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**News-Driven International Business Cycles:  
Effects of the US News Shock on  
the Canadian Economy**

Michiru Sakane

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# News-Driven International Business Cycles: Effects of the US News Shock on the Canadian Economy

Michiru Sakane <sup>\*†</sup>

Department of Economics, Duke University

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## Abstract

This paper studies the international transmission effects of the news about the Total Factor Productivity (TFP) of the US to the Canadian economy. First, using the Vector Error Correction Model (VECM), the impulse responses of Canadian macroeconomic variables to the US news shock are estimated. Next, I develop and estimate a two-country RBC model with the preference introduced by Jaimovich and Rebelo (2008) and investment adjustment cost to generate booms in Canadian variables in response to news about future US TFP. I find that international macroeconomic comovements between the US and Canada can be generated by the news about future TFP in the US. Unlike previous studies, I show that the response of Canadian TFP to the US news shock is important in order to generate the boom observed in empirical analysis. Estimated value of the preference parameter indicates that getting rid of the wealth effect on hours worked is important. I also show that low elasticity of substitution between domestically and foreign produced intermediate goods can also help explaining the domestic boom created by the news shock, which highlights the importance of analyzing an open economy.

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\*Department of Economics, Duke University. E-mail: michiru.sakane@duke.edu

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# 1 Introduction

This paper studies the international transmission effects of the news about the Total Factor Productivity (TFP) of the US to the Canadian economy. The recent studies, e.g., Beaudry and Portier (2006), Beaudry, Dupaigne and Portier (2008), Christiano et al. (2008), Jaimovich and Rebelo (2006, 2008), Schmitt-Grohé and Uribe (2008), suggest that business cycles can be explained using the news about future productivity. Among others, empirical studies such as Beaudry and Portier (2006) showed that the news shock can be detected when a shock to stock prices that is orthogonal to the innovation in TFP is highly correlated with a shock that drives long-run movements in TFP. This evidence suggests that stock prices incorporate information about future TFP. Their empirical evidence shows that news shocks generate positive booms in domestic output, consumption, investment and hours. Beaudry, Dupaigne and Portier (2008) showed empirical findings in which the news shocks transmit abroad and generate international comovements.

In this paper, I first use a Vector Error Correction Model (VECM) to estimate the impulse responses of Canadian macroeconomic variables to the news shock of TFP in the US. This estimation method is based on Beaudry and Portier (2006) and Beaudry, Dupaigne and Portier (2008). Beaudry and Portier (2006) estimates the impulse responses of US macroeconomic variables to the news shock of TFP in the US. Whereas Beaudry, Dupaigne and Portier (2008) also estimated impulse responses of Canadian variables to the news shock of TFP in the US, I introduce a two-step estimation that utilizes all the information about the news so that I can identify the news better than theirs. I find that Canadian TFP significantly responds to US news shock. Next, I develop and estimate a two-country RBC model with the preference of the type suggested by Jaimovich and Rebelo (2006, 2008) and investment adjustment cost to generate booms in Canadian variables in response to news about future US TFP. Using this model and feeding actual TFP processes driven by the news shock, I find that international macroeconomic comovements between the US and Canada can be generated by the news about future TFP in the US. Using a counterfactual analysis, I show that the response of Canadian TFP to US news shock is important in order to generate the boom observed in empirical analysis. Estimated value of the preference parameter indicates that getting rid of the wealth effect on hours worked is important. I also find that low elasticity of substitution between domestically produced intermediate goods and foreign produced goods can also help explaining the domestic boom created by the news shock, which highlights the importance of analyzing in open economy setting.

It is widely known that the standard real business cycle model does not account for comovements both in closed and open economy. Positive news shock increases

consumption because of a wealth effect. The wealth effect increases leisure and labor hours decrease. The decrease of labor hours pushes the output down and investment decreases as well, since there is an increase in consumption. Several studies have tried to tackle this problem. Beaudry and Portier (2004) used a closed-economy model with strong complementarities between different production sectors in order to induce comovements between the variables. Beaudry, Dupaigne and Portier (2008) proposed an alternative model to generate international comovements in response to news about future TFP in foreign countries. They use a two-country model augmented with strong complementarity between domestically-produced and foreign-produced intermediate goods. Jaimovich and Rebelo (2006,2008) emphasized the importance of the preference structure. Since wealth effect caused by positive news about future productivity, which is negative under standard preference structure such as Cobb-Douglas utility, is nil under GHH preference (after Greenwood et al. (1988)), the model gives rise to positive comovement by substitution effects. They also suggested that real rigidities such as adjustment costs of investment and labor are important.

This paper contributes to growing literature on the news-driven international business cycle in three ways. First, I make a tight link between the data and the model, which was lacking in previous literature of news-driven international business cycles, especially in their diffusion process of the news about future TFP. In this paper, I take into account the fact that Canadian TFP is also responding to the US news significantly. I show this fact using VECM estimation and feed this process into the model. Second, I use a two-country model with different size when I analyze the transmission of the news between US and Canada. For the US and Canadian economy, it is more conventional to use a small open economy model. However, this shuts down a possible demand channel of the model. Third, this paper also focuses on the response of the terms of trade, which is not considered by the previous literature on the transmission of news.

The organizations of this paper is as follows. In Section 2, I present empirical evidence using the VECM model to estimate the responses of Canadian variables to the US news shock. Section 3 presents a model. Section 4 shows the results of quantitative analysis in which I compare the empirical and theoretical impulse responses. Section 5 concludes.

## 2 Empirical evidence

The goal of this section is to provide the empirical evidences of international spillover of the news about US TFP to Canadian TFP and macroeconomic variables. The

identification and estimation methods follow and extend Beaudry and Portier (2006) and Beaudry, Dupaigne and Portier (2008).

## 2.1 Data

### 2.1.1 US data

In my empirical analysis, I use quarterly data. The data for the US is over period 1948Q1 to 2006Q4. For my bivariate VECM specification, I use US total factor productivity (TFP) and stock price (SP).

The US TFP series is defined as

$$\log TFP_t = [\log Y_t - s_h \log H_t - (1 - s_h) \log K_t] / s_h \quad (1)$$

where  $Y$  is output,  $H$  is labor hours,  $K$  is capital, and  $s_h$  is the labor share estimated by the average of the labor share from 1948 to 2006 (its value is 0.678). Output measure for calculating TFP ( $Y$ ) is the quarterly real GDP of non-farm business sector. The capital series ( $K$ ) is the real capital input in private business sector. Since the original series of the real capital input is available only at the annual frequency, I interpolate to obtain a quarterly series. The measure of hours worked ( $H$ ) is the hours index in non-farm business sector.

In higher dimensional systems, I also use output, consumption, investment, exports and imports. For output, I use real GDP. For the consumption measure, I use real personal consumption expenditures. For the investment measure, I use real fixed private investment. For the exports and imports measure, I use real exports and imports of goods and services. See Appendix A for more details.

### 2.1.2 Canadian data

I construct Canadian TFP series in the same way as (1)<sup>1</sup>. All the Canadian data except hours worked and capital series are over period 1961Q1 to 2006Q4. Hours worked is over period 1966Q1 to 2006Q4 and capital series is over period 1961Q4 to 2006Q4. Output measure is real GDP and capital measure is real capital series constructed by Bank of Canada. I calculate the measure of hours worked using data from the Bank of Canada<sup>2</sup>.

In higher dimension systems, I also use consumption, investment, exports, imports, trade balance and terms of trade. For the consumption measure, I use real

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<sup>1</sup>Rhys Mendes (Bank of Canada) kindly gave me the dataset for Canada.

<sup>2</sup>I calculate the measure of hours worked as follows. First, I multiply the Canadian population series by the participation rate series. I multiply that series by employment rate calculated using the unemployment rate to get the employment series. Then I multiply this by the average hours worked series to get the total hours worked.

personal expenditure on consumer goods and services. For the investment measure, I use real investment in non-residential structures and equipment. For exports and imports, I use real exports and imports. Terms of trade is defined as import price deflator divided by export price deflator. For the trade balance, in order to incorporate the effect of terms of trade, I first multiply the series of real imports by the terms of trade, subtract this series from real exports and divide by real GDP. This definition is consistent with that of the model I describe in Section 3.

## 2.2 Identification of the news shock: Evidence from bivariate VECM of $TFP$ and $SP$

In this subsection, I identify the news shock occurred in the US using two variables: US TFP and US stock price (S&P 500) following Beaudry and Portier (2006). I use quarterly data from 1948Q1 to 2006Q4.<sup>3</sup> Augmented Dickey-Fuller test suggests that these two variables are  $I(1)$  variables. Johansen's cointegration test indicates there is a cointegration between these two variables at 90% level. Therefore, I estimate a bivariate Vector Error Correction Model (VECM) instead of VAR. I use five lags in VECM following the result of likelihood ratio test.<sup>4</sup>

I estimate the following VECM model using Johansen's maximum likelihood procedure:

$$\begin{aligned}
\begin{bmatrix} \Delta TFP_t^{US} \\ \Delta SP_t \end{bmatrix} &= \underbrace{\begin{bmatrix} \gamma_1 \\ \gamma_2 \end{bmatrix}}_{\gamma} + \underbrace{\begin{bmatrix} \zeta_{11}^0 & \zeta_{12}^0 \\ \zeta_{21}^0 & \zeta_{22}^0 \end{bmatrix}}_{\zeta_0} \begin{bmatrix} TFP_{t-1}^{US} \\ SP_{t-1} \end{bmatrix} \\
&+ \underbrace{\begin{bmatrix} \zeta_{11}^1 & \zeta_{12}^1 \\ \zeta_{21}^1 & \zeta_{22}^1 \end{bmatrix}}_{\zeta_1} \begin{bmatrix} \Delta TFP_{t-1}^{US} \\ \Delta SP_{t-1} \end{bmatrix} \\
&+ \dots \\
&+ \underbrace{\begin{bmatrix} \zeta_{11}^k & \zeta_{12}^k \\ \zeta_{21}^k & \zeta_{22}^k \end{bmatrix}}_{\zeta_k} \begin{bmatrix} \Delta TFP_{t-k}^{US} \\ \Delta SP_{t-k} \end{bmatrix} + \underbrace{\begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}}_{u_t}. \tag{2}
\end{aligned}$$

Following Beaudry and Portier (2006), I identify the news shock by the sequential scheme. We can write above VECM model using following Wold representation:

$$\begin{pmatrix} \Delta TFP_t^{US} \\ \Delta SP_t \end{pmatrix} = C(L) \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$$

where  $C(L) = I + \sum_{i=1}^{\infty} C_i L^i$ .  $I$  is the identity matrix and  $L$  is the lag operator.

In order to identify the news shock, I use two different orthogonalization schemes.

<sup>3</sup>See Appendix for the explanation of data in detail.

<sup>4</sup>See page 143 of Lütkepohl (2005) for detail.

First, the short-run identification scheme has Wold (MA) representation as<sup>5</sup>:

$$\begin{pmatrix} \Delta TFP_t^{US} \\ \Delta SP_t \end{pmatrix} = \Gamma(L) \begin{pmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{pmatrix} \quad (3)$$

where  $\Gamma(L) = \sum_{i=0}^{\infty} \Gamma_i L^i$  and  $\epsilon_t \equiv [\epsilon_{1t} \epsilon_{2t}]'$  are the structural residuals whose variance covariance matrix is assumed to be an identity matrix and the (1, 2) element of  $\Gamma_0$  is zero. The latter means that the shock on  $SP$ ,  $\epsilon_{2t}$ , does not have any short-run impact on  $TFP$ .

Second, the long-run identification scheme has Wold representation as follows:

$$\begin{pmatrix} \Delta TFP_t^{US} \\ \Delta SP_t \end{pmatrix} = \tilde{\Gamma}(L) \begin{pmatrix} \tilde{\epsilon}_{1t} \\ \tilde{\epsilon}_{2t} \end{pmatrix} \quad (4)$$

where  $\tilde{\Gamma}(L) = \sum_{i=0}^{\infty} \tilde{\Gamma}_i L^i$  and  $\tilde{\epsilon}_t$  is the structural residual matrix whose variance covariance matrix is assumed to be an identity matrix. For this second scheme, I impose a restriction that the (1, 2) element of  $\tilde{\Gamma}(1)$ , i.e., long-run matrix, equals zero. This ensures that the shock to  $TFP$ ,  $\tilde{\epsilon}_{1t}$ , does not have any long-run impact on  $SP$ .

The resulting impulse responses are presented in Figure 1. The top graph presents the impulse response of  $TFP$  corresponding to  $\epsilon_{2t}$  shock (from short-run identification) and  $\tilde{\epsilon}_1$  shock (from long-run identification). As can be seen from this figure, the responses from these two identifications schemes have highly similar dynamics. On the one hand, the shock on  $SP$ ,  $\epsilon_2$ , which does not have contemporaneous impact on  $TFP$ , has long-run effect on  $TFP$ . On the other hand, the shock on  $TFP$ ,  $\tilde{\epsilon}_{1t}$ , which does not have a long-run effect on  $TFP$ , has no contemporaneous impact on  $TFP$ .

Similarly, the bottom graph in Figure 1 presents the response of  $SP$  corresponding to these two identification schemes. The responses are again highly correlated. These results together imply that stock prices incorporate the information of the future increase in productivity before the actual productivity goes up.

The scatter plot of  $\epsilon_2$  and  $\tilde{\epsilon}_1$  are shown in Figure 2. As can be seen from the figure, the  $\epsilon_{2t}$  and  $\tilde{\epsilon}_{1t}$  line up on the 45 degree line, which also supports the high correlation between these shocks.

These evidence indicates that a shock to stock prices that is orthogonal to the innovation in productivity is almost perfectly correlated with a shock that drives long-run movements in productivity. This means that stock prices incorporate information about future productivity. Therefore, the two structural shocks I derived are interpreted as news shock series, which is consistent with the result of Beaudry and Portier (2006).

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<sup>5</sup>See Hansen (2000) for the explanation of the derivation of Wold representation in the case of VECM model.

## 2.3 Empirical evidence of international spillover of the news about US TFP to Canadian TFP

In this section, I present empirical evidences about the performance of Canadian TFP in response to the news about future productivity in the US.

The data of Canadian TFP is constructed only from 1966Q1 since the data of hours worked is available only from that quarter. Figure 3 plots the TFP processes in log for the US and Canada. The likelihood ratio test on cointegration does not reject the hypothesis of cointegration. Therefore we assume that the processes are cointegrated and use VECM model for the estimation. I set up a three-variable VECM equation as follows.

$$\begin{aligned}
 \begin{bmatrix} \Delta TFP_t^{US} \\ \Delta SP_t \\ \Delta TFP_t^C \end{bmatrix} &= \underbrace{\begin{bmatrix} \tilde{\gamma}_1 \\ \tilde{\gamma}_2 \\ \tilde{\gamma}_3 \end{bmatrix}}_{\tilde{\gamma}} + \underbrace{\begin{bmatrix} \tilde{\zeta}_{11}^{(0)} & \tilde{\zeta}_{12}^{(0)} & 0 \\ \tilde{\zeta}_{21}^{(0)} & \tilde{\zeta}_{22}^{(0)} & 0 \\ \tilde{\zeta}_{31}^{(0)} & \tilde{\zeta}_{32}^{(0)} & \tilde{\zeta}_{33}^{(0)} \end{bmatrix}}_{\tilde{\zeta}_0} \begin{bmatrix} TFP_{t-1}^{US} \\ SP_{t-1} \\ TFP_{t-1}^C \end{bmatrix} \\
 &+ \underbrace{\begin{bmatrix} \tilde{\zeta}_{11}^{(1)} & \tilde{\zeta}_{12}^{(1)} & 0 \\ \tilde{\zeta}_{21}^{(1)} & \tilde{\zeta}_{22}^{(1)} & 0 \\ \tilde{\zeta}_{31}^{(1)} & \tilde{\zeta}_{32}^{(1)} & \tilde{\zeta}_{33}^{(1)} \end{bmatrix}}_{\tilde{\zeta}_1} \begin{bmatrix} \Delta TFP_{t-1}^{US} \\ \Delta SP_{t-1} \\ \Delta TFP_{t-1}^C \end{bmatrix} \\
 &+ \dots \\
 &+ \underbrace{\begin{bmatrix} \tilde{\zeta}_{11}^{(k)} & \tilde{\zeta}_{12}^{(k)} & 0 \\ \tilde{\zeta}_{21}^{(k)} & \tilde{\zeta}_{22}^{(k)} & 0 \\ \tilde{\zeta}_{31}^{(k)} & \tilde{\zeta}_{32}^{(k)} & \tilde{\zeta}_{33}^{(k)} \end{bmatrix}}_{\tilde{\zeta}_k} \begin{bmatrix} \Delta TFP_{t-k}^{US} \\ \Delta SP_{t-k} \\ \Delta TFP_{t-k}^C \end{bmatrix} \\
 &+ \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix}, \tag{5}
 \end{aligned}$$

where  $TFP^{US}$  is US TFP series,  $SP$  is stock price in the US and  $TFP^C$  is Canadian TFP series.

Since the available sample for Canadian TFP is much shorter than that of US TFP, I use following procedure to estimate the response of Canadian TFP to the US news shock so that I can utilize more information on the news of US TFP. First, I impose the upper 2 by 2 matrices in coefficient matrices in (5) to be equal to the coefficients obtained from the bivariate VECM with US TFP and stock price in (2).

Next, I regress  $\Delta TFP_t^C$  on all other variables as follows and load obtained coefficients in (5). Here I assume the cointegrating relationship between US TFP and Canadian TFP to be  $[1, -1]$ . Therefore, we estimate following equation using



OLS:

$$\begin{aligned} \Delta TFP_t^C = & \tilde{\gamma}_3 + \begin{bmatrix} \tilde{\zeta}_{31}^0 & \tilde{\zeta}_{32}^0 & \tilde{\zeta}_{33}^0 \end{bmatrix} \begin{bmatrix} TFP_{t-1}^{US} \\ SP_{t-1} \\ TFP_{t-1}^C \end{bmatrix} + \begin{bmatrix} \tilde{\zeta}_{31}^1 & \tilde{\zeta}_{32}^1 & \tilde{\zeta}_{33}^1 \end{bmatrix} \begin{bmatrix} \Delta TFP_{t-1}^{US} \\ \Delta SP_{t-1} \\ \Delta TFP_{t-1}^C \end{bmatrix} \\ & + \dots + \begin{bmatrix} \tilde{\zeta}_{31}^k & \tilde{\zeta}_{32}^k & \tilde{\zeta}_{33}^k \end{bmatrix} \begin{bmatrix} \Delta TFP_{t-k}^{US} \\ \Delta SP_{t-k} \\ \Delta TFP_{t-k}^C \end{bmatrix} + u_{3t} \end{aligned} \quad (6)$$

Finally, I calculate impulse response of  $TFP_t^C$  on the structural error series,  $\epsilon_{2t}$ , which was identified in the bivariate VECM in previous section. The identification is done by regressing the reduced error,  $u_{3t}$ , on the structural error series,  $\epsilon_{2t}$ , which I obtained in previous section. This gives the response of Canadian TFP to the news shock occurred in the US.

Figure 4 shows the first 40-period responses of US and Canadian TFP to the news about future TFP in the US. Figure 5 shows only the response of Canadian TFP to news with 90 % confidence band constructed using bootstrap of 1000 replications. It is indicated that the immediate response of US TFP to news is bigger compared to that of Canadian TFP. Canadian TFP is responding slowly at the beginning and converge slowly to the same level of US TFP over time.

## 2.4 Empirical evidence on the international transmission of US news shock

In order to obtain further insights, I also study the effects of the news shock on macroeconomic variables in the US and Canada. The variables of interest are consumption, investment, hours, output as well as trade variables (export, import, trade balance and the terms of trade).

### 2.4.1 Estimated responses of Canadian macroeconomic variables to US news shock

I estimate higher dimensional system using US productivity ( $TFP^{US}$ ), US stock price ( $SP$ ) and other macroeconomic variables of interest. I first estimate 8-variable system with  $TFP^{US}$ ,  $SP$ , Canadian output, consumption, investment, hours worked, terms of trade and trade balance. I also estimate the responses of exports and imports. When I estimate the responses of exports and imports, I replace trade balance and the terms of trade with these variables. The results are robust in various other specifications of the system. Figure 6 shows the point estimates of the responses of output, consumption, investment and hours worked. A

number of interesting results emerge. Output and consumption have big booms immediately after the shock occurs. After period two, their responses become flatter, however, they rise significantly. Hours worked also have a persistent rise, however, initially it has a little different dynamics. It has a boom until period 4 and becomes flatter after that. Investment also has a pattern of persistent rise. Investment boom lasts until period 4 after the shock and it exhibits flatter pattern after period 4.

Figure 7 shows responses of exports, imports, terms of trade and trade balance. As can be seen, the response of exports has a big initial boom. After period 5, it has a pattern of persistent increase. The response of imports also has an initial boom and persistent increase later, but the initial boom seems milder than that of exports. The response of terms of trade, which is defined as the import price divided by the export price, has a pattern of persistent decline, although it is not significant. Trade balance has a slightly hump-shaped pattern. Trade balance initially has a big boom and becomes persistent later.

#### **2.4.2 Estimated responses of US macroeconomic variables to US news shock**

Although the main focus in this paper is the response of Canadian variables, I also estimated responses of US variables to US news shock. I estimate 6-variable system with  $TFP$ ,  $SP$ , output, consumption, investment and hours worked. Figure 8 presents the results. The responses of output, consumption and hours have a large boom immediately after the shock. After that, they show a persistent increase. Investment has a significant boom after the shock and after period 3 it has a persistent pattern. Exports and imports exhibit initial booms as well.

### **3 The Model**

This section describes the model economy. The model is a two-country model based on Backus, Kehoe and Kydland(1994) augmented with different country size, the preference of the type suggested by Jaimovich and Rebelo (2006, 2008) and investment adjustment cost. Two countries are indexed by  $i = \{1, 2\}$  and we assume Country 1 (Canada) is relatively small compared to Country 2 (the US). All the variables are in per capita terms unless otherwise noted. Each country is the economy which consists of a representative household, intermediate good sector and final good sector. The household has preference over consumption and leisure. The intermediate good sector produces goods using capital and labor. The final good sector produces final goods using intermediate goods. The shocks to the economy are productivity shocks of Country 1 (Canada) and Country 2 (the US) driven by news

about future productivity in the US, which are identified in the previous section.

### 3.1 Household

The representative household chooses consumption, leisure, investment and borrowing. The lifetime utility of the household is:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(C_{it}, 1 - N_{it}, S_{it}).$$

where  $C_{it}$  denotes consumption of country  $i$  and  $N_{it}$  is hours worked in country  $i$ . For the function  $U(C_{it}, 1 - N_{it}, S_{it})$ , following Jaimovich and Rebelo(2006, 2008), I assume preference as:

$$U(C_{it}, 1 - N_{it}, S_{it}) = \frac{(C_{it} - \psi N_{it}^\nu S_{it})^{1-\gamma}}{1-\gamma}$$

where  $S_{it} = C_{it}^\kappa S_{it-1}^{1-\kappa}$  and  $\kappa \in (0, 1]$ . It is convenient to use this preference since it nests two types of preference. When  $\kappa = 0$ , this preference becomes GHH preference, which was named after Greenwood et al.(1988)<sup>6</sup>. On the other hand, when  $\kappa = 1$ , this preference becomes KPR preference, which was named after King, Plosser and Rebelo(1988). With  $\kappa = 0$  (GHH preference), there is no wealth effect on hours worked. However, with  $\kappa = 1$  (KPR preference), wealth effect on hours worked emerges.

The household's budget constraint for the household in country 1 is given by:

$$C_{1t} + X_{1t} + q_{1t}^a E_t Q_{t,t+1} B_{1t+1} = q_{1t}^a (W_{1t} N_{1t} + r_{1t}^k K_{1t}) + q_{1t}^a B_{1t}, \quad (7)$$

where  $X_{1t}$  denotes investment,  $q_{1t}^a$  is the relative price of intermediate goods produced in Country 1.  $Q_{t,t+1}$  is the stochastic discount factor to price the security,  $B_{1t+1}$ . Here I assumed that the complete market assumption holds.

The budget constraint for household in country 2 is written similarly as:

$$C_{2t} + X_{2t} + q_{2t}^b E_t Q_{t,t+1} B_{2t+1} = q_{2t}^b (W_{2t} N_{2t} + r_{2t}^k K_{2t}) + q_{2t}^b B_{2t}. \quad (8)$$

The capital accumulation is done according to following law of motion:

$$K_{it+1} = (1 - \delta)K_{it} + \left[ 1 - \Phi \left( \frac{X_{it}}{X_{it-1}} \right) \right] X_{it}, \quad (9)$$

where  $\Phi(x) = (\phi/2)(x - \mu_x)^2$  and the function  $\Phi$  satisfies  $\Phi(\mu_x) = 0$ ,  $\Phi'(\mu_x) = 0$  and  $\Phi''(\mu_x) = \phi > 0$ . This function  $\Phi(\cdot)$  denotes adjustment cost for investment. By introducing this, we can rule out overshooting of the investment possibly caused by the shocks.

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<sup>6</sup>If we set  $\kappa = 0$ , this preference becomes not consistent with steady-state growth. Therefore, when I solve the model with the case of GHH preference, I use  $\kappa = 0.001$ , which is a small number.

Letting  $\lambda_{1t}$ ,  $\mu_{1t}$  and  $\nu_{1t}$  be Lagrangian multiplier for the household's maximization problem, the optimal conditions for the households for consumption, leisure, bond holding, capital, investment and  $S_{1t}$  are:

$$U_c(C_{1t}, 1 - N_{1t}, S_{1t}) - \eta_{1t}\kappa C_{1t}^{\kappa-1} S_{1t}^{1-\kappa} = \lambda_{1t}, \quad (10)$$

$$U_n(C_{1t}, 1 - N_{1t}, S_{1t}) + \lambda_{1t}q_{1t}^a W_{1t} = 0, \quad (11)$$

$$\beta E_t \lambda_{1t+1} q_{1t+1}^a = \lambda_{1t} E_t Q_{t,t+1} q_{1t}^a, \quad (12)$$

$$\beta E_t \lambda_{1t+1} q_{1t+1}^a r_{1t+1} + \beta \mu_{1t+1} (1 - \delta) - \mu_{1t} = 0, \quad (13)$$

$$\begin{aligned} -\lambda_{1t} + \mu_{1t} \left[ 1 - \frac{\phi}{2} \left( \frac{X_{1t}}{X_{1t-1}} - \mu_x \right)^2 - \phi \left( \frac{X_{1t}}{X_{1t-1}} - \mu_x \right) \frac{X_{1t}}{X_{1t-1}} \right] \\ + \beta \mu_{1t+1} \left[ \phi \left( \frac{X_{1t+1}}{X_{1t}} - \mu_x \right) \frac{X_{1t+1}^2}{X_{1t}^2} \right] = 0 \end{aligned} \quad (14)$$

$$U_s(C_{1t}, 1 - N_{1t}, S_{1t}) + \eta_{1t} - \beta E_t \left[ \eta_{1t+1} C_{1t+1}^\kappa (1 - \kappa) S_{1t}^{-\kappa} \right] = 0 \quad (15)$$

The optimal conditions for the households in Country 2 can be written in similar fashion.

### 3.2 Intermediate goods sector

Intermediate goods sector is producing intermediate goods using capital,  $K_{it}$  and labor,  $N_{it}$ . The production function in the intermediate sector is the standard Cobb-Douglas function of capital and labor:

$$Y_{it} = Z_{it}^{1-\theta} K_{it}^\theta N_{it}^{1-\theta}, \quad (16)$$

where  $Z_{it}$  denotes the level of productivity in Country  $i$ . Then the profit maximization problem for the firm in intermediate goods sector is:

$$\max_{N_{it}, K_{it}} Y_{it} - w_{it} N_{it} - r_{it} K_{it},$$

subject to  $K_{it}, N_{it} \geq 0$ .

The optimal conditions for the intermediate sector are:

$$r_{it} = \theta Z_{it}^{1-\theta} \left( \frac{K_{it}}{N_{it}} \right)^{\theta-1}, \quad (17)$$

where  $r_{it}$  denotes the rental rate of capital in Country  $i$ , and

$$w_{it} = (1 - \theta) Z_{it}^{1-\theta} \left( \frac{K_{it}}{N_{it}} \right)^\theta, \quad (18)$$

where  $w_{it}$  is the real wage in Country  $i$ . Capital and Labor are assumed to be immobile.

### 3.3 Final goods sector

Final goods sector is producing final goods using intermediate goods as inputs. Letting  $a_{it}$  and  $b_{it}$  denote intermediate goods produced in Country 1 and 2, the production functions for final goods are following Armington aggregator introduced by Armington (1969):

$$F_{1t}(a_{1t}, b_{1t}) = \left[ \omega_1^{\frac{1}{\sigma}} a_{1t}^{\frac{\sigma-1}{\sigma}} + (1 - \omega_1)^{\frac{1}{\sigma}} b_{1t}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \quad (19)$$

and

$$F_{2t}(a_{2t}, b_{2t}) = \left[ (1 - \omega_2)^{\frac{1}{\sigma}} a_{2t}^{\frac{\sigma-1}{\sigma}} + \omega_2^{\frac{1}{\sigma}} b_{2t}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}. \quad (20)$$

Here,  $\sigma$  denotes the elasticity of substitution between domestic and foreign goods.

The profit maximization problem for the firm in final goods sector is:

$$\max_{a_{it}, b_{it}} F_i - q_i^a a_i - q_i^b b_i$$

subject to  $a_{it}, b_{it} \geq 0$ .

The optimal conditions for the final goods sector are:

$$a_{1t} = (q_{1t}^a)^{-\sigma} \omega_1 F_{1t} \quad (21)$$

$$b_{1t} = (q_{1t}^b)^{-\sigma} (1 - \omega_1) F_{1t} \quad (22)$$

$$a_{2t} = (q_{2t}^a)^{-\sigma} (1 - \omega_2) F_{2t} \quad (23)$$

$$b_{2t} = (q_{2t}^b)^{-\sigma} \omega_2 F_{2t} \quad (24)$$

### 3.4 International risk sharing

Following Chari et al.(2002), by iterating the first order condition for state-contingent securities in Country 1 and 2, we obtain following international risk sharing condition under complete market assumption:

$$\frac{U_c(C_{2t}, 1 - N_{2t}, S_{2t})}{U_c(C_{1t}, 1 - N_{1t}, S_{1t})} = RER_t. \quad (25)$$

where  $RER$  denotes real exchange rate. It is defined as  $RER_t \equiv q_{1t}^a / q_{2t}^a$ .

### 3.5 Market clearing conditions

Market clearing for intermediate goods sector is:

$$\Pi_1 Y_{1t} = \Pi_1 a_{1t} + \Pi_2 a_{2t}, \quad (26)$$

and

$$\Pi_2 Y_{2t} = \Pi_1 b_{1t} + \Pi_2 b_{2t}. \quad (27)$$

where  $\Pi_1$  denotes ratio of Country 1's population in the world and  $\Pi_2$  denotes population of Country 2 in the world. We assume that  $\Pi_1 + \Pi_2 = 1$ .

For the final goods market,

$$F_{1t} = C_{1t} + X_{1t} \quad (28)$$

and

$$F_{2t} = C_{2t} + X_{2t} \quad (29)$$

### 3.6 Other variables of interest

Terms of trade for Country 1 is defined as the relative price of imported good and exported good:

$$TOT_t = \frac{q_{1t}^b}{q_{1t}^a}. \quad (30)$$

Trade balance of Country 1 over GDP of Country 1 is defined as

$$TB_{1t} = \frac{\Pi_2 a_{2t} - \Pi_1 \left( \frac{q_{1t}^b}{q_{1t}^a} \right) b_{1t}}{\Pi_1 Y_{1t}}. \quad (31)$$

### 3.7 The choice of the processes of US and Canadian TFP

In this model, I take the TFP processes of Country 1 (Canada) and Country 2 (the US) as exogenous. In contrast to the standard assumption of international real business cycle models, I choose TFP processes obtained from (2) and (5) in the VECM estimation discussed in Section 2.

My approach here is motivated by the two facts about actual TFP processes. First, what the empirical analysis in Section 2 shows is that the TFP processes are driven by slow diffusion process of the news. In previous theoretical literature on the news-driven business cycles, it is more common to assume that the agents in the model anticipate the actual materialization of the TFP occurs at some point in the

future, not currently. However, according to the VECM results, the TFP responds to the news about future TFP slowly but contemporaneously. This empirical results make sense in light of slow adoption of technological innovation. Second, according to the estimation results in Section 2.3, there is a significant international spillover effect of the news. In the previous theoretical literature such as Beaudry, Dupaigne and Portier (2008), foreign TFP is not positively affected by the domestic TFP process driven by the news. However, in my paper, since there is a strong empirical evidence of this, I feed the estimated Canadian TFP process into the model as well. In Section 4.4, I show the importance of feeding Canadian TFP process driven by the US news.

Since all the model equations are converted in stationary terms, I convert the TFP variables in levels into the growth rate terms and feed into the model.

### 3.8 Competitive equilibrium

The competitive equilibrium in this model consists of sequences of allocations for  $i = 1, 2$ ,  $\{C_{it}, S_{it}, X_{it}, K_{it+1}, B_{it+1}, N_{it}, Y_{it}, F_{it}, a_{it}, b_{it}\}_{t=0}^{\infty}$  and prices  $\{w_{it}, r_{it}^k, q_{it}^a, q_{it}^b\}_{t=0}^{\infty}$  such that, taking  $\{B_{10}, B_{20}, K_0\}$  and exogenous sequences  $\{Z_{1t}, Z_{2t}\}_{t=0}^{\infty}$  as given,

- $\{C_{it}, S_{it}, X_{it}, K_{it+1}, B_{it+1}, N_{it}\}_{t=0}^{\infty}$  solves households' problem.
- $\{Y_{it}, F_{it}, a_{it}, b_{it}\}_{t=0}^{\infty}$  solves firms' problem.
- Market clearing conditions and the resource constraint are satisfied.

## 4 Quantitative analysis

### 4.1 Parameter values

The stochastic discount factor,  $\beta$ , is set equal to 0.99. I set the capital depreciation rate,  $\delta$ , as 0.025. The capital share of output is set to  $\alpha = 0.32$ , since the labor share calculated using US data is 0.68. The steady state imported goods share for Canada,  $1 - \omega_1$ ,<sup>7</sup> is set to 0.32, and since I assume that the Canadian population at the steady state is 1/10 of that of the US, the steady state imported goods share for the US,  $1 - \omega_2$ , is calibrated to 0.032.

The elasticity of substitution between consumption and leisure,  $\gamma$ , is set equal to 2. Following Jaimovich and Rebelo(2008), I set the preference parameter  $\nu$  as 1.4. I calibrated  $\psi$  so that the steady state values of hours worked,  $N_{1t}$  and  $N_{2t}$ , become 0.2.

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<sup>7</sup>This value is taken from Raffo(2006) (WP version).

For  $\kappa$ ,  $\phi$  and  $\sigma$ , I take two different approaches. In the first approach, I assume hypothetical values for these parameters. For GHH-type preference, I set  $\kappa$  equal to 0.001, which is very small. Under this parameter, the wealth effect on labor supply is very small or negligible. For KPR-type preference, I assume  $\kappa = 1$ . Under this type of preference, there is a substantial wealth effect on labor supply. For  $\phi$ , investment adjustment cost parameter, I use either  $\phi = 0$  (no adjustment cost) or  $\phi = 5$  (with adjustment cost). The latter value is the estimated value in Schmitt-Grohé and Uribe (2008). For  $\sigma$ , the elasticity of substitution between domestically produced intermediate goods and foreign produced intermediate goods, I assume either  $\sigma = 1.5$  (for standard assumption) or  $\sigma = 0.3$  (for low elasticity of substitution). Former value is used in Backus, Kehoe and Kydland (1994), which is taken as a standard assumption in the previous literature.

In the second approach, I estimate the values of  $\kappa$ ,  $\phi$  and  $\sigma$  using impulse response matching estimation, which I explain in later section.

## 4.2 Impulse response analysis with calibrated parameter values

This section compares the empirical and theoretical impulse responses to the news shock. Before estimating the parameters, I assume some hypothetical values for the GHH preference parameter,  $\kappa$ , investment adjustment cost parameter,  $\phi$  and the elasticity of substitution between domestically and foreign produced intermediate goods,  $\sigma$ , in order to obtain intuitions. Figures 9 and 10 display these model-based impulse responses for Canadian variables assuming different sets of parameter values along with empirical responses which I described in earlier section. Figure 11 displays the results for the US variables. The dark solid line and the shaded region are the point estimate and 90 % confidence bands for the empirical impulse response.

Line with diamonds denote the response of the variable in the case of standard KPR preference ( $\kappa = 1$ ), no investment adjustment cost ( $\phi = 0$ ) and the elasticity of substitution between domestically and foreign produced goods under standard assumption ( $\sigma = 1.5$ ). While the immediate response of Canadian consumption is positive, the response of hours worked is negative. This is because of the large wealth effect driven by the positive news about future TFP. The impact on the investment is negative because of this wealth effect and this drives the negative response of output. Since there occurs a positive increase in US TFP, the price of intermediate goods produced in the US declines, which means an appreciation of the terms of trade.

Line with crosses denote the response of the variable in the case of standard



KPR preference ( $\kappa = 1$ ), investment adjustment cost ( $\phi = 5$ ) and the elasticity of substitution between domestically and foreign produced goods under standard assumption ( $\sigma = 1.5$ ). In this case, it avoids the large decline of investment, however, the response is still negative. Hours worked and thus output has negative response because of the wealth effect.

Line with squares denote the case of GHH preference ( $\kappa = 0.001$ ), investment adjustment cost ( $\phi = 5$ ) and the elasticity of substitution between domestically and foreign produced goods under standard assumption ( $\sigma = 1.5$ ). GHH preferences get rid of the negative wealth effect. Interestingly, the model-based response of exports becomes positive. This is because Canadian intermediate good firm is producing more goods. The response of US imports becomes positive, correspondingly. Canadian imports of intermediate goods has larger positive responses compared to the case of  $\kappa = 1$ . However, it is still hard to match the response of the trade balance. The point estimate of the empirical response in Canadian trade balance is positive.

Then I further introduce the assumption of low elasticity of substitution between domestically and foreign produced goods. Line with circles denote this case of GHH preference ( $\kappa = 0.001$ ), investment adjustment cost ( $\phi$ ) and low elasticity of substitution between domestically and foreign produced goods ( $\sigma = 0.3$ ). As can be seen, this helps explaining the positive response of Canadian trade balance. However, it comes with at cost of worsening the match of the terms of trade. Since demand of Canadian goods increases with the lower elasticity, the Canadian exports and thus output have larger positive response compared to the previous case. Correspondingly, consumption and hours have larger response as well.

### 4.3 Estimation of $\kappa$ , $\phi$ and $\sigma$ using impulse response matching estimation

Now I estimate  $\kappa$  and  $\phi$  by matching the model-based impulse responses to the news with the empirical VECM estimates. First, I collect the empirical impulse responses to the vector in  $IR^{data}$  and choose  $W$  to be a diagonal matrix with the variance of impulse responses along its diagonal. The parameters are estimated using following minimization problem:

$$\min_{\Theta} \left( IR(\Theta) - IR^{data} \right)' W^{-1} \left( IR(\Theta) - IR^{data} \right). \quad (32)$$

where  $\Theta = \{\kappa, \phi, \sigma, \nu\}$ .  $IR(\Theta)$  denotes a vector that consists of model-based impulse responses.

I use the information criterion advocated by Hall et al. (2007) to choose the optimal lags to match. Using the Relevant Impulse Response Selection Criterion (RIRSC), I decided to match 11 lags responses of Canadian output, consumption,

investment hours worked, terms of trade and trade balance. The estimated values are  $\kappa = 0.01$  (std.error 0.007),  $\phi = 87.11$  (std.error 30.15),  $\sigma = 0.18$ (std.error 0.06) and  $\nu = 2.95$ (std.error 0.05) for Canada. The results are presented in Figure 12, 13 and 14. Line with stars denote the model-based response using estimated parameters. As the figures show, the Canadian output, consumption, investment and hours worked match well with the point estimates. The responses of exports, imports and trade balance are qualitatively the same as point estimates. It is difficult to get rid of the overshooting of the terms of trade, however, the response is qualitatively the same.

The low estimated value of  $\kappa$ , 0.01 indicates that getting rid of the wealth effect on hours worked is important. The estimated value of  $\sigma$ , the elasticity of substitution, is also low relative to the value used as standard assumption ( $\sigma = 1.5$ ). Lower elasticity means there is a complementarity between domestically and foreign produced intermediate goods. As can be seen in the previous subsection, this also helps to explain the domestic boom.

#### **4.4 Counterfactual experiment where Canadian TFP does not respond US news shock**

This subsection justifies the importance of feeding the response of Canadian TFP to US news shock in to the model. To show this, I conduct a counterfactual experiment assuming zero response of Canadian TFP to US news shock. Parameter values are assumed to be the same as previous section.

The results are presented in Figures 12, 13 and 14, along with the results in the previous subsection. Dashed line denote the response from this counterfactual experiment. As can be seen, if I do not feed the Canadian TFP process driven by the US news shock, responses of output, consumption, investment and hours are much lower than the point estimates. Therefore, the response of Canadian TFP to US news shock is important to match the empirical responses of Canadian variables.

## **5 Conclusion**

In this paper, I study the international transmission effects of news about US Total Factor Productivity (TFP) to the Canadian economy. Using the Vector Error Correction Model (VECM), I estimate the impulse responses of Canadian macroeconomic variables to the news shock of US TFP. I find that the Canadian TFP responds to the US news positively and significantly. Then I construct and estimate a two-country RBC model with Jaimovich-Rebelo preferences and investment adjustment cost. By feeding the actual TFP processes driven by the news shock

obtained in the empirical analysis, I find that the international comovements between the US and Canada can be generated by the news about future TFP in the US. In order to generate the comovements to match with the data, I show that the preference parameter that generates a lower wealth effect on hours worked, investment adjustment cost and lower substitution of elasticity between domestically and foreign produced intermediate goods are important. Using a counterfactual experiment, I also show that the response of Canadian TFP to US news shock is important.

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# A The Data

## A.1 US Data

- Population: I used the data from The U.S. Government Printing Office. Table B-34 in <http://www.gpoaccess.gov/eop/tables09.html> The original data is taken from Department of Commerce (Bureau of Census).
- GDP for calculating TFP: Real GDP (non-farm business sector). Source: Bureau of Economic Analysis (BEA), "Table 1.3.6. Real Gross Value Added by Sector, Chained Dollars".
- Output: Real GDP (gross). Source: BEA, "Table 1.3.6. Real Gross Value Added by Sector, Chained Dollars" in NIPA Table. (Series ID: GDPC1)
- Consumption: Real personal consumption expenditures. Source: BEA, series taken from FRED database. (Series ID: PCECC96)
- Investment: Real fixed private investment, quarterly data in annual level. Source: BEA, series taken from FRED database. (Series ID: FPIC1)
- Hours worked: Hours index, non-farm business sector. Source: Bureau of Labor Statistics, <http://www.bls.gov/data/#productivity>. (Series ID: PRS85006033)
- Labor share: Labor share, annual data from 1948. Source: Bureau of Labor Statistics, series number: PRS85006173. I also use Beaudry and Portier's(2006) dataset.
- Stock price: Nominal stock price divided by the deflator explained below. Standard & Poors 500 composite stock prices index, downloaded from Global Financial Database. I obtained monthly data from 1939M1 and converted into quarterly series. I used closing price.
- Deflator: Price index of business sector. Source: BEA, "Table 1.3.4. Price Indexes for Gross Value Added by Sector".
- Capital: Capital services index, private business sector. Source: Bureau of Labor Statistics.
- Exports: Real exports of goods and services, 1 decimal. Source: FRED database.
- Imports: Real imports of goods and services, 1 decimal. Source: FRED database.

## A.2 Canadian data

Data were kindly given by Bank of Canada.

- Population: Canadian population (15 years over). Source: CANSIM database, Statistics Canada. Series ID: v2091030.
- GDP: Real GDP. Source: CANSIM database, Statistics Canada. Series ID: V1992067
- Consumption: Real consumption. Source: CANSIM database, Statistics Canada. Series ID: V1992044
- Investment: Real investment. Source: CANSIM database, Statistics Canada.
- Capital: Calculated by Bank of Canada.
- Hours worked: Using the population data, I multiplied the series by participation rate obtained from Bank of Canada. I multiplied that by employment rate which I calculated using data of unemployment rate to get the employment data. Then I multiplied that by the series of average hours worked to get total hours worked.
- Exports: Real exports. Source: CANSIM database, Statistics Canada. Series ID: V1992060
- Imports: Real imports. Source: CANSIM database, Statistics Canada. Series ID: V1992063
- Canadian terms of trade: Defined as import deflator divided by export deflator. Source: SourceOECD database.

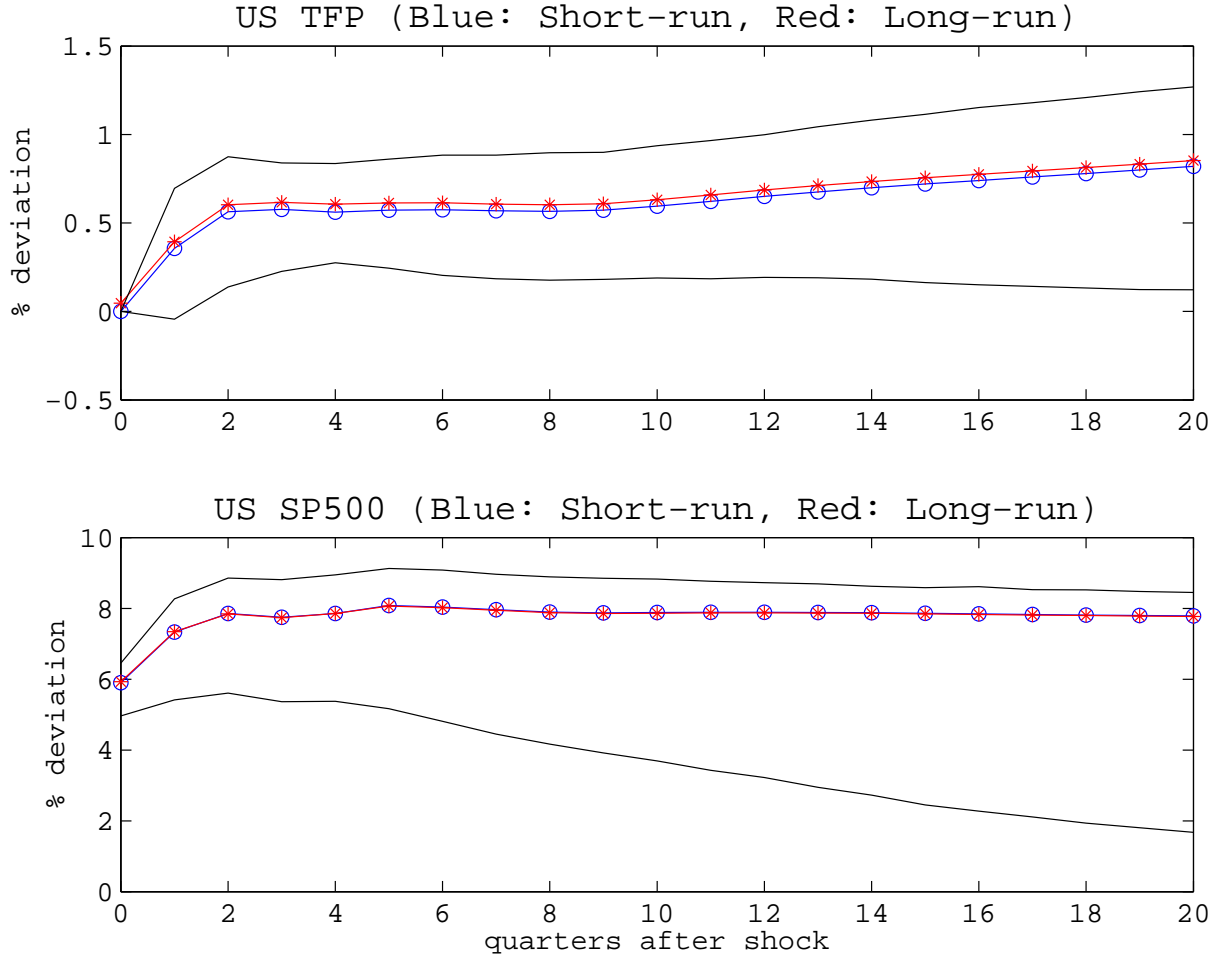


FIGURE 1: IDENTIFICATION OF NEWS SHOCK *Note:* The blue line with circles denotes impulse response estimated using short-run identification. The red line with stars denotes impulse response estimated using long-run identification, that is the response of  $TFP^{US}$  to  $\tilde{\epsilon}_{1t}$ . The black lines indicate 90% confidence bands using short-run identification, that is the response of  $TFP^{US}$  to  $\epsilon_{2t}$ .



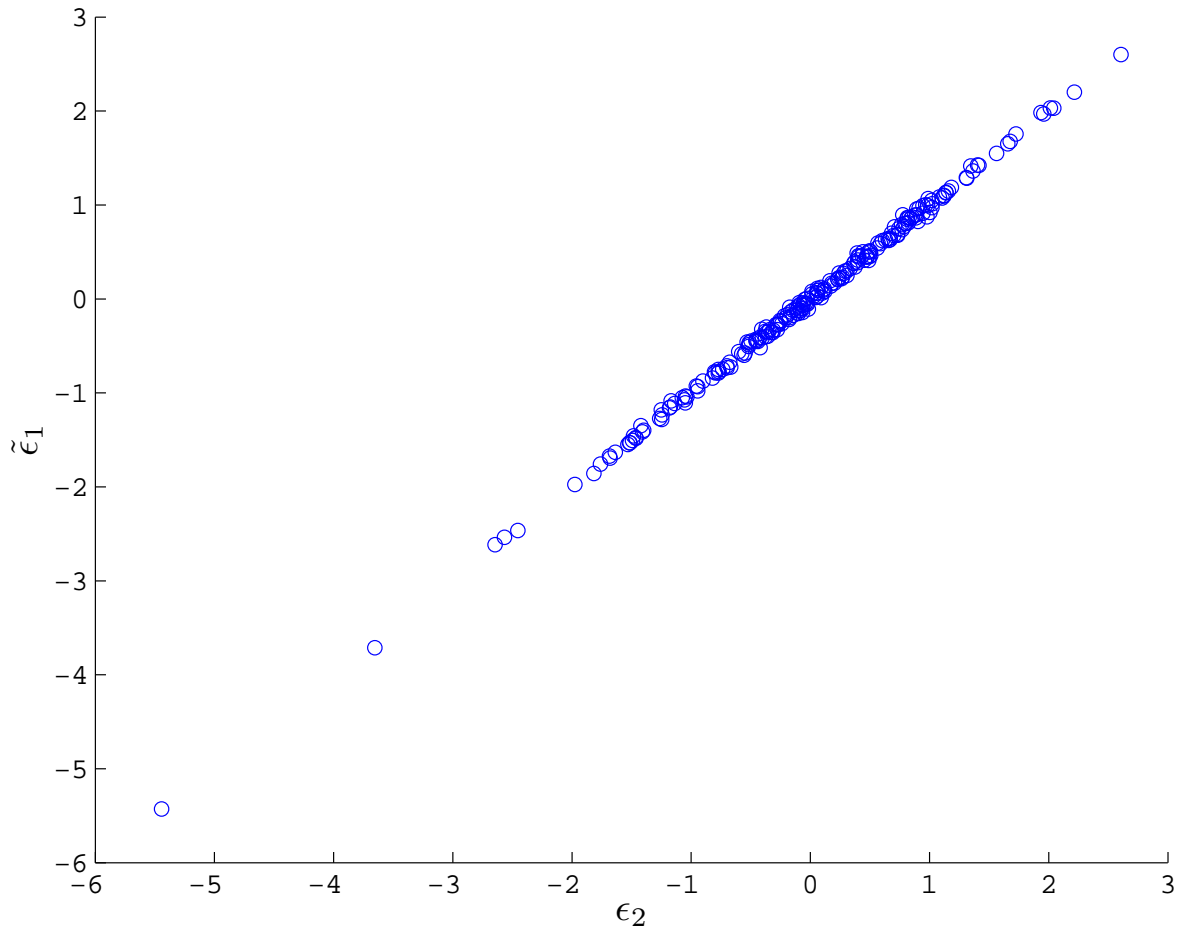


FIGURE 2: SCATTER PLOT OF  $\epsilon_2$  AGAINST  $\tilde{\epsilon}_1$

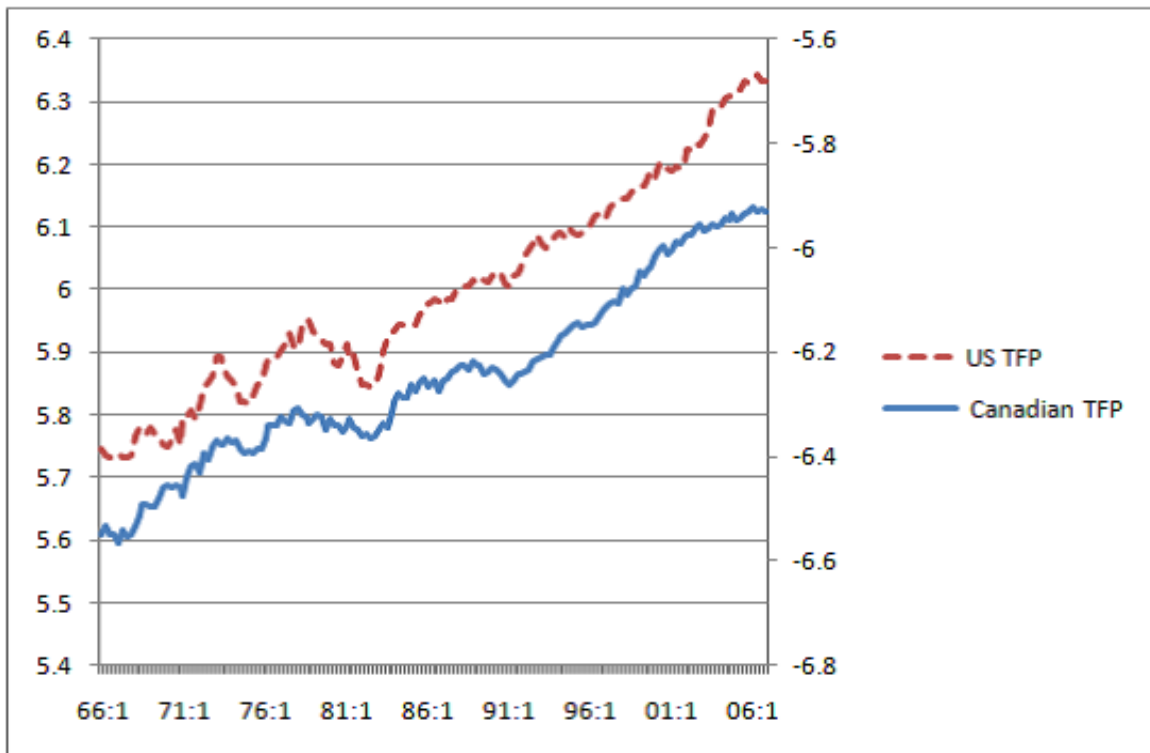


FIGURE 3: TFP PROCESSES FOR THE US AND CANADA

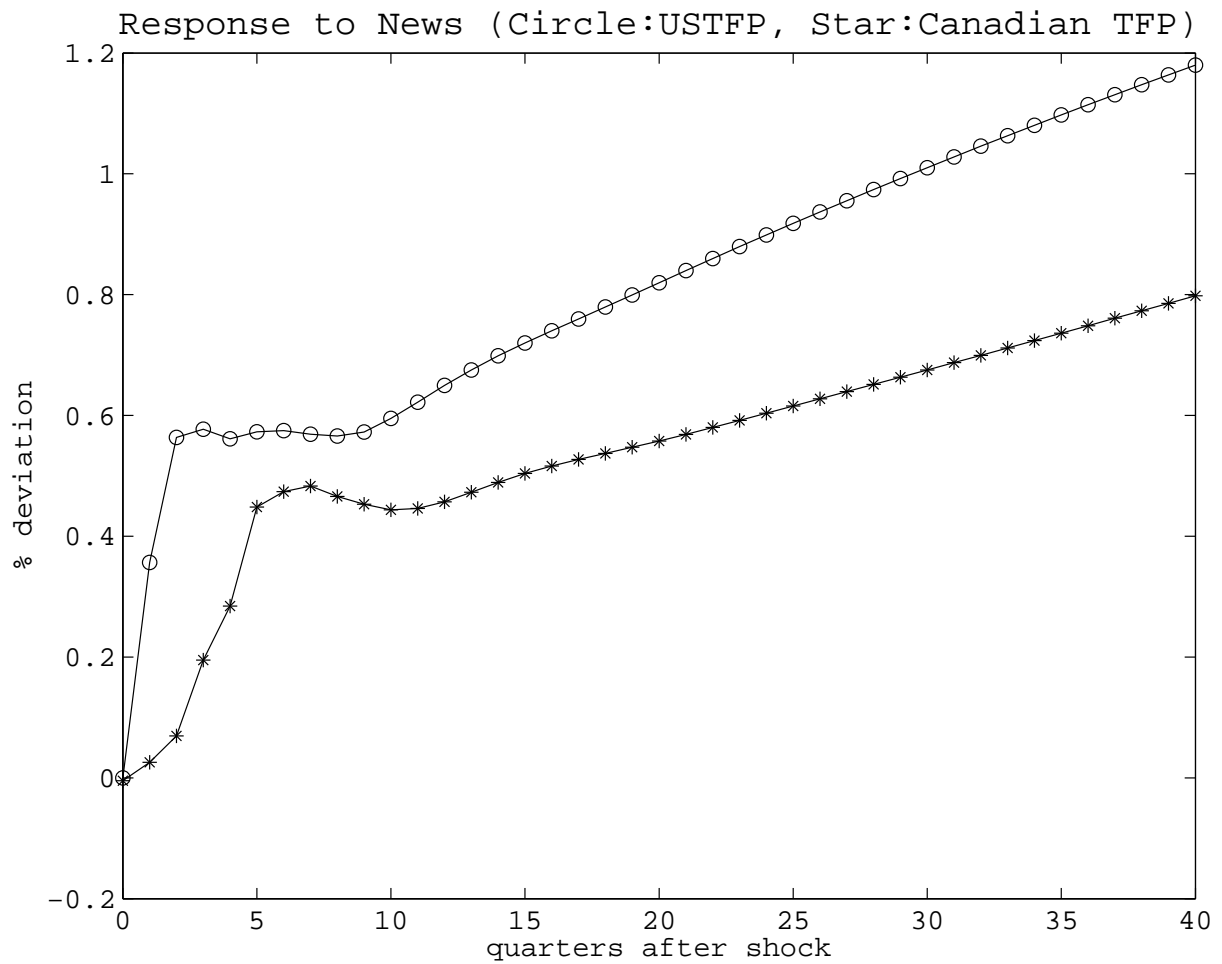


FIGURE 4: RESPONSE OF US TFP AND CANADIAN TFP TO NEWS ABOUT FUTURE US TFP *Note:* The blue line is the impulse response of US TFP and the red line is the impulse response of Canadian TFP to the news shock.

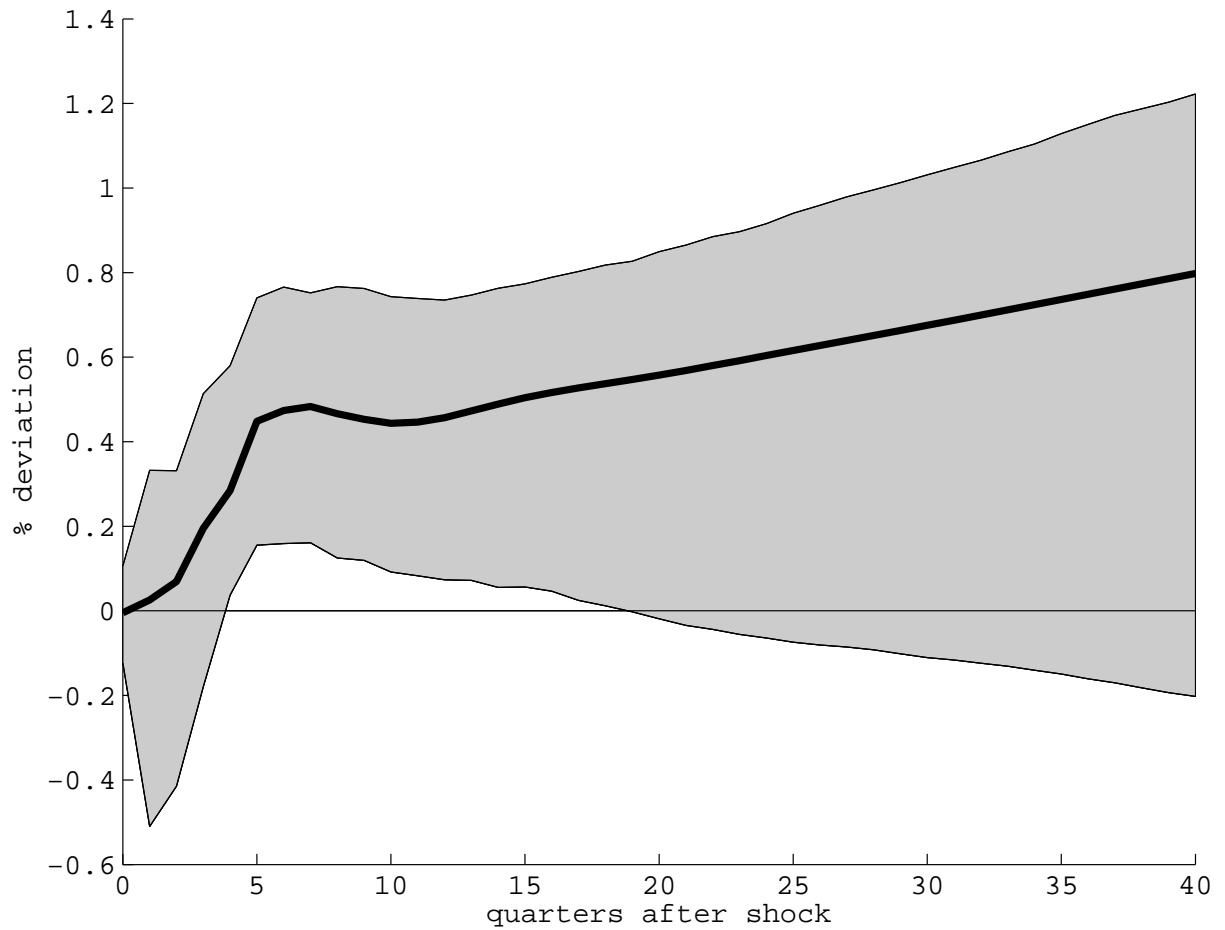


FIGURE 5: ESTIMATED RESPONSES OF CANADIAN TFP TO NEWS ABOUT FUTURE US TFP *Note:* The solid line and the shaded region are the point estimate and 90 % confidence bands.

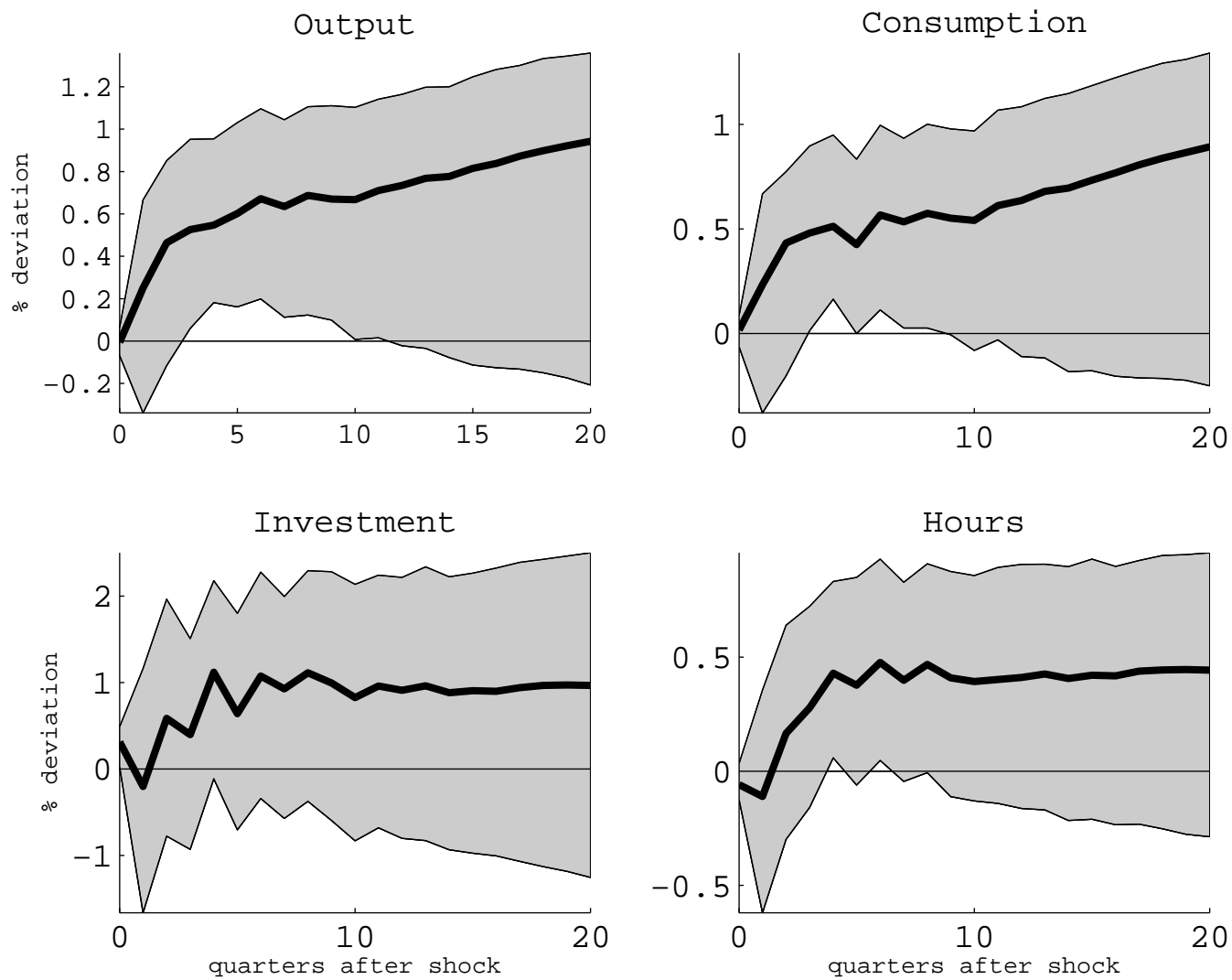


FIGURE 6: ESTIMATED RESPONSES OF CANADIAN VARIABLES TO NEWS ABOUT FUTURE US TFP *Note:* The solid line and the shaded region are the point estimate and 90 % confidence bands.

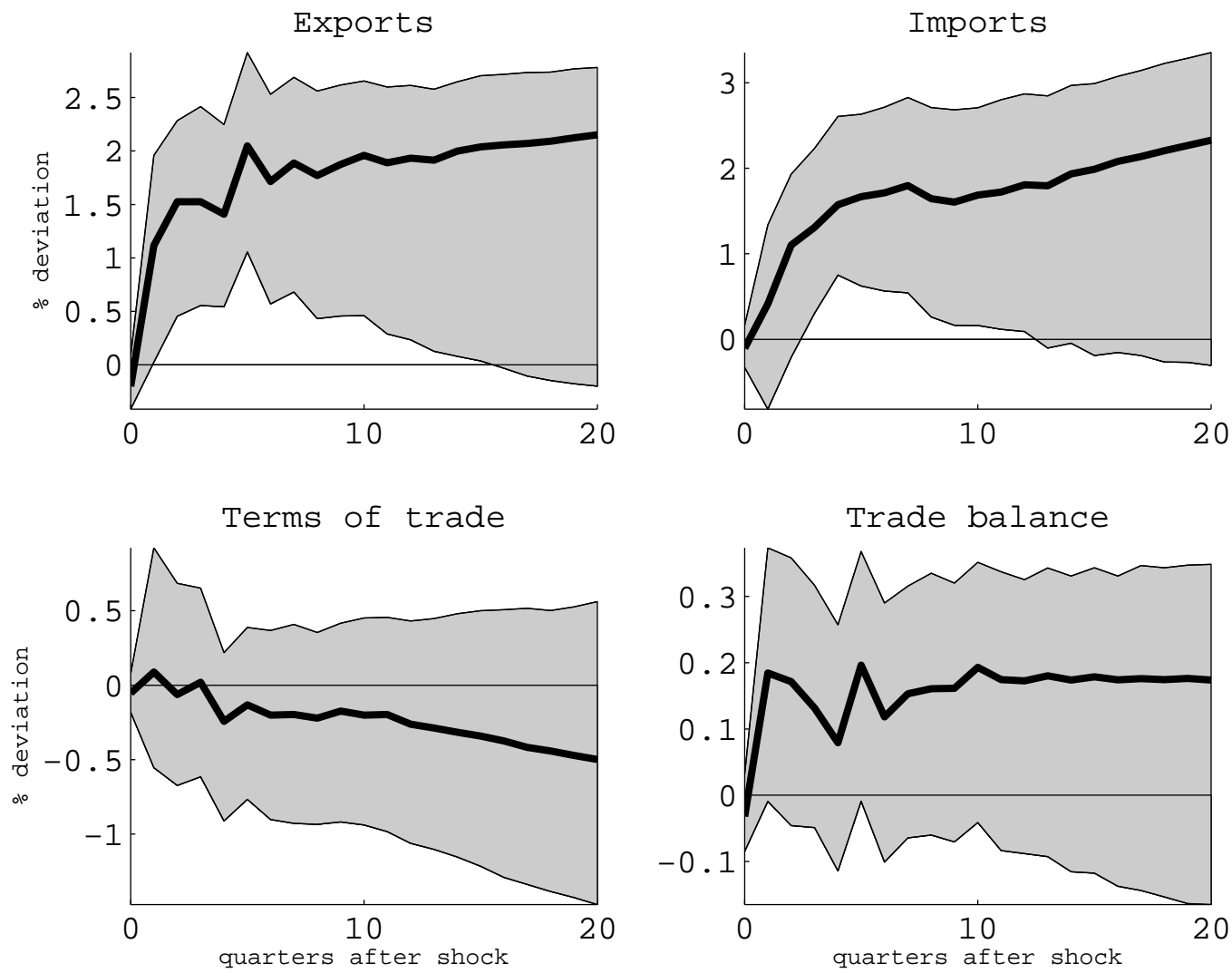


FIGURE 7: ESTIMATED RESPONSES OF CANADIAN VARIABLES TO NEWS ABOUT FUTURE US TFP *Note:* The solid line and the shaded region are the point estimate and 90 % confidence bands.

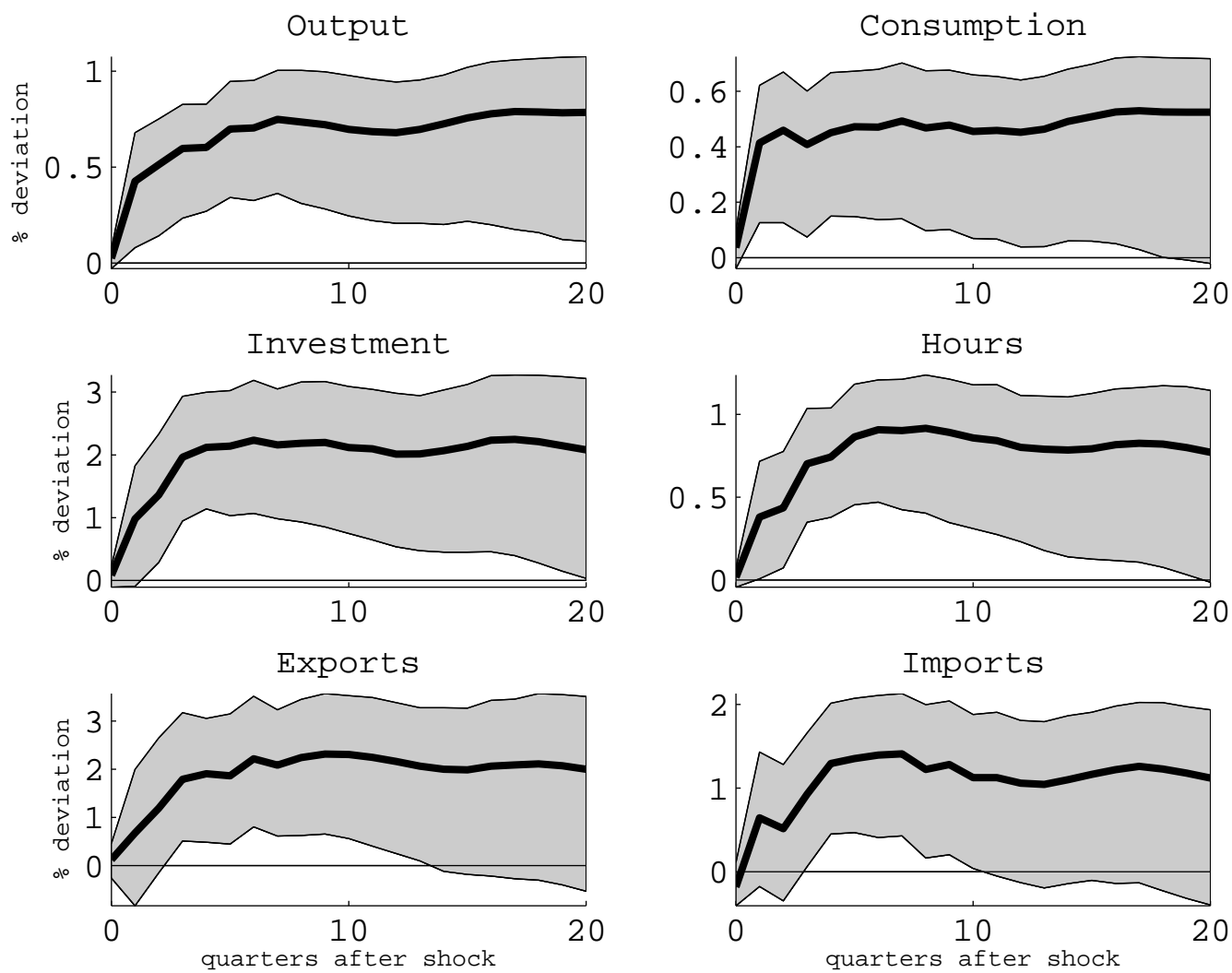


FIGURE 8: ESTIMATED RESPONSES OF US VARIABLES TO NEWS ABOUT FUTURE US TFP *Note:* The solid line and the shaded region are the point estimate and 90 % confidence bands.

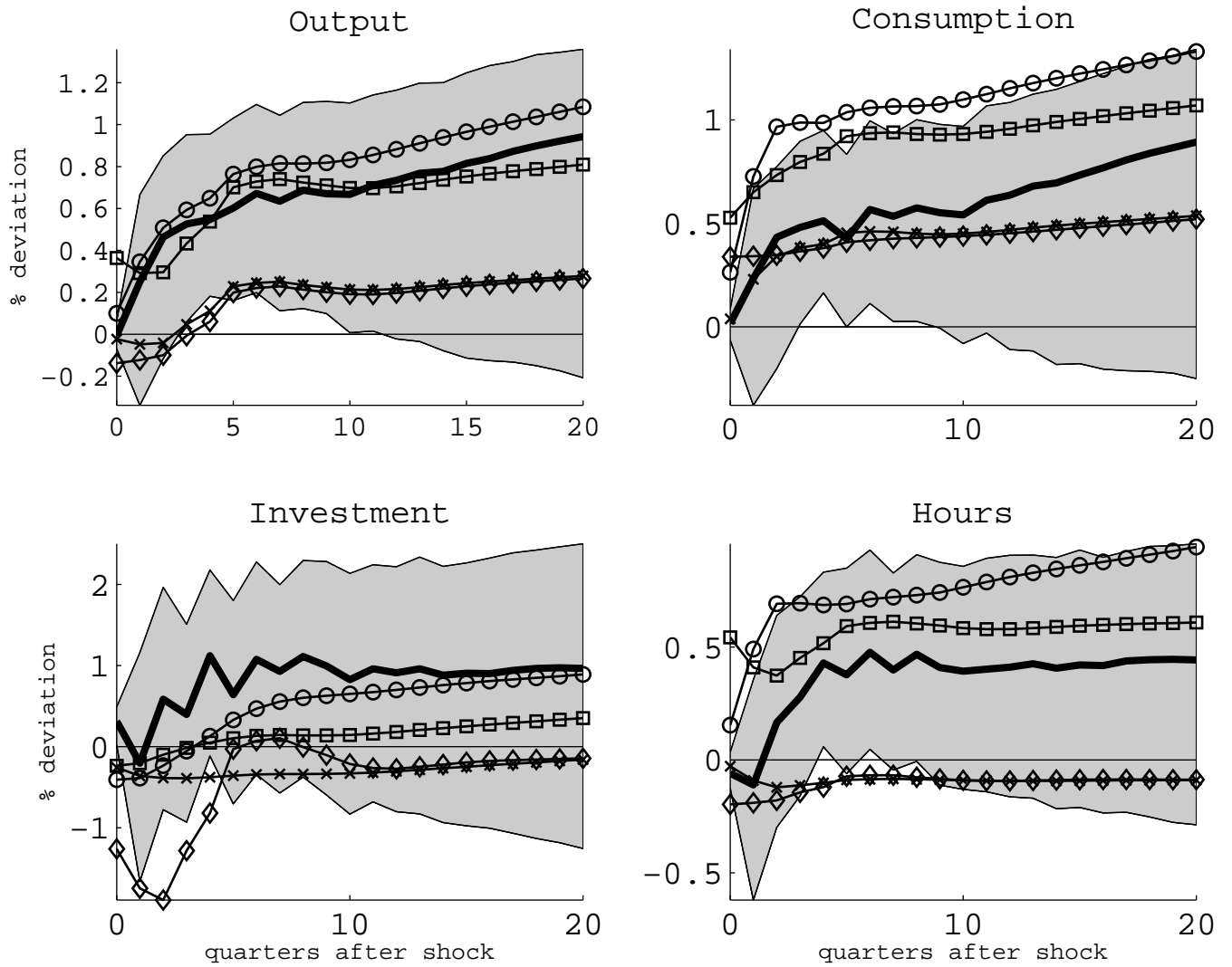


FIGURE 9: RESPONSES OF CANADIAN VARIABLES TO NEWS ABOUT FUTURE US TFP IN THE MODEL *Notes:* The solid line and the shaded region are the point estimate and 90 % confidence bands for the empirical impulse response. In following three cases, I set the elasticity of substitution between domestically produced and foreign produced intermediate goods,  $\sigma$ , equal to 1.5 (standard assumption). Line with diamonds denote the response of the variable in the case of KPR preference ( $\kappa = 1$ ) and no investment adjustment cost ( $\phi = 0$ ). Line with crosses denote the case with KPR preference ( $\kappa = 1$ ) and investment adjustment cost ( $\phi = 5$ ). Line with squares denote the case with GHH preference ( $\kappa = 0.001$ ) and investment adjustment cost ( $\phi = 5$ ). Line with circles denote the case with GHH preference ( $\kappa = 0.001$ ), investment adjustment cost ( $\phi = 5$ ), and low elasticity of substitution between domestically produced and foreign produced intermediate goods ( $\sigma = 0.3$ ).



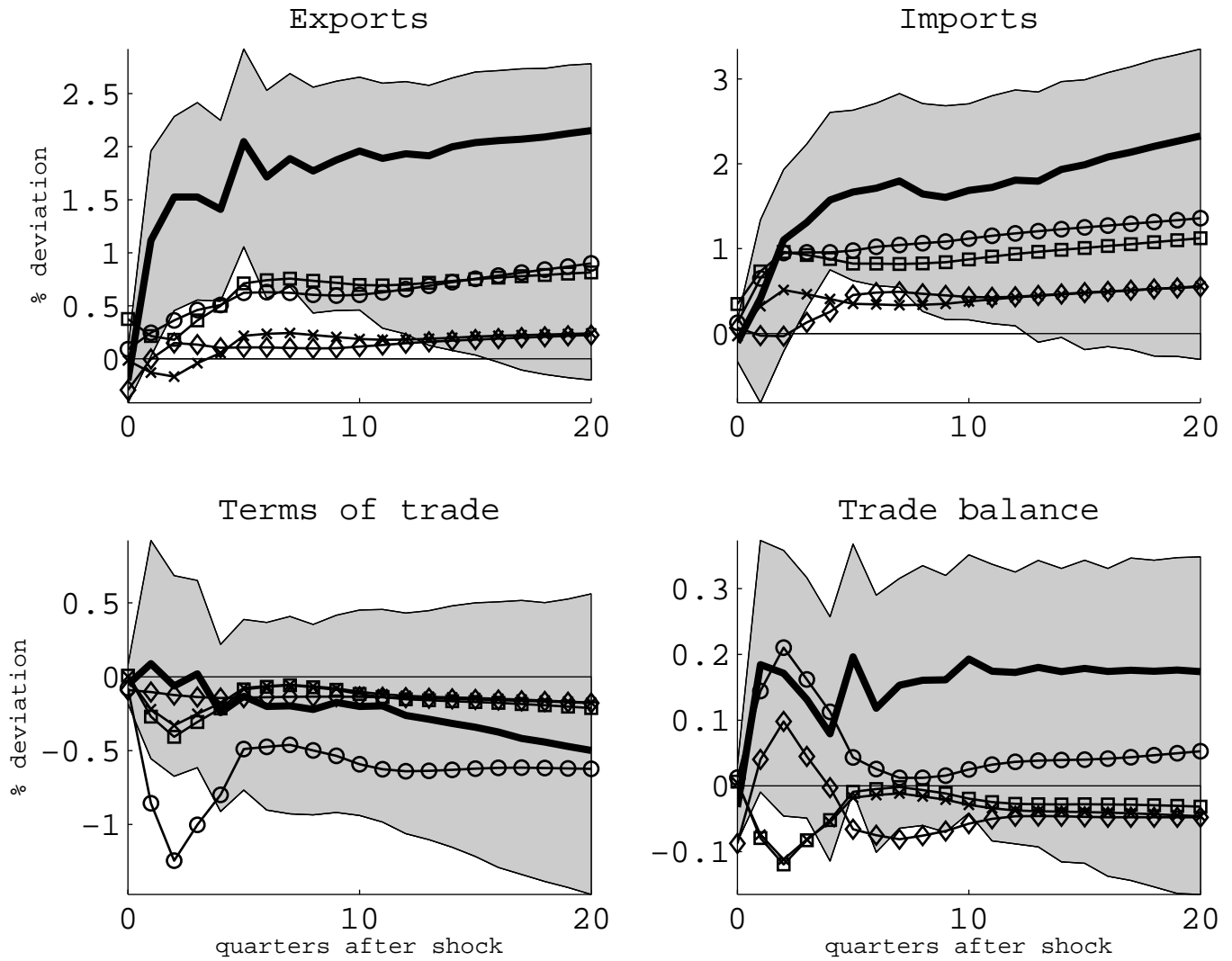


FIGURE 10: RESPONSES OF CANADIAN TRADE VARIABLES TO NEWS ABOUT FUTURE US TFP IN THE MODEL *Notes:* The solid line and the shaded region are the point estimate and 90 % confidence bands for the empirical impulse response. In following three cases, I set the elasticity of substitution between domestically produced and foreign produced intermediate goods,  $\sigma$ , equal to 1.5 (standard assumption). Line with diamonds denote the response of the variable in the case of KPR preference ( $\kappa = 1$ ) and no investment adjustment cost ( $\phi = 0$ ). Line with crosses denote the case with KPR preference ( $\kappa = 1$ ) and investment adjustment cost ( $\phi = 5$ ). Line with squares denote the case with GHH preference ( $\kappa = 0.001$ ) and investment adjustment cost ( $\phi = 5$ ). Line with circles denote the case with GHH preference ( $\kappa = 0.001$ ), investment adjustment cost ( $\phi = 5$ ), and low elasticity of substitution between domestically produced and foreign produced intermediate goods ( $\sigma = 0.3$ ).

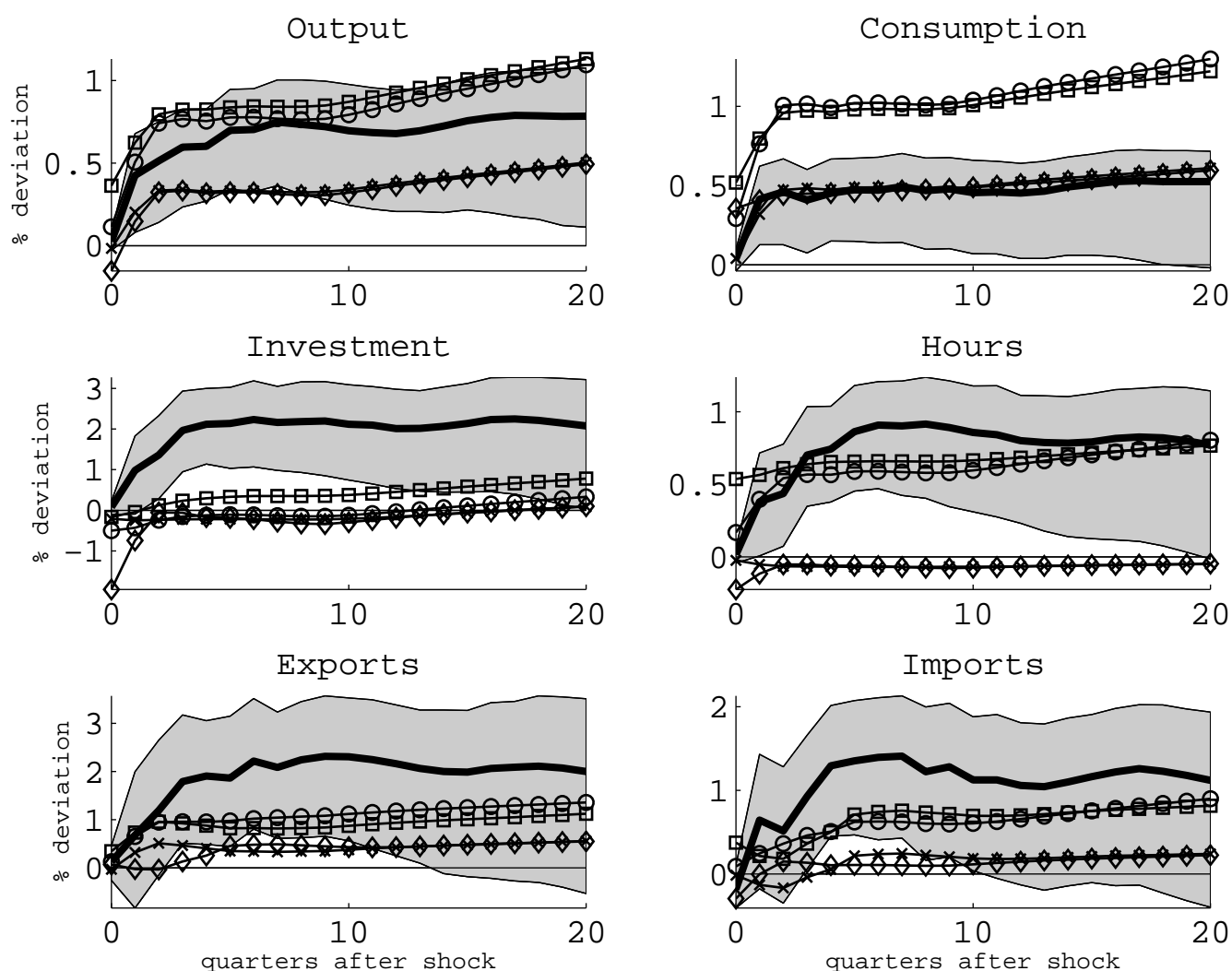


FIGURE 11: RESPONSES OF US VARIABLES TO NEWS ABOUT FUTURE US TFP IN THE MODEL *Notes:* The solid line and the shaded region are the point estimate and 90 % confidence bands for the empirical impulse response. In following three cases, I set the elasticity of substitution between domestically produced and foreign produced intermediate goods,  $\sigma$ , equal to 1.5 (standard assumption). Line with diamonds denote the response of the variable in the case of KPR preference ( $\kappa = 1$ ) and no investment adjustment cost ( $\phi = 0$ ). Line with crosses denote the case with KPR preference ( $\kappa = 1$ ) and investment adjustment cost ( $\phi = 5$ ). Line with squares denote the case with GHH preference ( $\kappa = 0.001$ ) and investment adjustment cost ( $\phi = 5$ ). Line with circles denote the case with GHH preference ( $\kappa = 0.001$ ), investment adjustment cost ( $\phi = 5$ ), and low elasticity of substitution between domestically produced and foreign produced intermediate goods ( $\sigma = 0.3$ ).

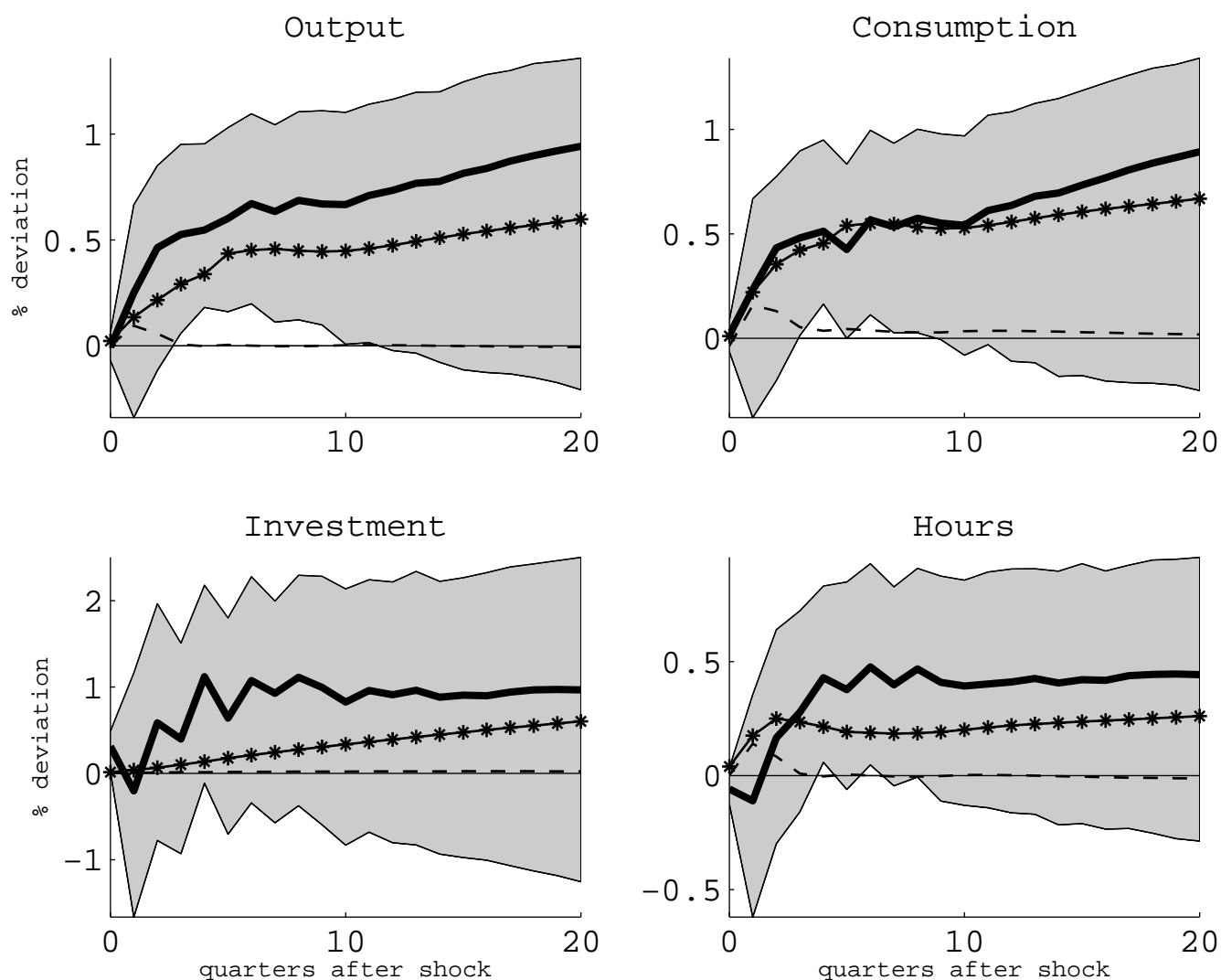


FIGURE 12: RESPONSES OF CANADIAN VARIABLES TO NEWS ABOUT FUTURE US TFP IN THE MODEL WITH ESTIMATED PARAMETERS *Notes:* The solid line and the shaded region are the point estimate and 90 % confidence bands for the empirical impulse response. Line with stars denote the model-based response with estimated parameters and feeding both Canadian and US TFP processes driven by the US news shock. The dashed line denotes the model-based response from counterfactual experiment without feeding Canadian TFP processes driven by the US news shock.

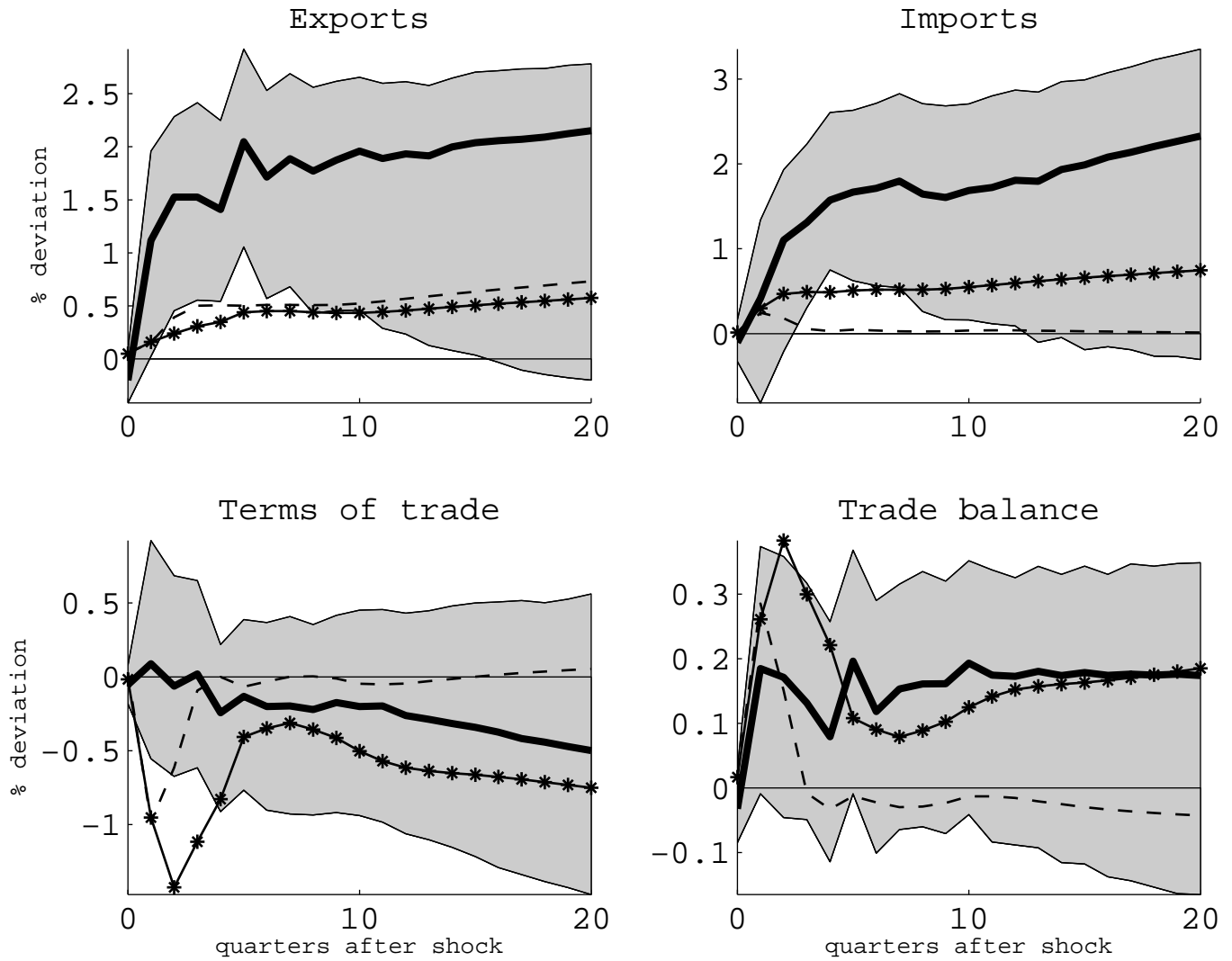


FIGURE 13: RESPONSES OF CANADIAN TRADE VARIABLES TO NEWS ABOUT FUTURE US TFP IN THE MODEL WITH ESTIMATED PARAMETERS *Notes:* The solid line and the shaded region are the point estimate and 90 % confidence bands for the empirical impulse response. Line with stars denote the model-based response with estimated parameters and feeding both Canadian and US TFP processes driven by the US news shock. The dashed line denotes the model-based response from counterfactual experiment without feeding Canadian TFP processes driven by the US news shock.

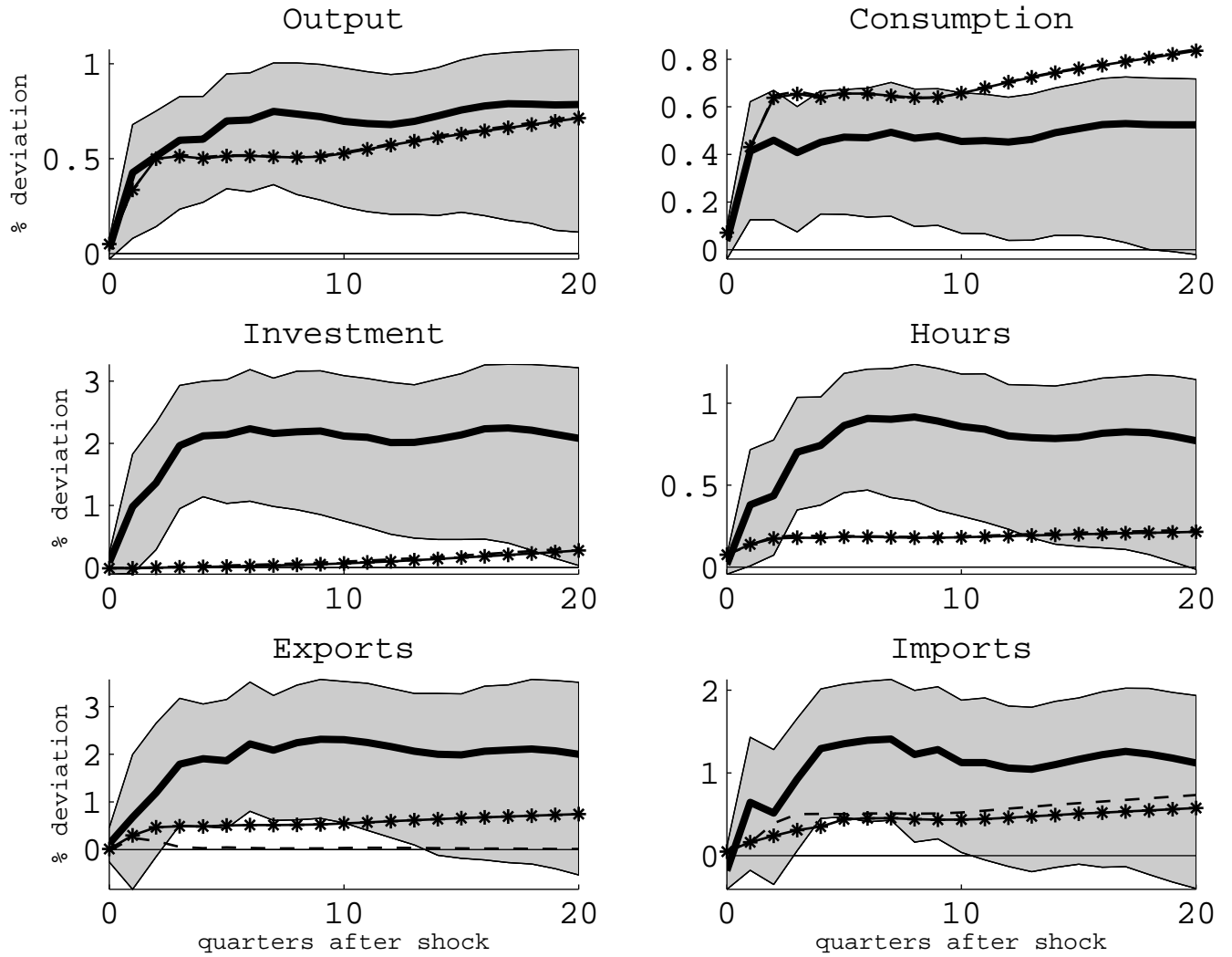


FIGURE 14: RESPONSES OF US VARIABLES TO NEWS ABOUT FUTURE US TFP IN THE MODEL *Notes:* The solid line and the shaded region are the point estimate and 90 % confidence bands for the empirical impulse response. Line with stars denote the model-based response with estimated parameters and feeding both Canadian and US TFP processes driven by the US news shock. The dashed line denotes the model-based response from counterfactual experiment without feeding Canadian TFP processes driven by the US news shock.