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

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Abstract

In this paper, we study the effects of news about future productivity changes (news shocks) and contemporaneous productivity changes (contemporaneous shocks) on the real exchange rate and terms of trade. Following Barsky and Sims' (2010) identification method, we decompose US total factor productivity (TFP) into news and contemporaneous productivity changes. We find that the identified news TFP shocks play a much more important role than the identified contemporaneous TFP shocks in driving the US real exchange rate and terms of trade. We also find that the real exchange rate is more volatile when conditional on the news TFP shock than on the contemporaneous TFP shock. These findings suggest that news shocks are an important element to consider when modeling exchange rate volatility in open-economy macro models. In addition, we find that the real exchange rate and cross-country relative consumption are highly negatively correlated conditional on news TFP shocks. However, the negative correlation also exists when conditional on contemporaneous TFP shocks, suggesting that news TFP shocks alone may not be enough to explain the Backus-Smith puzzle.

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1 Introduction

In this paper, we empirically study the effects of news about future productivity changes and contemporaneous shocks to productivity on the real exchange rate and terms of trade. Recently, there has been a revived interest of studying the role of news shocks to productivity 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. News shocks to productivity are information received by economic agents about future productivity in each period. Unlike contemporaneous productivity shocks, which change productivity immediately, news shocks only affect productivity in the future. A large body of literature suggests that news shocks to productivity 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 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. Their identified news shocks predict productivity several years into the future. Kurmann and Otrok (2010) find that movements in the slope of the term structure of interest rates mainly reflect the asset market's response to news about future productivity.

On the other hand, recent research supports the idea that exchange rates behave like financial asset prices. Engel and West (2005) show that existing empirical exchange rate models can be written in a present-value asset-pricing format. Engel and West (2005) and Chen, Rogoff, and Rossi (2010) find that exchange rates are helpful in forecasting fundamentals in the data. These empirical findings are consistent with exchange rates being determined by fundamentals as in a linear present-value asset-pricing model. Several recent studies apply the asset-pricing exchange rate models in Engel and West (2005) to study exchange rate predictability. For instance, see Molodtsova and Papell (2009), Wang and Wu (2009), and Chen and Tsang (2009), among others.

The findings that news about future productivity 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. In this paper, we decompose the variation in US utilization-adjusted total factor productivity (TFP) 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, which affect productivity immediately. We then study the effects and relative importance of news and contemporaneous TFP shocks in driving the US real exchange rate and terms of trade.

We include in our benchmark vector error correction model (VECM) the utilization-adjusted TFP series in Fernald (2009), 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 therefore measured productivity, immediately if the productivity data are left unadjusted. In this case, it violates Barsky and Sims' (2010) identification assumption that news shocks have no immediate effect on productivity. We find that 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 up to 4 quarters. 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 up to 4 quarters and only about 15% at horizons of 8 quarters or more. This finding suggests that anticipated changes in future productivity are more important than changes in current productivity in determining the US real exchange rate, which supports the literature of studying exchange rates as asset prices. News shocks are also found becoming more important in driving TFP and the US real exchange rate after 1985 than in the data before 1985. This finding supports Jaimovich and Rebolo's (2009) conjecture that news about future productivity became increasingly available after 1985 due to the rapid progress in the IT industry.

The real exchange rate is much more volatile than output in the data, and replicating this relative volatility in standard international macroeconomic models is difficult. For instance, see Chari, Kehoe, and McGrattan (2002) and Devereux and Engel (2002), among others. 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 when conditional on contemporaneous shocks to TFP, while the difference in the volatility of other macro variables such as output and consumption when conditional these two shocks, is much smaller. This finding provides empirical support to theoretical studies that use news shocks to generate exchange rate volatility in international macro models. 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 dynamic stochastic general equilibrium (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 addition, we find that the US real exchange rate appreciates following a positive news shock to TFP, while it depreciates following a positive contemporaneous TFP 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). This difference may reflect the wealth effect of expected productivity gains that is emphasized in Corsetti, Dedola, and Leduc (2008). When expecting a future productivity increase, households increase consumption immediately, even if current TFP remains constant. If consumption is biased towards home goods, an increase in aggregate consumption disproportionately falls on home goods, therefore raising home goods prices relative to foreign goods prices. We also 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 impulse response functions to news productivity shocks for each country. With the exception of Japan, we find no strong evidence that the real exchange rate and the terms of trade appreciate following a positive news shock to productivity. 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. It may be interesting to study other factors responsible for this cross-country heterogeneity in future research.

Our empirical findings are robust in systems that are either larger or smaller than our benchmark specification. Our results also hold up well when all variables are in their levels, and when the real exchange rate is replaced with the terms of trade in our empirical models. Similar results also hold when cross-country differences are substituted for US data. We find in the data of cross-country differences that the cross-country relative consumption and the real exchange rate are highly negatively correlated when conditional on the news TFP shock. This finding is consistent with Opazo (2006), which uses the news shock to explain the Backus-Smith puzzle. However, the correlation between the real exchange rate and relative consumption is also found to be negative when conditional on the contemporaneous TFP shock, suggesting that the news TFP shock alone may not be enough to explain the Backus-Smith puzzle. This finding highlights the importance of Corsetti, Dedola, and Leduc's (2008) explanation to the puzzle.

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, and Section 5 concludes and discusses directions for future research.

2 Empirical Strategy and Data

Before introducing our identification strategy, we use a simple example to describe news shocks to TFP that we want to identify in the data. Suppose log TFP (a_t) follows:

$$a_{t+1} = \rho_a a_t + x_{t-p} + \varepsilon_{a,t+1}$$
$$x_{t+1} = \rho_x x_t + \varepsilon_{x,t+1},$$

where $\varepsilon_{x,t}$ is a shock to x_t and will only affect TFP level at time $t+p+1$ even though it becomes known at time t. This shock is usually called a news shock in the literature since it contains news (information) about future productivity. The shock to a_t ($\varepsilon_{a,t}$) is called the contemporaneous shock. Note that both shocks can affect future TFP when $\rho_a \neq 0$. The fundamental difference between these two shocks is their timing. The contemporaneous shock changes TFP immediately, while the news shock only affects TFP in the future. This is the most important assumption that we use to identify these two shocks.

2.1 Identification Strategy

In this section, we briefly describe 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 strategies for identifying news shocks.

Barsky and Sims (2010) assume that news and contemporaneous TFP shocks fully explain variation in TFP. Contemporaneous shocks are 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, news shocks are identified as a structural shock that is orthogonal to contemporaneous shocks 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:

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

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:

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

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

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

The news and contemporaneous shocks are identified by choosing the elements of A_0 such that the above condition holds as closely as possible. Because contemporaneous shocks are identified as innovations in TFP, the share of the forecast error variance of TFP attributable to the contemporaneous shock (i.e., $\Omega_{1,1}\left(h\right)$) 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, $\Omega_{1,2}\left(h\right)$, 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 end date of our sample is chosen to avoid the effects of the recent global financial crisis on exchange

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

rates, since exchange rates during this period were 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. Jaimovich and Rebelo (2009) and Nam and Wang (2010) show, in a model with variable capital utilization, that a positive news shock to TFP can increase labor productivity immediately because it raises the capital utilization rate; thus, a utilization-adjusted TFP series helps us satisfy the identification assumption better than a non-adjusted series. 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 serve as our measures of consumption and investment, respectively, and are obtained from the US Bureau of Economic Analysis (BEA). We divide these four series by the population (civilian non-institutional population aged sixteen and over from the BLS) to convert them into per capita values. All series are then logged. As 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 the BLS.

In theory, it is the relative productivity that affects the real exchange rate. So ideally, we should use the relative variables between the US and the rest of the world in our exercise. However, corresponding measures of TFP are generally difficult to obtain in other countries. This is a common problem for empirical studies in open-economy macroeconomics literature. For instance, Enders and Muller (2009) use the US productivity in a similar study, though the differences between the US data and the rest of world data are used for other variables. We follow their setup in one robustness check and find that our benchmark results hold up qualitatively well when relative variables are used.

The real exchange rate is defined as the foreign price divided by the US price. As a result, an increase

[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.

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 the 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 3. Changing the number of cointegrating relationships and the number of lags does not qualitatively change our main results. 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 VAR model.[4]

There are two sets of main results. First, we use several variance decompositions to show that news

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

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

shocks to TFP are more important than contemporaneous shocks to TFP in driving the US real exchange rate. Next, 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.

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. In addition, we also use the relative variables between the US and the rest of world (ROW) in one of our robustness checks.

3.1 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.

3.1.1 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 time horizons for each variable in our benchmark model. The lower panel of Table 1 reports the share of the FEV that is attributed to these two shocks jointly.

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 up to 8 quarters. As the forecast horizon increases, 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 or 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 virtually 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, the identified news and contemporaneous 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 about 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.

3.1.2 Historical Decomposition of the Real Exchange Rate

Figure 1 plots the cumulative effects of the identified news and contemporaneous shocks to TFP on the US real exchange rate (the solid lines) during our sample period. 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. Figures 1(a) and 1(b) show the cumulative effects of the news and contemporaneous TFP shocks, respectively. These charts indicate that both news and contemporaneous shocks to TFP have historically made fairly significant contributions to US real exchange rate fluctuations. Overall, the real exchange rate conditional on the news TFP shock traces the actual real exchange rate more closely than the real exchange rate conditional on the contemporaneous TFP shock, suggesting that 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. After 1985, the cumulative effect of the news shock on the real exchange rate in Figure 1(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 to the Great Moderation after the mid-1980s.

Figure 2 displays the time series plots of identified news and contemporaneous shocks to TFP. The series are expressed as a four-quarter moving average to smooth out noises in the series and make the charts easier to read. Figures 2(a) and 2(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 increased 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 2(a), a series of large positive news shocks to US TFP occurred 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 booms and busts during this period. We acknowledge, however, that the question of 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 1 that news TFP shocks contributed to most of the initial strong appreciation and the subsequent depreciation of the US real exchange rate from the late 1990s to the early 2000s. This is in sharp contrast with the early 1980s. During 1980 and 1985, news and contemporaneous TFP shocks together explain only about 50% of the strong appreciation of the dollar, indicating that other factors also played an important role during this period. For instance, Cumby (1988) and Froot and Thaler (1990) find that the risk premium was important for the dollar's appreciation in the early 1980s.

3.1.3 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 counterfactual data series 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 whether the counterfactual data conditioning on news shocks yield a higher correlation with the actual data. However, a high correlation itself is not sufficient: the shock on which the counterfactual data are conditional may not adequately explain 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 when data are 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 the real exchange rate. For instance, the correlation conditional on the news shock is about twice as large as the correlation 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 when 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 TFP shocks into international macroeconomic models may be a promising and empirically relevant avenue for these 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 news TFP shock contributes more to business cycle variance of the variables in our benchmark specification than does the contemporaneous TFP shock, except for 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 news 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 news TFP shocks are more important than contemporaneous TFP shocks in explaining US real exchange rate fluctuations at business-cycle frequencies. Results are mixed for other macroeconomic variables such as output, investment, and hours worked. 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 news TFP shocks fail to account for US output fluctuations at business-cycle frequencies, although they are important at medium to low frequencies. However, we also find that contemporaneous TFP shocks contribute less than news TFP shocks to the volatility of these variables in our sample.

3.2 Impulse Response Functions

Figure 3 presents the estimated impulse response functions for our benchmark specification. Figures 3(a) and 3(b) display impulse response functions 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

[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.

by bootstrap sampling with 2000 replications. Following a favorable news shock, TFP, output, consumption, and investment all rise and then converge to their new long-run levels, indicating that the news TFP shock has a permanent effect on these variables. The number of hours worked declines on the impact of the news shock and exhibits 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 (i.e., increase the consumption of leisure when expecting future productivity increases. Similar results are also documented in Barsky and Sims (2010). Although the number of hours worked declines on impact of a positive news shock, output remains virtually constant. Given that the news shock does not change TFP immediately, this result suggests an increase in capital utilization under the standard Cobb-Douglas production function with constant return to scale. This finding is consistent with model predictions in Jaimovich and Rebelo (2009) and Nam and Wang (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 dictates whether a shock has a transitory or permanent effect on each variable. Our results are consistent with Barsky and Sims' (2010) findings 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. Output increases less than TFP on impact of a positive contemporaneous shock, although the number of hours worked also increases. This result implies a decline in capital utilization on impact of a productivity increase under the standard Cobb-Douglas production function. Our finding is consistent with Basu, Fernald, and Kimball (2006), who document a decline in utilization following a technology improvement in US data.

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 Figures 3(a) and 3(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 real exchange rate barely responds after a positive contemporaneous shock. Then, it depreciates gradually and exhibits a hump-shaped response over the following periods. For both news and contemporaneous shocks, 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 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 3. This finding suggests that our results for the real exchange rate may not be mainly driven by the Balassa-Samuelson effect.

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) and Enders and Muller (2009) for examples using the long-run restrictions method in SVAR models, or Steinsson (2008) for a univariate example.

Corsetti, Dedola, and Leduc (2006) and Enders and Muller (2009) find that the US real exchange rate appreciates following a positive productivity shock identified by the long-run restrictions method. We performed a similar exercise with our data.[6] Figure 4 shows the impulse response functions to a positive productivity shock in which productivity shocks are identified by assuming that long-run productivity is only affected by these shocks, following Gali (1999). In Figures 4(a) and 4(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. We also repeat the long-run restriction method in our data with the relative variables between the US and the rest of the world and find similar results. It is unlikely that our finding that the US real exchange rate moves in the opposite directions following news and contemporaneous TFP shocks is mainly driven by something special in our data sample.

Several recent studies investigate the effects of productivity changes on international relative prices, following the seminar work of Corsetti, Dedola, and Leduc (2006, 2008).[7] Corsetti, Dedola, and Leduc (2008) consider two cases in which strong wealth effects from positive productivity shocks lead to a real appreciation under incomplete markets: (1) short-run trade elasticity is low enough; (2) productivity shocks

[6] Corsetti, Dedola, and Leduc (2006) use labor productivity in manufacturing as a measure of productivity shocks in the tradable goods sector. In addition, they use cross-country differences of variables in their study.

[7] For instance, see Corsetti, Martin, and Pesenti (2007), Corsetti, Dedola, and Leduc (2009), Enders and Muller (2009), and Enders, Muller, and Scholl (forthcoming).

are persistent enough and trade elasticity is large. Following Corsetti, Dedola, and Leduc (2008), Nam and Wang (2010) show that strong wealth effects from positive news shocks to productivity can generate a real appreciation. In a two-country DSGE model, they show 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, and therefore the supply of home goods, immediately. 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 for contemporaneous shocks. As a result, the real exchange rate and the terms of trade depreciate following a positive contemporaneous shock to productivity, but appreciate following a positive news shock in Nam and Wang (2010). The findings in this paper are consistent with 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 3(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.

Although our empirical findings are consistent with theoretical predictions in Nam and Wang (2010), one important caveat has to be noted. The purpose of our paper is not to provide an empirical test on Nam and Wang (2010). Therefore, we do not use it as a rigorous theoretical framework in our empirical study. For instance, Nam and Wang (2010) study productivity shocks for tradable goods, but we use TFP in this paper. It would be interesting to see whether our results hold up in the case with trade-sector productivity shocks. We leave this for our future research.

3.3 Robustness Checks

In this subsection, we report the 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 utilization-adjusted 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. In all cases, we confirm our finding that news TFP shocks are important in driving the US real exchange rate. However, the finding that the real exchange rate moves in the opposite directions in response to news and contemporaneous TFP shocks seems less robust.

Figure 5 shows the results of the smaller model. 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.[8] 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, 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. 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.[9] 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. However, in response to a positive contemporaneous shock, the real exchange rate first appreciates on impact of the shock before it depreciates gradually in the following periods as in the benchmark specification. Note that the appreciation of the real exchange rate following a contemporaneous TFP shock is much smaller and also less persistent than in the case with the TFP shock identified by the long-run restriction method.

Figure 7 displays the estimated impulse response functions to a favorable news shock when utilization-

[8] 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.

[9] 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.

adjusted TFP is replaced with labor productivity. Labor productivity is measured by output per hour. To avoid collinearity, the number of 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. 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.

3.4 Results for the US-ROW Data

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.[10] 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

[10] 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.

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.[11]

Figure 9 shows the impulse response functions for the US-ROW data. The US real exchange rate appreciates strongly and persistently following a positive news shock to TFP. In response to a positive contemporaneous shock, the US real exchange rate appreciates slightly on impact and then depreciates persistently. 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.[12] The impulse response function of the terms of trade is included in Figure 9 as well. In 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 that do not differentiate between 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, differ 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 3.1 for the US-ROW data. Our main findings in that section do not change qualitatively.[13] 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 neg-

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

[12] The US terms of trade are calculated from the export and import price indexes obtained from the BEA.

[13] Results are available upon request.

atively 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 when conditional on the contemporaneous TFP shock in our US-ROW data. This reflects the fact that the US real exchange appreciates initially following a positive contemporaneous TFP shock in Figure 9(b), although it depreciates in the following periods. This empirical finding suggests that Corsetti, Dedola, and Leduc's (2008) explanation is important to understand the Backus-Smith puzzle.

Note in Table 4 that sizable differences exist between the correlations that are 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.[14]

4 Cross-country Comparisons

We find in the US data that the real exchange rate exhibits a persistent appreciation following a favorable news shock to productivity. In this section, we investigate whether similar patterns exist in other countries. Problems with data availability 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 employed person, which is less accurate than output per hour because it does not take into account the variation of hours worked

[14]Significant differences exist between these two shocks when we apply the variance decomposition exercises in Section 3.1 to the US-ROW data. Results are available upon request.

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 employed person), 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).[15] 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.[16]

With the exception of 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 data availability issues, 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 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, (e.g., 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. For instance, Fujiwara, Hirose, and Shintani (forthcoming) estimate a DSGE model with news shocks to TFP using Bayesian methods. They find that news shocks play a relatively more important role in the US than in Japan. 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.

[15]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.

[16]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.

5 Conclusion

In this paper, we empirically investigate the effects of news about future productivity on the US real exchange rate. Our study is inspired by two findings in the literature: (1) news shocks to productivity are found important in driving asset prices; (2) exchange rates behave like asset prices. Employing Barsky and Sims' (2010) methodology, we identify news and contemporaneous shocks to US TFP. We find that news about future productivity plays a more important role than contemporaneous innovations in productivity in driving the US real exchange rate. This finding is consistent with several recent studies. If exchange rate movements contain information about future fundamentals, the exchange rate should be able to forecast these 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 when 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 the 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.

In addition, we find that the US real exchange rate appreciates in response to a positive news shock and depreciates in response to a positive contemporaneous shock. Similar results are also found for the US terms of trade. These findings suggest that distinguishing these two shocks is important when studying the international transmission of shocks both empirically and theoretically and merits further investigation.

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 quarters or more), they account for a relatively small share (30%) at short horizons. Shocks from other resources such as demand, monetary policy, and financial market 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 important 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) study the effects of news shocks to monetary policy in a DSGE model. We leave these studies for the future research.

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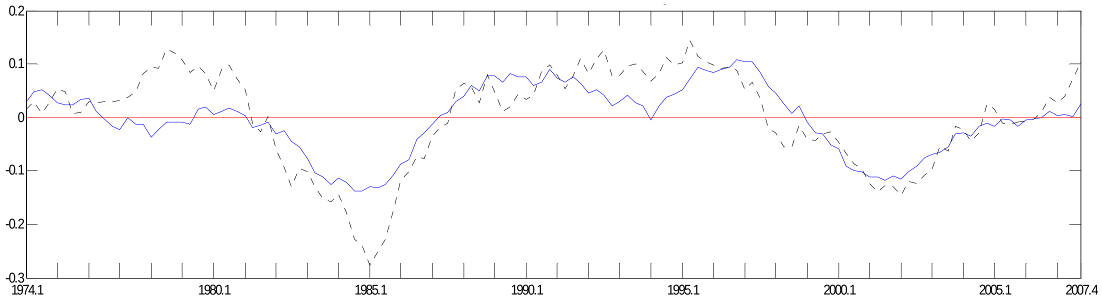
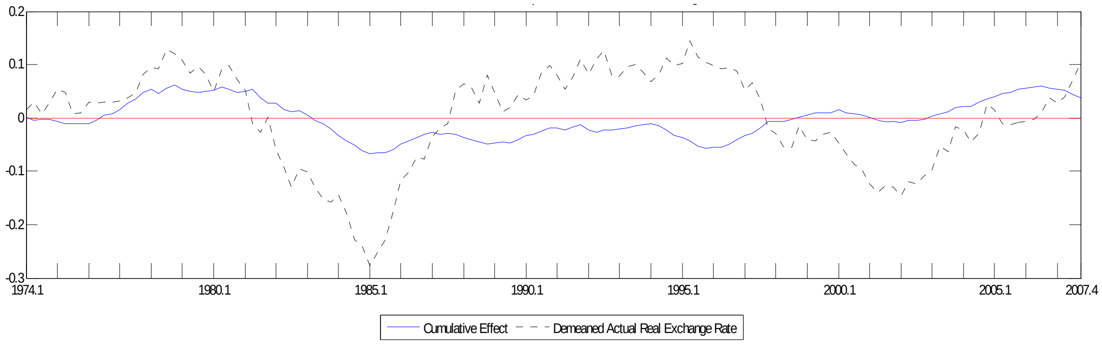
Figure 1: Cumulative Effects of News and Contemporaneous Shocks on the Real Exchange Rate



(a) News Shock

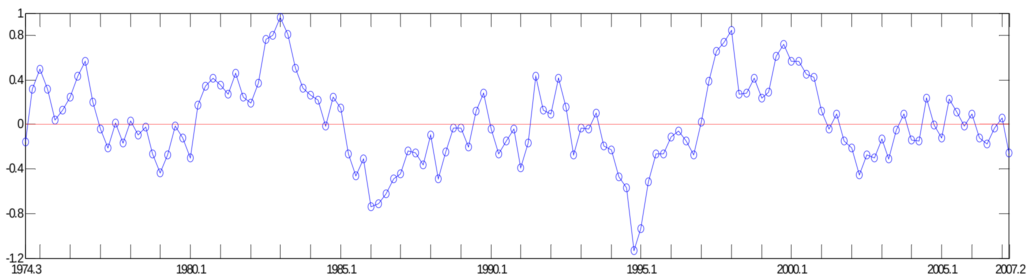


(b) Contemporaneous Shock

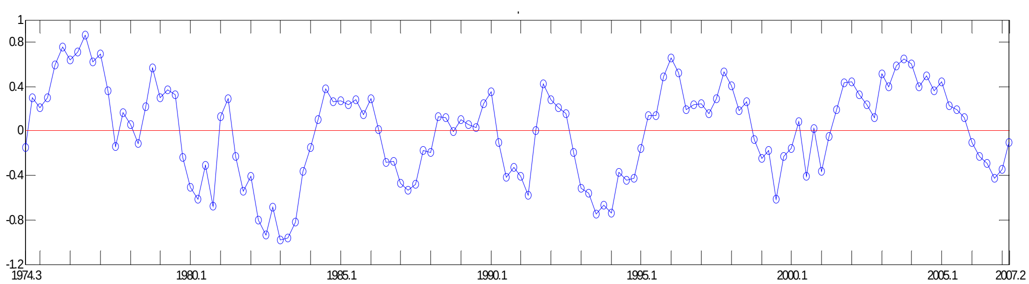
Note:

–The cumulative effect of each shock is the fitted value of the log real exchange rate calculated from our benchmark model conditional on that shock.

Figure 2: Time Paths of News and Contemporaneous Shocks (4-quarter Moving Average)



(a) News Shock



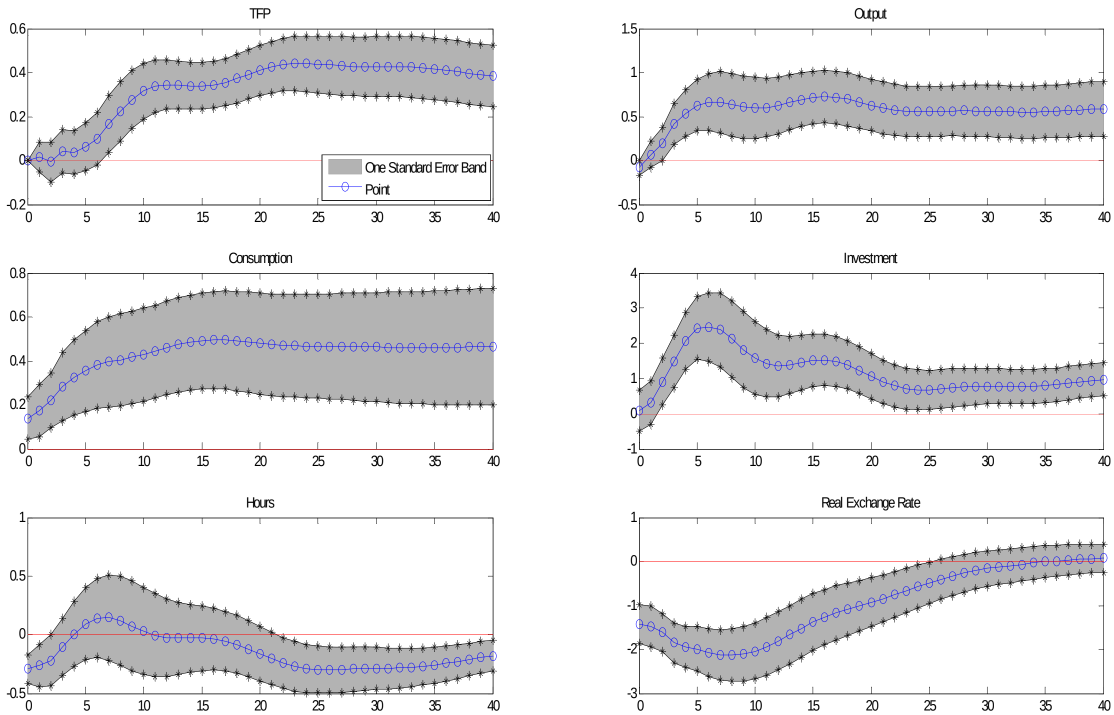
(b) Contemporaneous Shock

Notes:

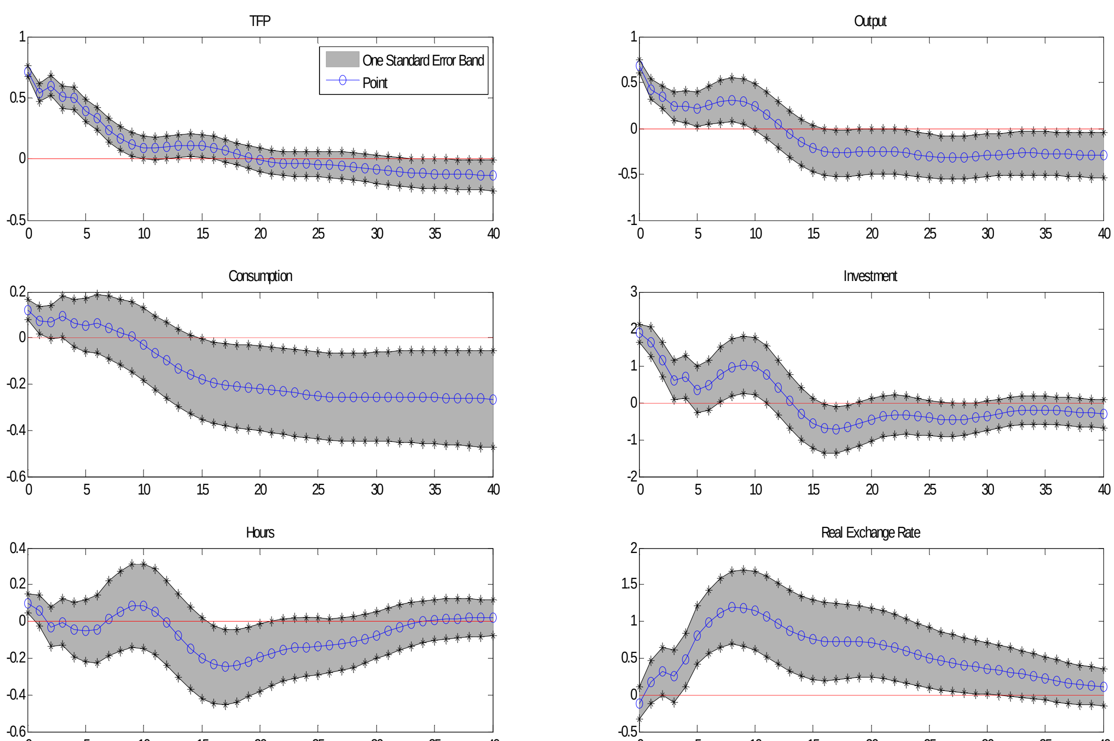
–This figure displays time series paths of news and contemporaneous shocks identified in the benchmark model with US data.

–The time paths are expressed in four-quarter moving averages to smooth out noises.

Figure 3: Impulse Response Functions: Benchmark Specification



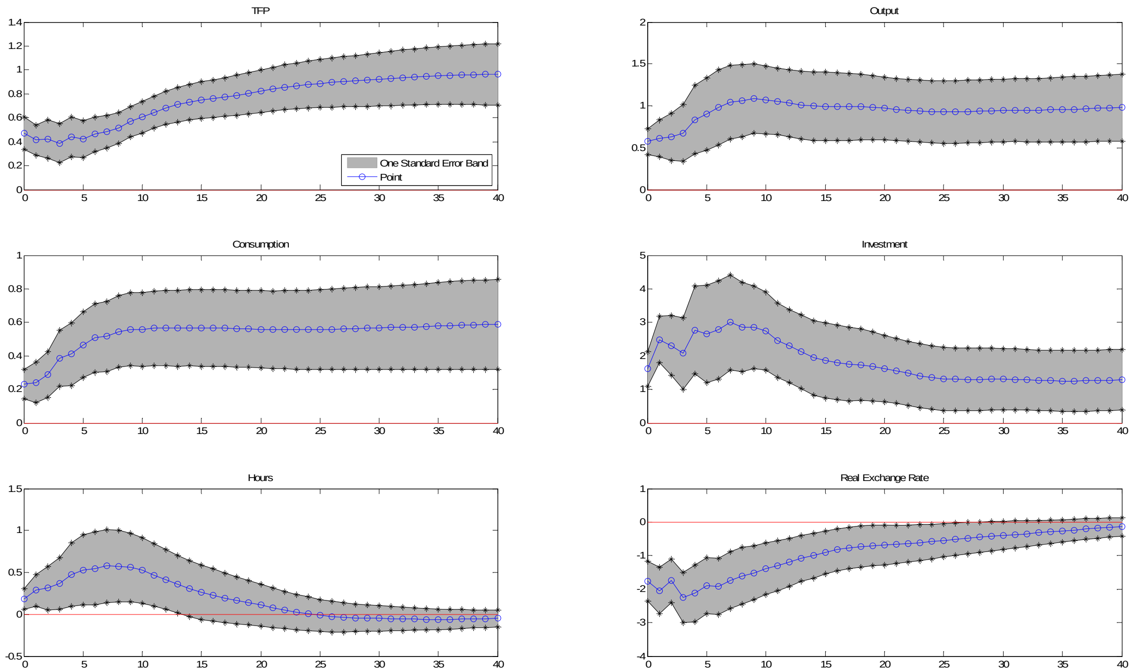
(a) News Shock



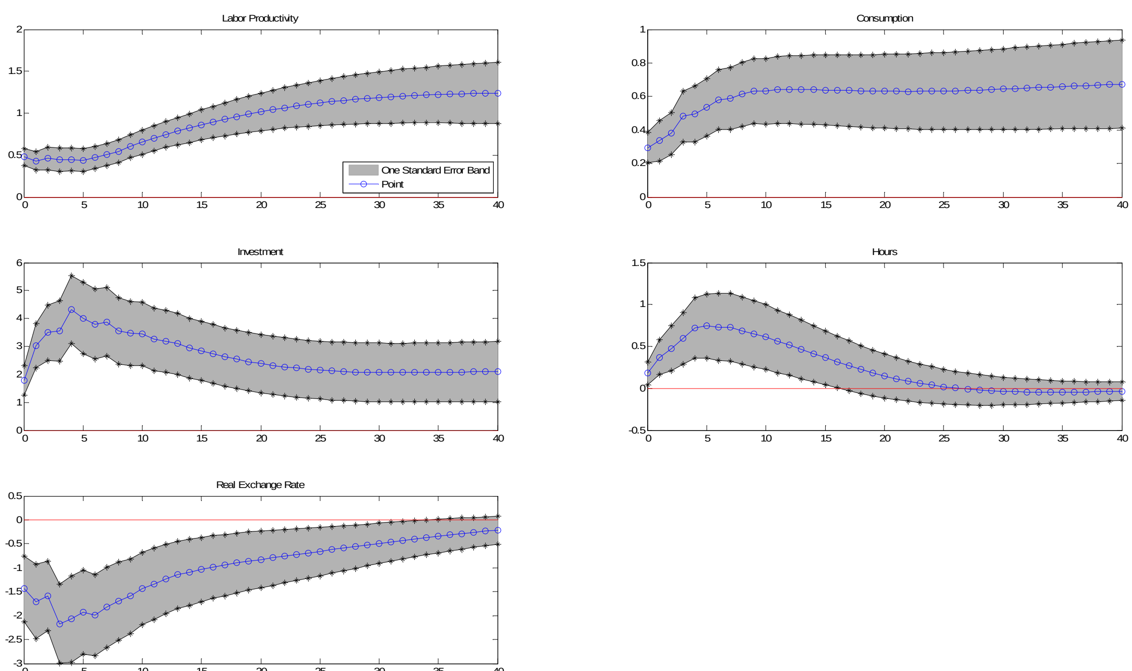
(b) Contemporaneous Shock

Note:
–The horizontal axis shows quarters following a positive shock and the vertical axis is the percentage deviation of each variable from its steady state.

Figure 4: Impulse Response Functions: Long-run Restrictions Method



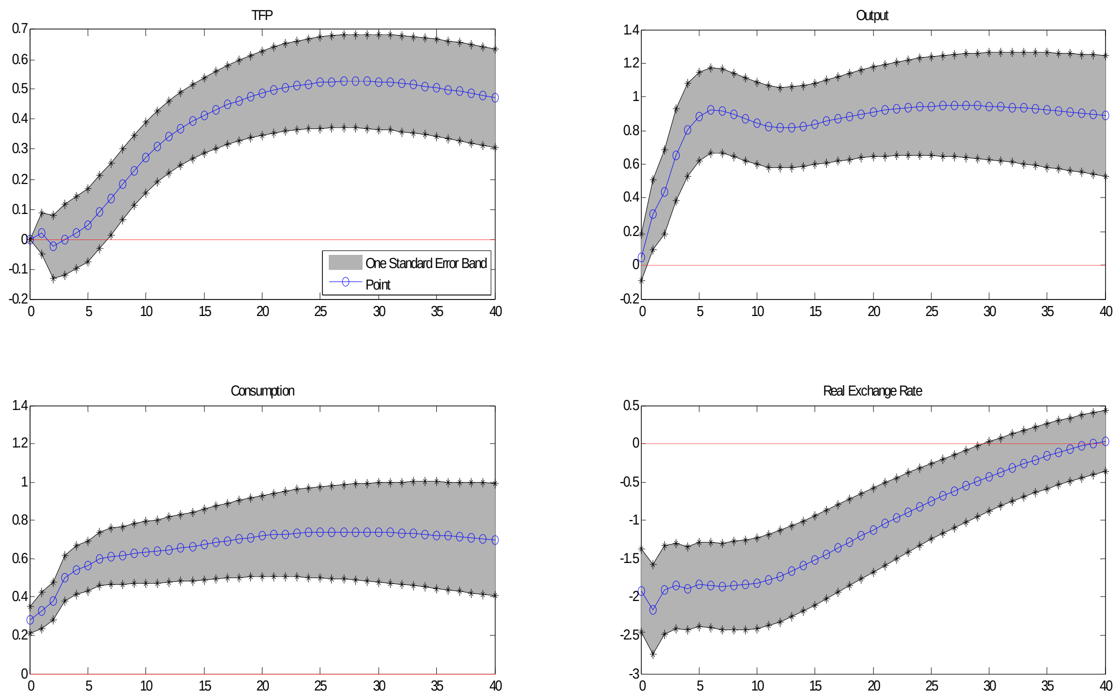
(a) Utilization-adjusted TFP as the Measure of Productivity



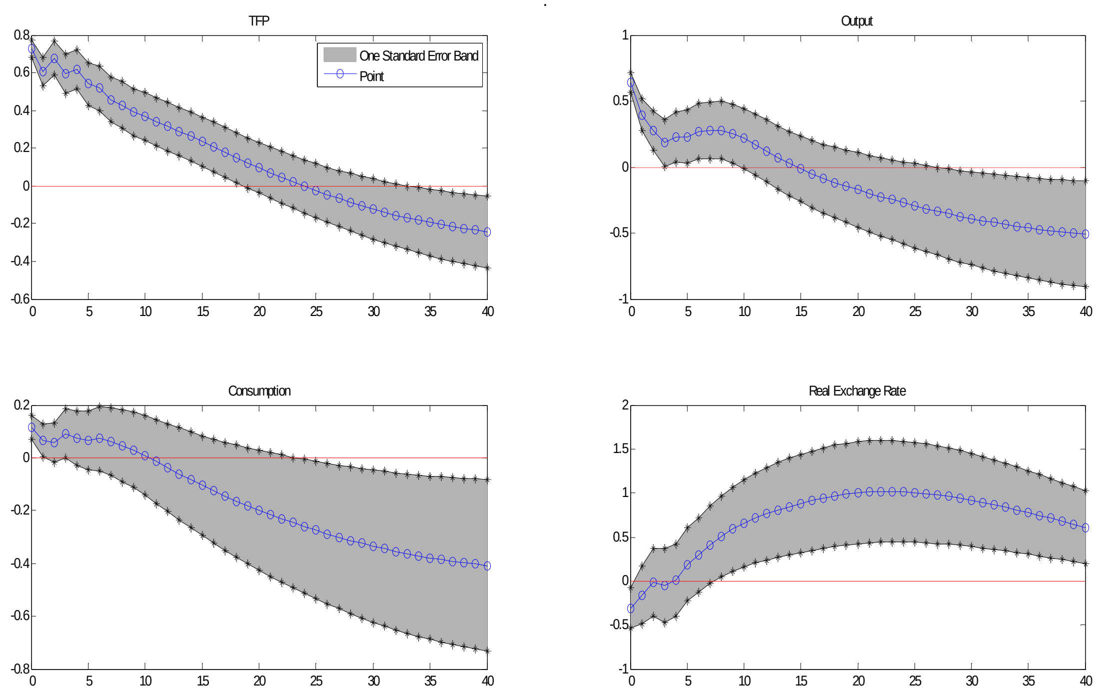
(b) Labor Productivity (output per hour) as the Measure of Productivity

Note:
–The horizontal axis shows quarters following a positive shock and the vertical axis is the percentage deviation of each variable from its steady state.

Figure 5: Impulse Response Functions: Small Model



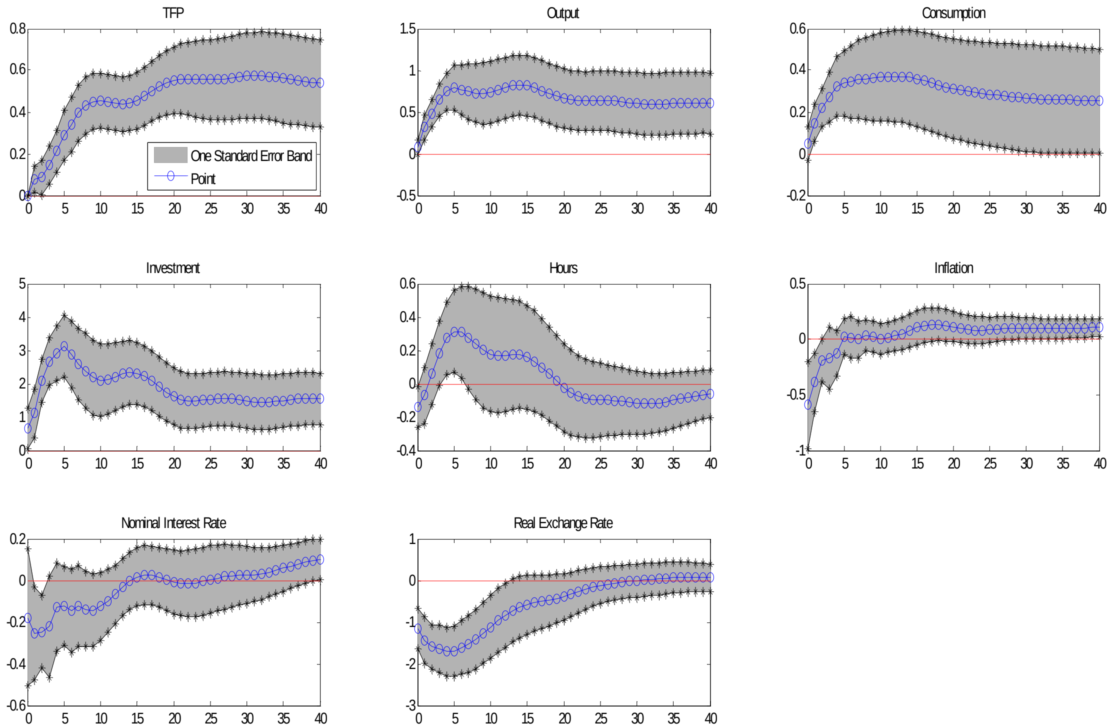
(a) News Shock



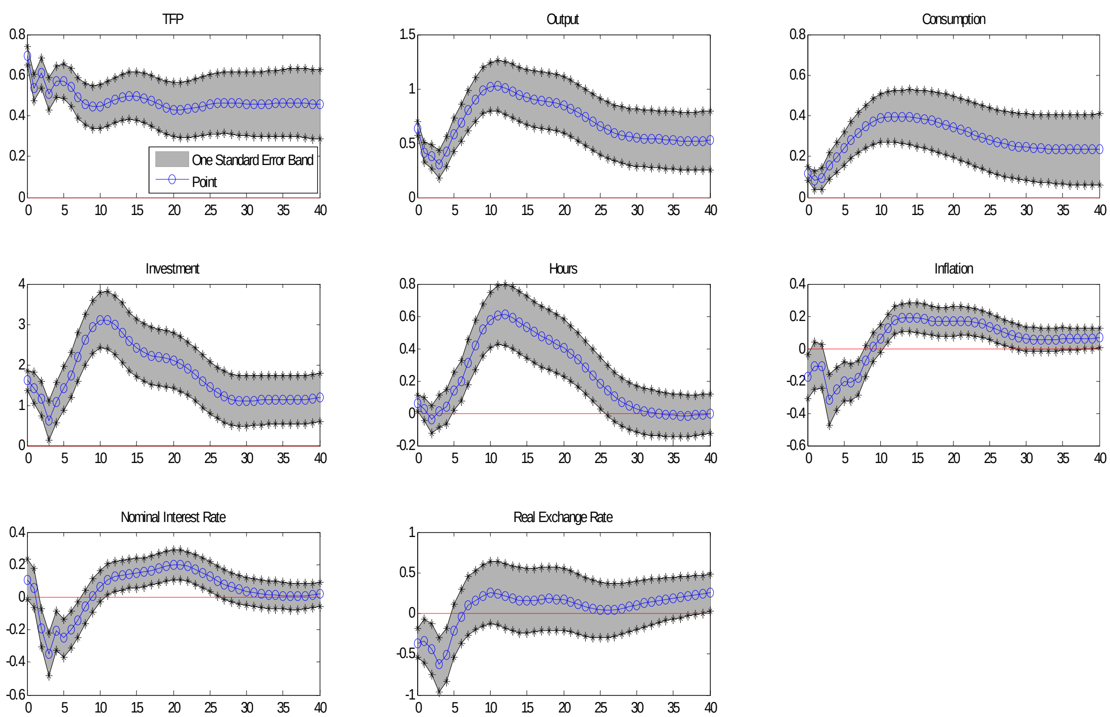
(b) Contemporaneous Shock

Note:
–The horizontal axis shows quarters following a positive shock and the vertical axis is the percentage deviation of each variable from its steady state.

Figure 6: Impulse Response Functions: Large Model



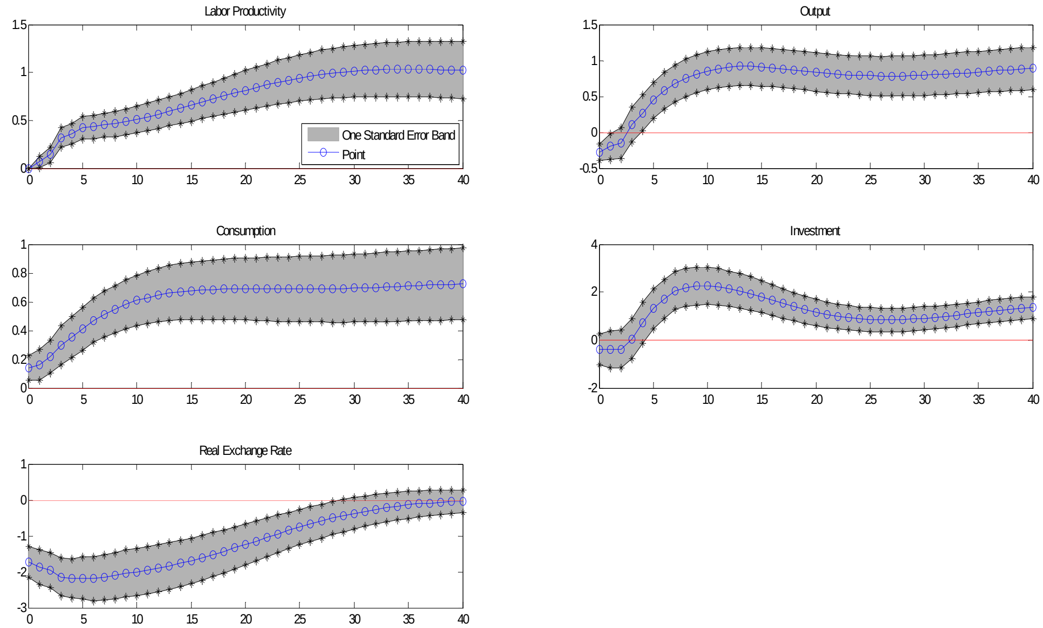
(a) News Shock



(b) Contemporaneous Shock

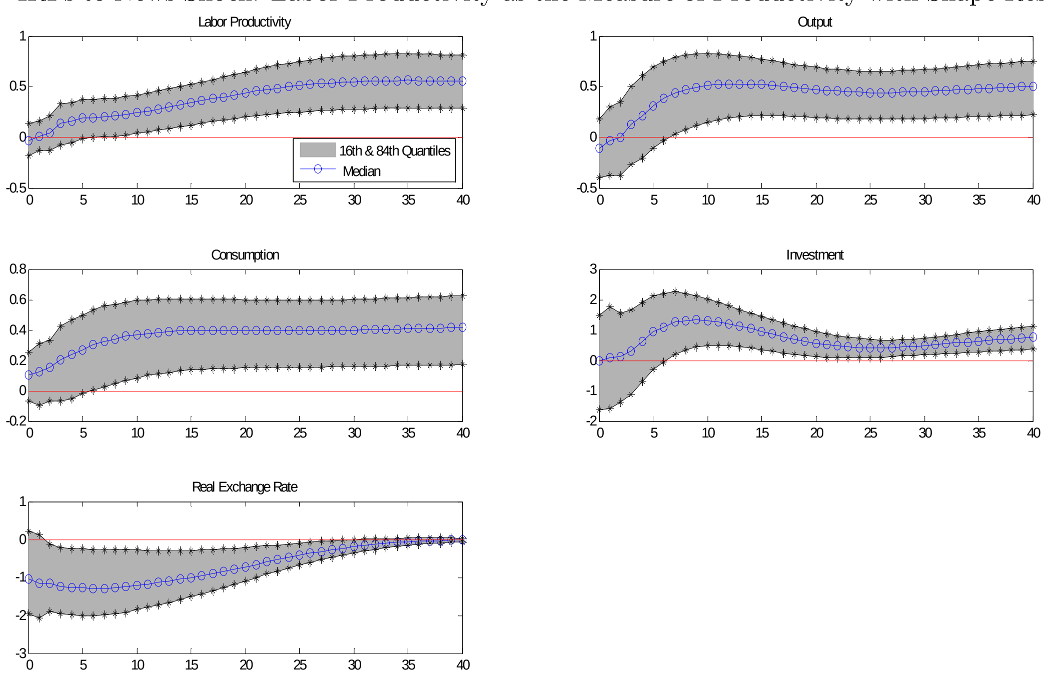
Note:
–The horizontal axis shows quarters following a positive shock and the vertical axis is the percentage deviation of each variable from its steady state.

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



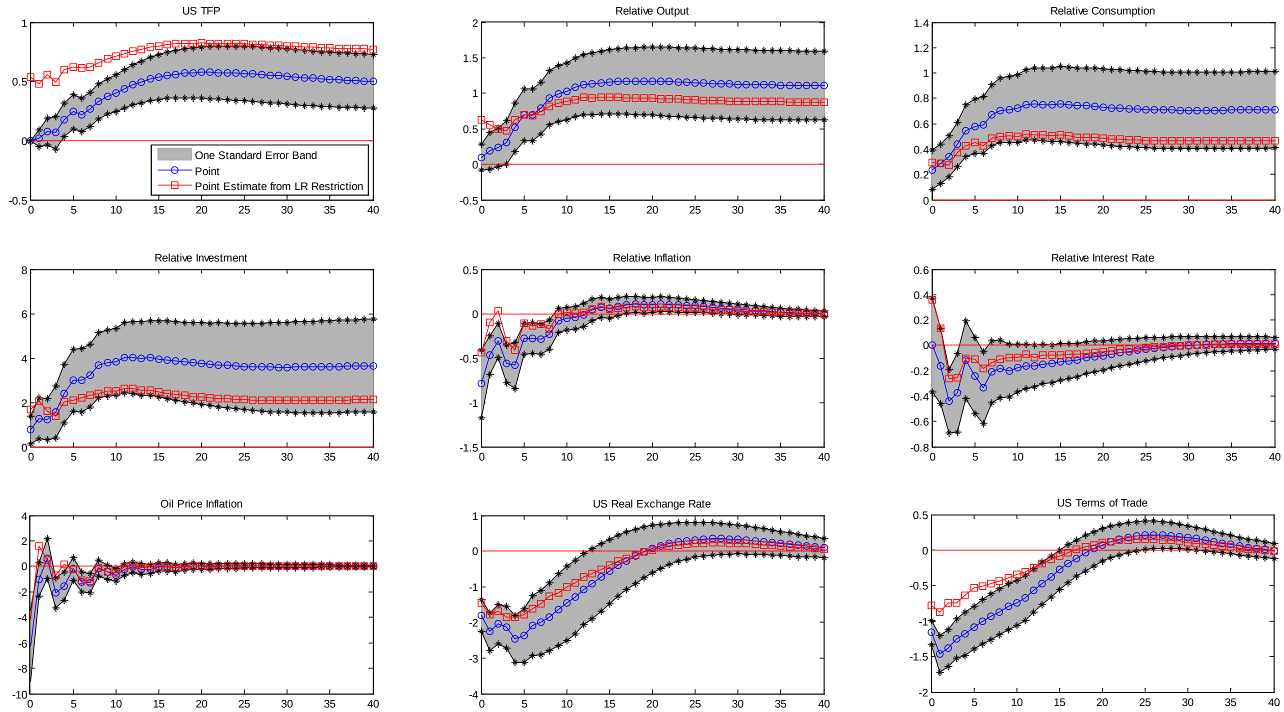
Note:
–The horizontal axis shows quarters following a positive shock and the vertical axis is the percentage deviation of each variable from its steady state.

Figure 8: IRFs to News Shock: Labor Productivity as the Measure of Productivity with Shape Restrictions

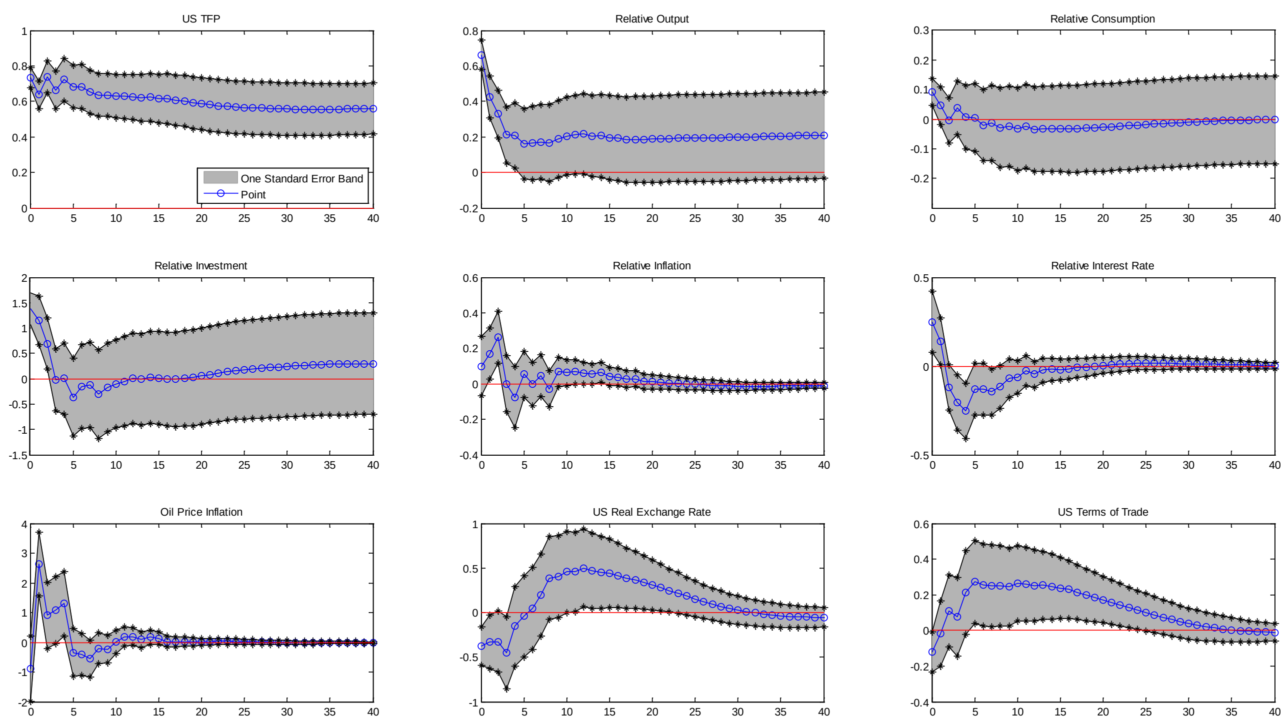


Note:
–The horizontal axis shows quarters following a positive shock and the vertical axis is the percentage deviation of each variable from its steady state.

Figure 9: Impulse Response Functions: Cross-country Differences



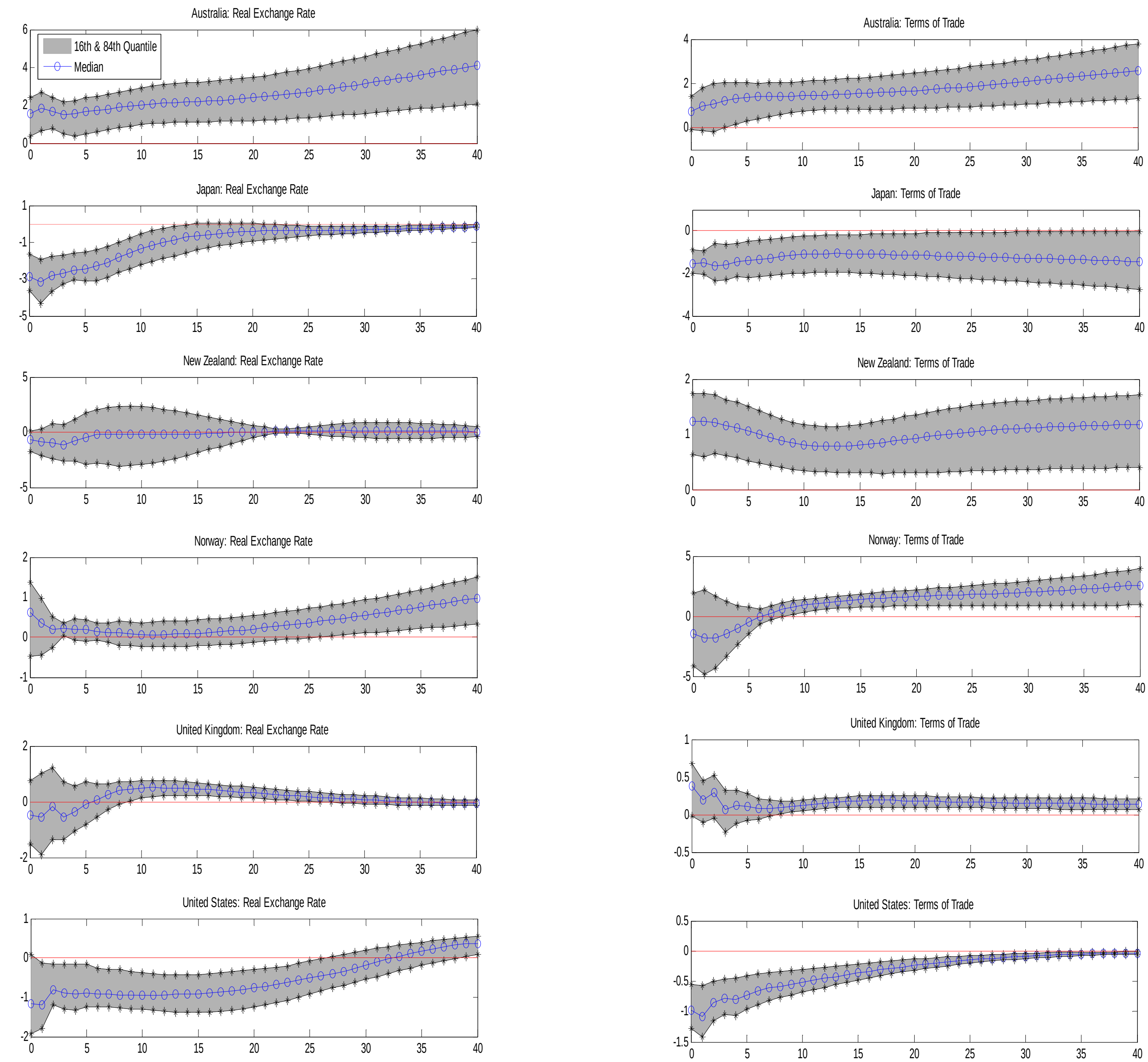
(a) News Shock



(b) Contemporaneous Shock

Note:
–The horizontal axis shows quarters following a positive shock and the vertical axis is the percentage deviation of each variable from its steady state.

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



Note:
–The horizontal axis shows quarters following a positive shock and the vertical axis is the percentage deviation of each variable from its steady state.

Table 1: Decomposition of Forecast Error Variance (FEV)

	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	0.90
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	0.30	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

Notes:

–This table reports the decomposition of the forecast error variance for our benchmark model with US data.

–Entries in the upper panel are shares of the forecast error variance that are attributed to each shock at different horizons. Numbers in parentheses are standard errors obtained from 2000 bootstrap replications.

–Entries in the lower panel are shares of the forecast error variance that are attributed to the news and contemporaneous shocks jointly.

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)

Notes:
–This table reports the correlations between the actual and counterfactual data that are conditional on either the news or the contemporaneous TFP shocks.
–The actual data are quarterly US data from 1973Q1 to 2007Q4. The counterfactual data are fitted values of our benchmark model conditional on each shock.
–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	Conditional on news shock	Conditional on 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)

Notes:
–The actual data are quarterly US data from 1973Q1 to 2007Q4.
–All data are logged and HP-filtered with a smoothing parameter of 1600.
–Numbers in parentheses are standard errors obtained from 2000 bootstrap replications.
–The right panel reports the ratio of the variance of counterfactual data conditional on each shock to the variance of actual data.

Table 4: Correlations with the Real Exchange Rate

	Data	Conditional on news shock	Conditional on contemporaneous shock	Conditional 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

Notes:
–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 $\gamma^* = (0, \gamma_{\mathbf{2}}^{*\prime})'$, where $\gamma_{\mathbf{2}}^*$ 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.