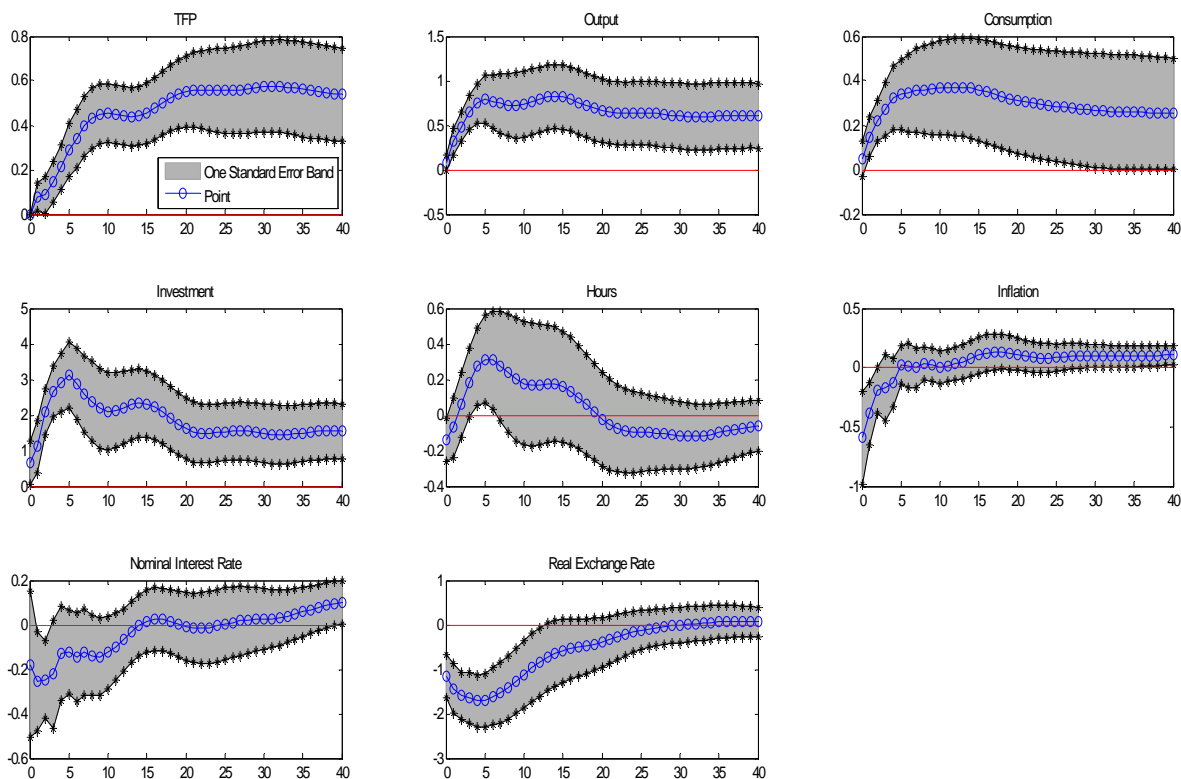Figure 5: Impulse Response Functions: Small Model
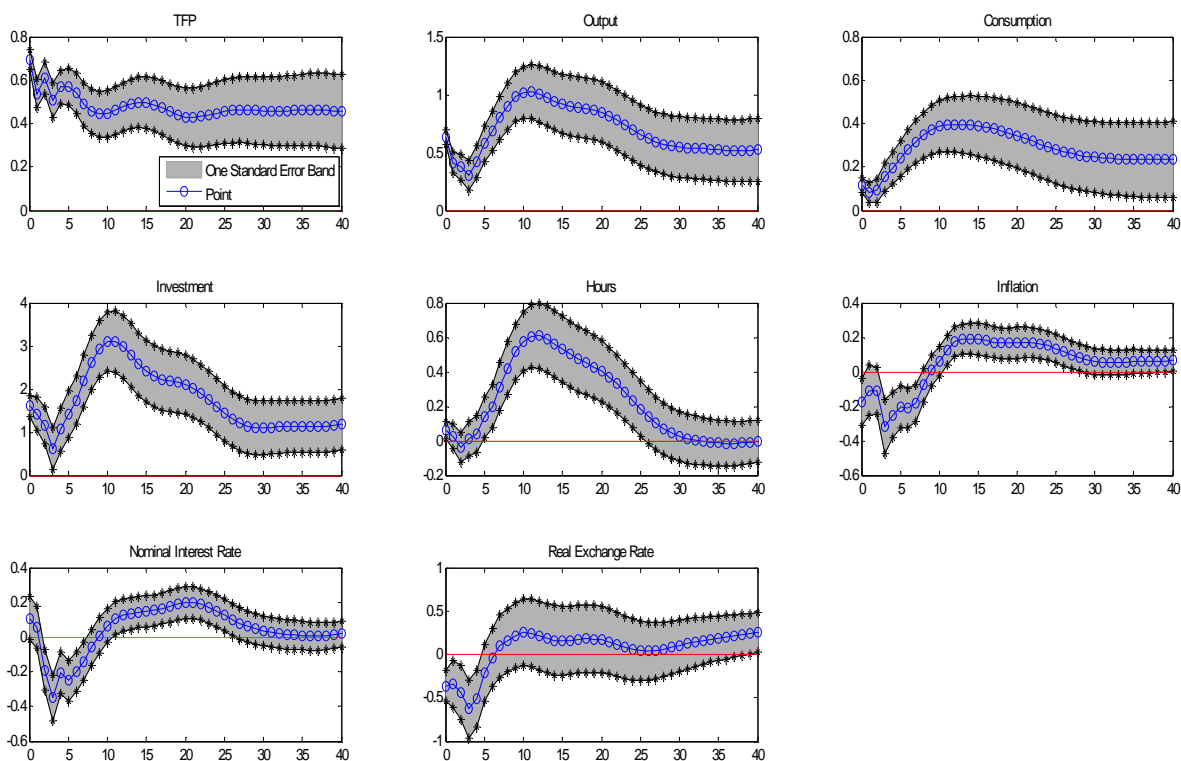

(a) News Shock

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(b) Contemporaneous Shock

Figure 6: Impulse Response Functions: Large Model

(a) News Shock

(b) Contemporaneous Shock

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Figure 7: IRFs to News Shock: Labor Productivity as the Measure of Productivity
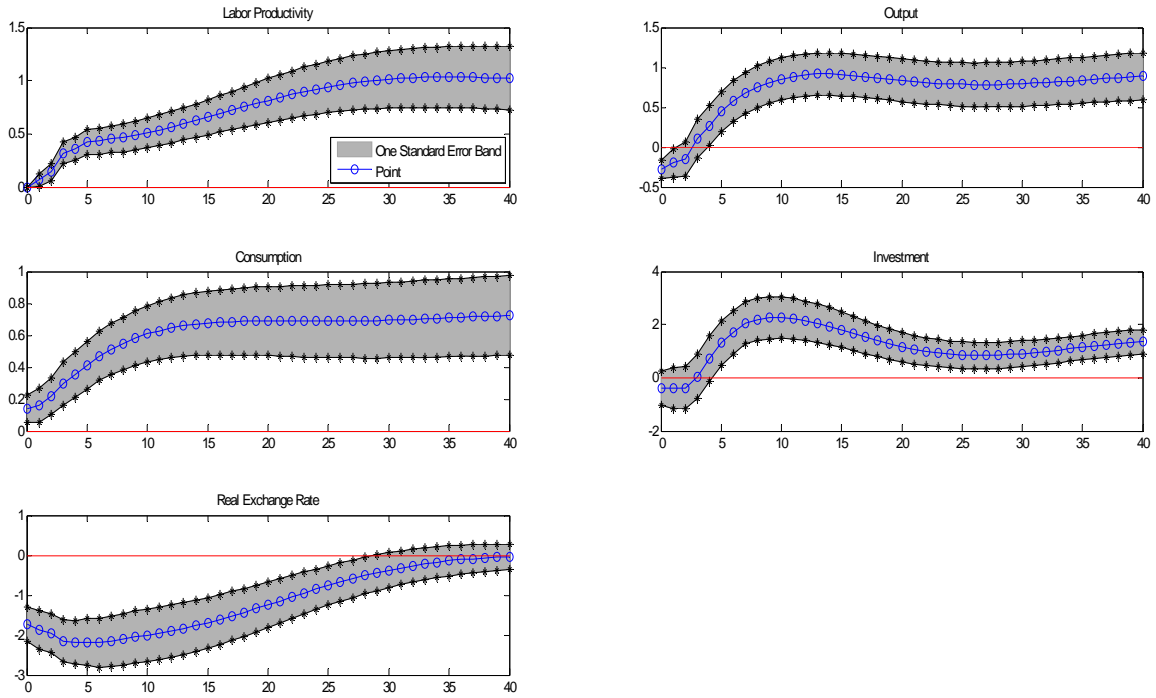

Figure 8: IRFs to News Shock: Labor Productivity as the Measure of Productivity + Shape Restrictions
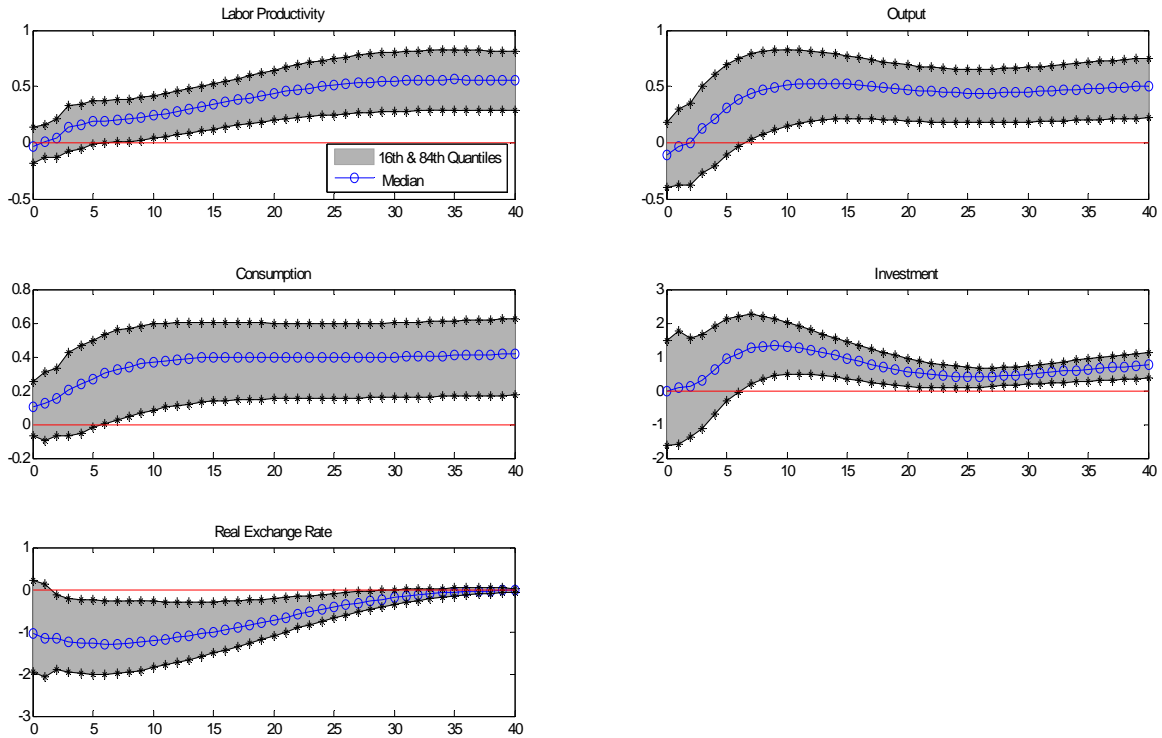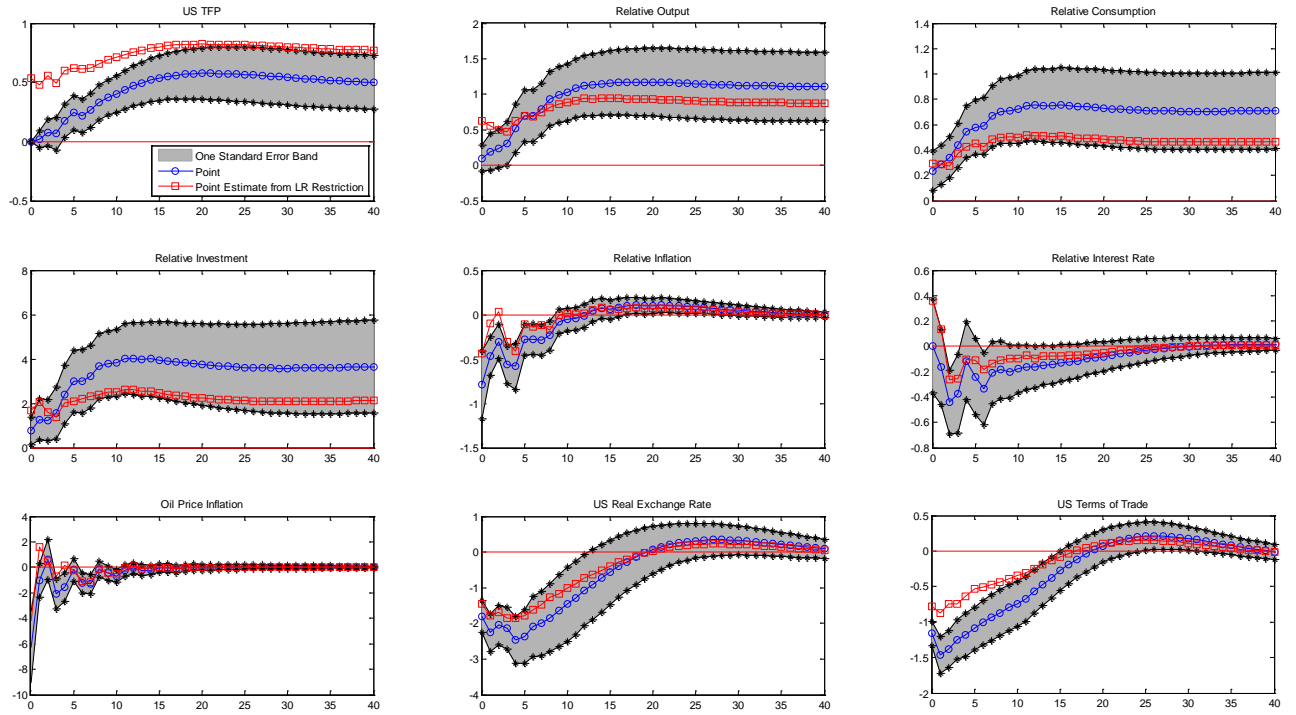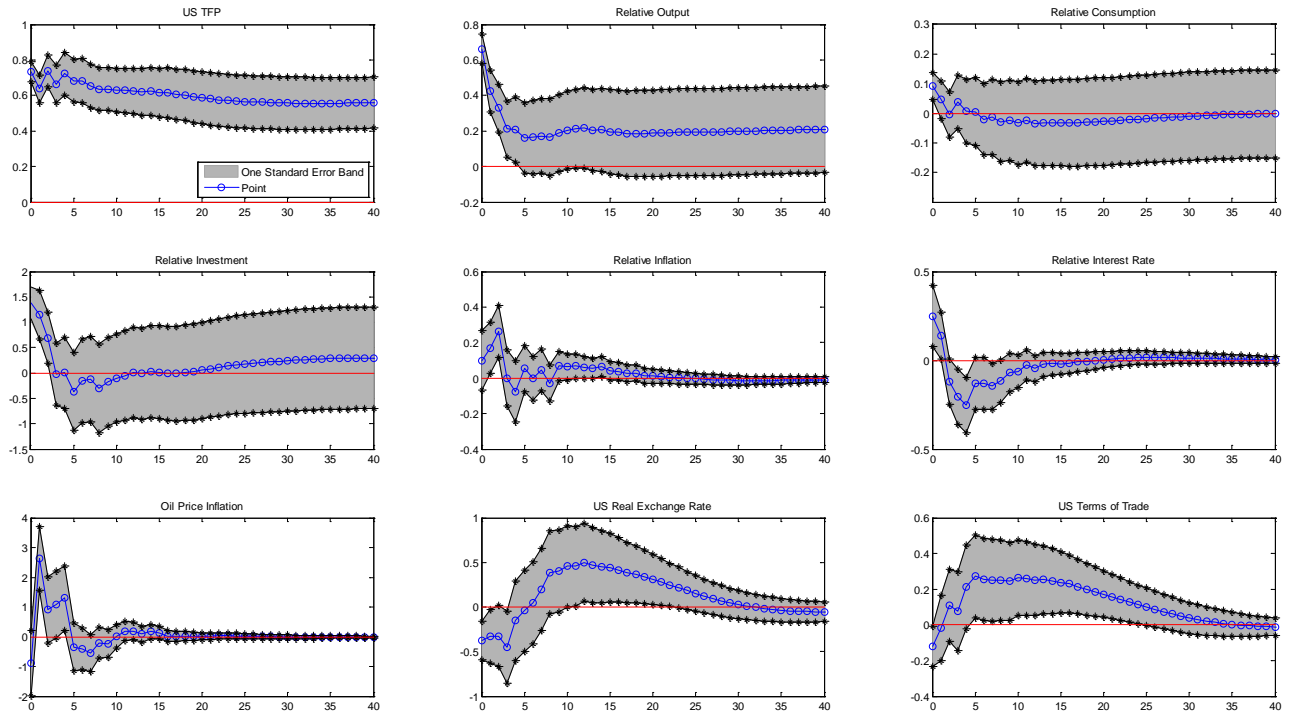
Figure 9: Impulse Response Functions: Cross-country Differences

(a) News Shock

(b) Contemporaneous Shock

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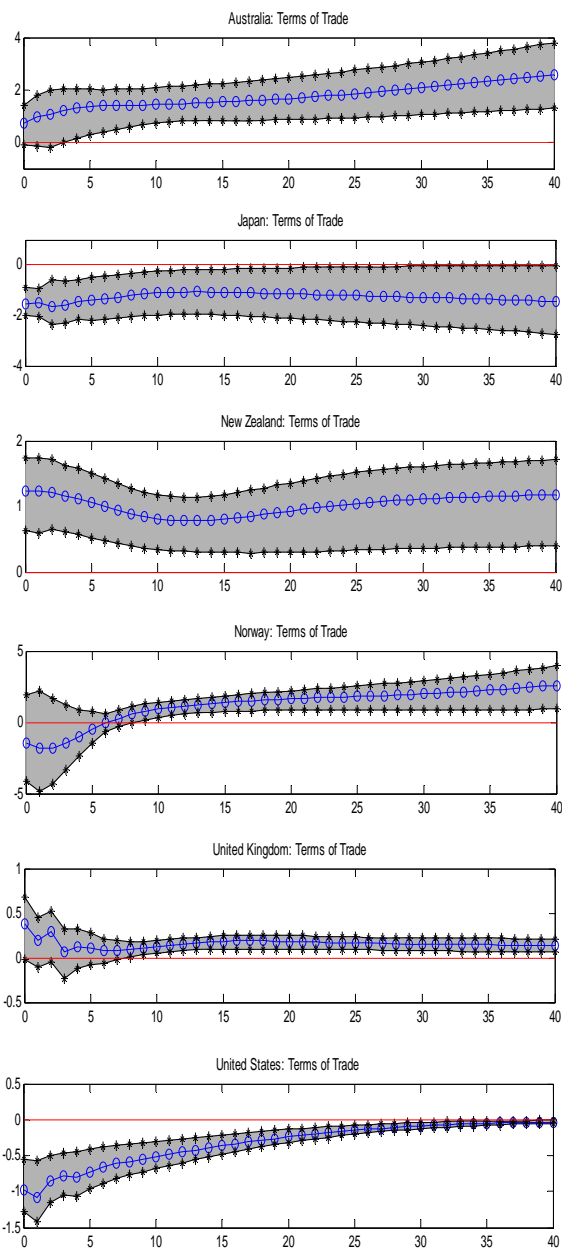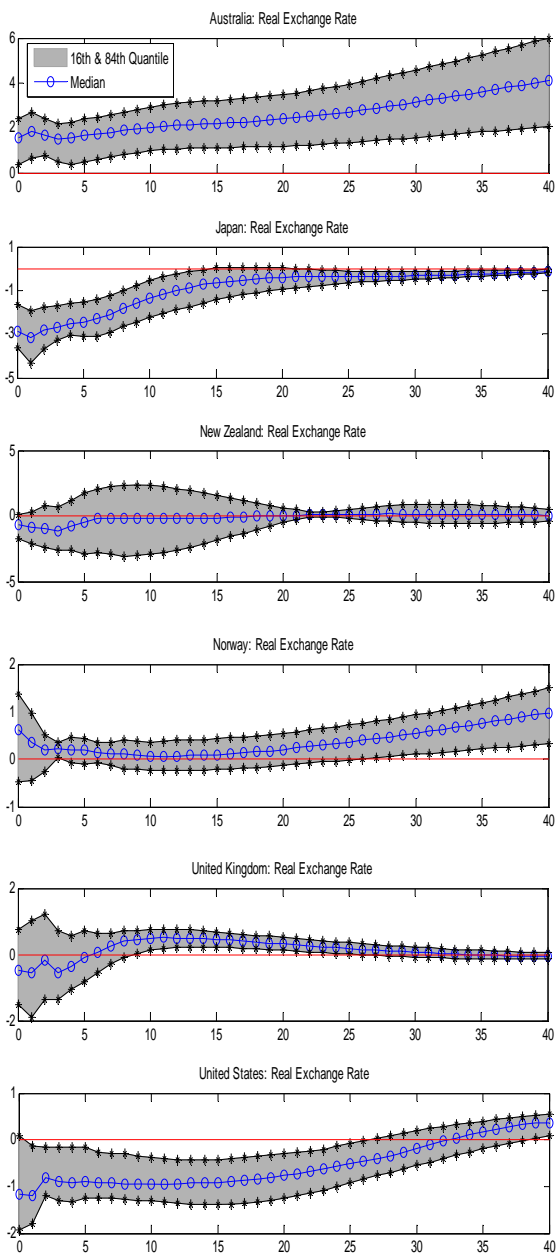Figure 10: IRFs to News Shock: Cross-country Comparison

Table 1: Decomposition of Forecast Error Variance

	Share of FEV Attributable to News Shock							Share of FEV Attributable to Contemporaneous Shock					
	Forecast Horizon (Quarters)							Forecast Horizon (Quarters)					
	0	4	8	16	24	40		0	4	8	16	24	40
TFP	0.00	0.00	0.04	0.29	0.49	0.63		1.00	0.96	0.88	0.63	0.45	0.28
	(0.00)	(0.03)	(0.08)	(0.13)	(0.13)	(0.14)		(0.00)	(0.05)	(0.09)	(0.11)	(0.11)	(0.11)
Output	0.01	0.13	0.22	0.29	0.35	0.38		0.70	0.22	0.11	0.08	0.08	0.09
	(0.03)	(0.13)	(0.19)	(0.21)	(0.21)	(0.22)		(0.05)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)
Consumption	0.12	0.20	0.24	0.32	0.36	0.37		0.10	0.03	0.01	0.02	0.05	0.08
	(0.18)	(0.22)	(0.24)	(0.25)	(0.25)	(0.26)		(0.06)	(0.05)	(0.05)	(0.07)	(0.08)	(0.10)
Investment	0.00	0.14	0.27	0.30	0.32	0.35		0.34	0.16	0.09	0.09	0.09	0.09
	(0.06)	(0.10)	(0.16)	(0.17)	(0.17)	(0.16)		(0.07)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)
Hours worked	0.27	0.07	0.03	0.02	0.04	0.10		0.03	0.01	0.00	0.01	0.03	0.03
	(0.18)	(0.12)	(0.13)	(0.14)	(0.13)	(0.13)		(0.04)	(0.03)	(0.04)	(0.06)	(0.07)	(0.07)
Real exchange rate	0.32	0.52	0.60	0.60	0.58	0.57		0.00	0.02	0.09	0.13	0.15	0.16
	(0.17)	(0.18)	(0.18)	(0.18)	(0.18)	(0.17)		(0.02)	(0.04)	(0.08)	(0.11)	(0.12)	(0.12)

	Share of FEV Attributable to Both Shocks					
	0	4	8	16	24	40
TFP	1.00	0.97	0.92	0.92	0.94	0.9
Output	0.71	0.35	0.33	0.37	0.43	0.47
Consumption	0.22	0.22	0.26	0.34	0.41	0.45
Investment	0.34	0.3	0.36	0.38	0.41	0.44
Hours worked	0.31	0.07	0.04	0.03	0.07	0.13
Real exchange rate	0.32	0.54	0.69	0.73	0.73	0.73

Note:
–FEV is the abbreviation of forecast error variance.
–Numbers in parentheses are standard errors obtained from 2000 bootstrap replications.

Table 2: Correlation Between Actual and Counterfactual Series

	Y	C	I	Hours	RE	ΔY	ΔC	ΔI	Hours	RE
Series conditional on	0.48	0.55	0.48	0.42	0.63	0.39	0.44	0.35	0.57	0.86
news shock	(0.13)	(0.17)	(0.12)	(0.14)	(0.13)	(0.07)	(0.13)	(0.07)	(0.16)	(0.15)
Series conditional on	0.65	0.46	0.65	0.58	0.34	0.76	0.50	0.60	0.66	0.22
contemporaneous shock	(0.11)	(0.16)	(0.11)	(0.15)	(0.15)	(0.05)	(0.08)	(0.06)	(0.18)	(0.22)

Note:
   –This table reports the correlations between the actual and counterfactual data that are conditional on either the news or the contemporaneous TFP shocks.
   –In the left panel, data are HP-filtered with a smoothing parameter of 1600 before calculating the correlations.
   –Δ in the right panel indicates first differencing. C is consumption, I is investment, and RE is the real exchange rate.
   –Numbers in parentheses are standard errors obtained from 2000 bootstrap replications.

Table 3: Business Cycle Volatility

	Standard deviation relative to that of output			Business cycle variance decomposition	
	Actual	Conditional on news shock	Conditional on contemporaneous shock	News shock	Contemporaneous shock
Output	1.00	1.00	1.00	0.32	0.35
				(0.11)	(0.09)
Consumption	0.42	0.42	0.32	0.32	0.20
		(0.05)	(0.04)	(0.17)	(0.09)
Investment	3.67	3.93	3.41	0.37	0.30
		(0.34)	(0.27)	(0.10)	(0.07)
Hours worked	0.92	0.86	0.66	0.28	0.18
		(0.12)	(0.11)	(0.12)	(0.08)
Real exchange rate	1.87	2.45	1.32	0.55	0.17
		(0.65)	(0.43)	(0.14)	(0.08)

Note:
   –All data are logged and HP-filtered with a smoothing parameter of 1600.
   –Numbers in parentheses are standard errors obtained from 2000 bootstrap replications.

Table 4: Correlations with the Real Exchange Rate

	Data	Conditioning on news shock	Conditioning on contemporaneous shock	Conditioning on TFP shock from LR restrictions
Relative consumption	-0.29	-0.61	-0.26	-0.65
Relative output	0.05	-0.18	-0.25	-0.52
Relative investment	-0.06	-0.42	-0.32	-0.56
Relative inflation	0.24	0.60	0.00	0.31
Relative interest rate	0.24	0.44	0.03	0.08
Oil price inflation	0.09	0.19	-0.16	0.01

Note:
   –The relative variables are the US data relative to the rest of the world data.
   –All series are logged and HP filtered with a smoothing parameter of 1600 before calculating the correlations.

APPENDIX (not for publication)

A.1 Optimization Problem in Identifying News Shocks

As mentioned in the paper, the optimization problem is to choose the elements of A_0 to maximize the contribution of $\Omega_{1,2}(h)$ over h. Since such contribution depends upon only a single column of A_0 (i.e., $\widetilde{A}_0 \gamma_2$), the optimization problem reduces to choosing the second column of the impact matrix:

$$\gamma^* = \arg\max \rho(\gamma) = \sum_{h=0}^{H} \Omega_{1,2}(h) = \sum_{h=0}^{H} \frac{\sum_{\tau=0}^{h} \mathbf{B}_{1,\tau} \widetilde{A}_0 \gamma \gamma' \widetilde{A}_0' \mathbf{B}_{1,\tau}'}{\sum_{\tau=0}^{h} \mathbf{B}_{1,\tau} \Sigma_u \mathbf{B}_{1,\tau}'}$$

$$s.t. \ \widetilde{A}_0(1,j) = 0, \forall j > 1; \ \gamma(1,1) = 0; \ \gamma'\gamma = 1.$$

The above objective function can be expressed as $\rho(\gamma) = \gamma' \mathbf{F} \gamma$, where $\mathbf{F}$ is an $N \times N$ symmetric matrix defined by:

$$\mathbf{F} = \left(\sum_{h=0}^{H} \frac{\sum_{\tau=0}^{h} \left(\mathbf{B}_{1,\tau} \widetilde{A}_0 \right)' \left(\mathbf{B}_{1,\tau} \widetilde{A}_0 \right)}{\sum_{\tau=0}^{h} \mathbf{B}_{1,\tau} \Sigma_u \mathbf{B}_{1,\tau}'} \right).$$

The corresponding Lagrangian can be expressed as $\mathcal{L}(\gamma) = \gamma' \mathbf{F} \gamma - (\gamma'\gamma - 1)$. Since $\gamma(1,1) = 0$, this Lagrangian implies that $\gamma^* = (0, \gamma_2^{*\prime})'$, where γ_2^* is the eigenvector corresponding to the largest eigenvalue of the $(N-1) \times (N-1)$ sub-matrix of $\mathbf{F}$ (i.e., the one obtained from eliminating the first row and the first column of $\mathbf{F}$).

A.2 Rest of the World Data

The "rest of the world" (ROW) data comprises Canada, the euro area, Japan and the UK following Enders and Muller (2009). The following quarterly data are taken from the OECD dataset for each country/region: real GDP, private final consumption, gross fixed capital formation, consumer price index, and the 3-month interest rate. The sample period is from 1973Q1 to 2006Q3. Our sample ends in the third quarter of 2006 because euro area data are discontinued after that date.

To avoid national basis effects, we construct the ROW real GDP, consumption and investment by first calculating quarterly growth rates and then aggregating the growth rates weighted by each country's GDP share. The GDP shares are calculated using the PPP-based GDP shares of the world total that we obtain

from the International Monetary Fund. The aggregate growth rates of real GDP, consumption and investment are then cumulated to obtain the series in levels. The ROW CPI inflation rate and the 3-month interest rate are GDP weighted averages of the inflation and interest rates in the ROW members.