Essays in International Business Cycles

by

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Dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in the Department of Economics
in the Graduate School of Duke University
2011
Abstract
(Economics)

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Abstract

This dissertation consists of two chapters on international business cycles. In the first chapter, I revisit the problem of the anomaly of terms of trade dynamics. First, I empirically analyze the effect of a US aggregate labor productivity shock on the US terms of trade using a Vector Autoregression (VAR) and Maximum Forecast Error Variance identification. I find that the shock appreciates the terms of trade of the US. Next, using a non-homothetic preference, I explain the dynamics of the terms of trade in response to a positive aggregate productivity shock theoretically. Using a model with endogenous markup and heterogeneous firm-specific productivities, the appreciation of the terms of trade can be generated even under a complete asset market assumption. Unlike previous studies, I explain the dynamics of the terms of trade through a new channel, which is the channel of relative cutoff firm-specific productivity that determines the optimal export decisions of the firms. Depending on the asset market structure, two competing effects, i.e., the income effect and the markup effect, have different implication to terms of trade dynamics. Under the assumption of financial autarky, the income effect is bigger than the markup effect and the terms of trade depreciates in response to a positive aggregate productivity shock. However, if we allow for the trade of state-contingent or non-state contingent bonds, the markup effect also comes into play and the terms of trade appreciates, which is in line with the empirical findings.

In the second chapter, I study the international transmission effects of the news
about the Total Factor Productivity (TFP hereafter) of the US to the Canadian and Japanese economy. First, using the Vector Error Correction Model (VECM), the impulse responses of Canadian and Japanese macroeconomic variables to the US news shock are estimated. Next, I develop and estimate a two-country real business cycle (RBC) model with investment adjustment cost and the preference which eliminates the wealth effect on hours worked to generate booms in Canadian and Japanese variables in response to news about future US TFP. I find that international macroeconomic comovements can be generated by the news about future TFP in the US. Unlike previous studies, I show that the response of Canadian or Japanese TFP to the US news shock is important in order to generate the boom observed in the empirical analysis. Estimated value of the preference parameter indicates that eliminating 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 explain the domestic boom created by the news shock, which highlights the importance of analyzing an open economy.
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1

Product Variety, Firm Entry, and Terms of Trade Dynamics

1.1 Introduction

International business cycle models have been used to analyze the determination of the terms of trade in response to aggregate productivity shocks. The standard two-country real business cycle (RBC) models such as Backus et al. [1994], hereafter BKK, imply that the terms of trade depreciates, i.e., the relative price of domestic goods decreases, in response to a positive productivity shock. In standard models, relative price of goods produced in domestic economy falls when domestic output goes up and this leads to a depreciation of the terms of trade. Obstfeld and Rogoff [2007] calculated how much depreciation of the terms of trade is needed to stabilize the current account of the US. According to the standard model, the magnitude of the depreciation of the terms of trade varies from 9% to 15%, depending on the parameters of the model.

However, the empirical literature has shown that the terms of trade tends to appreciate in response to a positive domestic productivity shock. Using VAR analyses
and long-run identification\(^1\), Corsetti et al. [2008b] show that the terms of trade appreciates in response to domestic labor productivity in large economies such as the US or Japan. Enders and Müller [2009] show similar results using data from the US and the aggregate of the industrialized countries.

In this paper, I argue that firms’ endogenous markups and heterogeneity in firm-specific productivities are the key mechanism that induces the dynamics of the terms of trade observed in empirical studies. I use a non-homothetic preference as in Melitz and Ottaviano [2008] in a dynamic stochastic general equilibrium model\(^2\). In this model, firms decide whether to enter the export market depending on their firm-specific productivity. Importantly, this type of preference exhibits preference over different varieties of goods and it generates endogenous markup distribution across firms. The terms of trade derived in this model depends on two factors. One is the relative cost of units of effective labor and the other is the relative cutoff firm-specific productivity. I find that the latter factor is the channel that explains the dynamics of the terms of trade observed in empirical analyses. There are two competing effects that determine the dynamics of the terms of trade through the channel of the relative cutoff firm-specific productivity: the income effect and the markup effect. The relative degrees of these two effects differ according with the asset market structure assumed in the model. I simulate the model under three different assumptions of the asset market: financial autarky, an incomplete asset market and a complete asset market. Under the assumption of financial autarky, the income effect is bigger than the markup effect. A positive aggregate home productivity shock increases the income in the home economy and thus it increases the demand for

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\(^1\) The long-run identification method is commonly used for identifying a productivity shock and was first used in Galí [1999].

\(^2\) This type of preference was first introduced in Ottaviano et al. [2002]. The preference I use in my model differs from Melitz and Ottaviano [2008] since I incorporate both the income effect and the markup effect to understand the implications of this type of preference in a general equilibrium setting. I explain the details in Section 1.3.
varieties. Therefore, even less productive foreign firms can export and the relative
cutoff productivity of foreign exporting firms decreases. Mainly through this channel,
the terms of trade depreciates under the assumption of financial autarky.

However, if we allow for the trade of state-contingent or state non-contingent
bonds by using either complete or incomplete asset market assumption, the income
effect on the cutoff productivity of foreign exporting firms is mitigated since the
representative household can access to the bonds and the international risk sharing
between two countries smoothes out the relative change of demand for goods across
countries. On the other hand, the income effect on the cutoff productivity of domestic
exporting firms becomes bigger than that of foreign exporting firms since foreign
demand for varieties increases because of the increase of wealth in foreign economy.
Furthermore, the markup effect comes into play. In response to a positive aggregate
productivity shock in the home economy, home firms can produce more goods at lower
cost and more home firms enter the home market. Therefore, the number of home
firms serving the home market increases. This means that the home market becomes
more competitive and the average markup in the home market decreases. Foreign
firms exporting to the home market face this higher competition and thus they
need to decrease their markups as well. This generates a decrease in their expected
profit and thus foreign firms which have relatively higher firm-specific productivity
can enter the home market. Thus, the cutoff productivity of foreign exporting firm
increases relative to that of home exporting firms and the terms of trade appreciates
through this channel. The terms of trade appreciates most in the case of complete
asset market, where the international risk sharing is perfect.

There is a growing literature seeking a resolution to this anomaly of the terms of
trade by introducing extensive margin into a standard two-country model. Corsetti
et al. [2007] analyze the changes in the terms of trade in response to a productivity
gain using a model augmented with product variety. Their model predicts the appre-
ciation of the terms of trade when there is a reduction of market entry costs, however, it does not predict the appreciation when there is a reduction of manufacturing costs. Ghironi and Melitz [2005] analyze the effect of an aggregate productivity shock on the real exchange rate using a model with heterogeneous firms and product variety. However, their model does not fully account for the appreciation of the terms of trade in the short run, although in the long run it tends to appreciate. In their model, the appreciation of the terms of trade arises from the change in relative production cost between two countries. If there is a positive productivity shock, then firms’ production cost is reduced and it becomes easier for the firms to enter the market. This surges the increase of labor demand, which increases the equilibrium wage and the relative production cost. However, this result crucially depends on their assumptions about the labor market. In their model, labor is inelastically supplied in each period and thus exaggerates the effect of a surge of labor demand. Farhat [2009] analyzes the effect of a positive productivity shock in a model based on Ghironi and Melitz [2005] but augmented with an endogenous labor supply. In his model, the terms of trade depreciates in response to a positive productivity shock since an elastic labor supply curve mitigates the effect of a surge of labor demand on the equilibrium wage.

There is another strand of literature that uses a standard two-country model without extensive margin. Corsetti et al. [2008a] and Enders and Müller [2009] both show that the combination of an incomplete asset market and low elasticity of substitution between home and foreign goods can account for the appreciation of the terms of trade. It has been a common consensus that this anomaly cannot be resolved without the incomplete asset market assumption in a model without extensive margin. The intuition behind this result is as follows. If there is a positive

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3 Fattal-Jaef and Lopez [2010] also analyze a model based on Ghironi and Melitz [2005] but augmented with capital accumulation and endogenous markup. They also find that the terms of trade depreciates in response to a positive productivity shock.
productivity shock in the home economy, then the wealth of the home economy increases relative to the foreign economy if international risk sharing is not complete. This surges an increase of demand for domestically-produced goods if the substitution elasticity between the home and foreign goods is low. This increases the equilibrium price of domestic goods and appreciates the terms of trade.

This paper differs from previous studies in two important ways. First, unlike previous studies, by using a model augmented with heterogeneity in firm-specific productivities and firms’ endogenous markups, I explain the dynamics of the terms of trade through a new channel, which is the channel of relative cutoff firm-specific productivity that determines the optimal export decisions of the firms. This resolution does not resort to strong assumptions on the labor market, home bias, elasticity of substitution between goods and the persistence of productivity that previous studies have imposed in their models. Second, this paper contributes to our understanding of the implications of financial openness on the terms of trade dynamics. I evaluate the model by analyzing three different cases of asset market assumptions: financial autarky, an incomplete market and a complete market.

There is a theoretical literature that demonstrates the importance of firms’ variable markups to explain the behavior of tradable goods prices. Simonovska [2010] incorporates a non-homothetic preference into the monopolistic competition framework of Melitz [2003] and Chaney [2008]. She analyzes the relative prices of goods between multiple countries in a static framework. Goksel [2011] incorporates a non-homothetic preference as in Melitz and Ottaviano [2008] into a static multiple-country framework. Rodriguez-Lopez [2006, 2011] analyzes the exchange rate pass-through using a model augmented with endogenous markup and sticky wage without firm entry. However, none of these studies have accounted for the implications of a productivity gain on the terms of trade dynamics while incorporating both the income effect and the markup effect resulting from a non-homothetic preference in a
dynamic stochastic general equilibrium (DSGE) setting.

The organization of this paper is as follows. In Section 1.2, I present empirical evidence for the effects of a positive productivity shock on the terms of trade. Section 1.3 outlines a two-country DSGE model augmented with heterogeneous productivity and endogenous markup. Section 1.4 explains the calibration parameters of the model. Section 1.5 explains the underlying mechanism that explains the dynamics of the terms of trade in my model. In Section 1.6, I show the results of impulse response analyses using the model. Section 1.7 compares the responses of the terms of trade observed in the data and obtained using the theoretical model in Section 1.3. Section 1.8 concludes.

1.2 Empirical Evidence

In this section, I empirically study the dynamics of the terms of trade of the US in response to a technology shock in the US. I estimate a Structural Vector Autoregression (SVAR) model and identify the shocks using the Maximum Forecast-Error Variance (MFEV) approach following Uhlig [2004a,b] and Francis et al. [2007].

1.2.1 Identification of a Productivity Shock Using the MFEV Approach

I begin by discussing the identification method using the MFEV approach following Francis et al. [2007]. I first estimate the reduced-form VAR model as follows:

\[ y_t = B(L)u_t, \]

(1.1)

where \( y_t \) denotes an \( n \times 1 \) vector of variables at time \( t \) with labor productivity, \( Z_t \), placed at the top. \( B(L) = \sum_{i=0}^{\infty} B_i L^i \) where \( L \) is the lag operator and \( u_t \) is a vector of the reduced residuals at time \( t \). I assume there is a mapping between the reduced

\(^4\) This approach has been recently actively used also in the literature on news shock. For example, see Sims [2011], Barsky and Sims [2010] and Kurmann and Otrok [2010].
residuals, \( u_t \), and the structural residuals, \( \varepsilon_t \), as follows:

\[
u_t = A_0 \varepsilon_t. \tag{1.2}\]

The goal of the identification is to find the matrix, \( A_0 \). I can write \( y_t \) as a Moving Average (MA) representation using structural residuals, \( \varepsilon_t \) as follows:

\[
y_t = C(L)\varepsilon_t, \tag{1.3}\]

where \( C(L) = \sum_{i=0}^{\infty} C_i L^i \). I assume that the variance-covariance matrix of \( \varepsilon_t \) is an identity matrix, \( I \). I can write \( C(L) \) as

\[
C(L) = B(L)A_0. \tag{1.4}\]

I assume that the variance-covariance matrix of \( u_t \) is \( \Sigma \), i.e., \( E_t[u_t u'_t] = \Sigma \). From (1.2), I can write \( \Sigma \) as :

\[
\Sigma = E_t[A_0 \varepsilon_t \varepsilon'_t A'_0] = A_0 A'_0.
\]

However, the decomposition into \( A_0 \) is not unique. Therefore, by using some arbitrary orthogonalization\(^5\), \( \tilde{A}_0 \), and \( D \) where \( DD' = I \), \( \Sigma \) can be decomposed as follows:

\[
\Sigma = \tilde{A}_0 D D' \tilde{A}_0' \tag{1.5}\]

We can rewrite the impulse responses \( C(L) \) associated with the structural shocks \( \varepsilon_t \) as:

\[
C(L) = B(L) \tilde{A}_0 D. \tag{1.6}\]

Then the forecast error \( h \)-period ahead can be written as:

\[
y_{t+h} - E_{t-1} y_{t+h} = \sum_{i=0}^{h} B_i \tilde{A}_0 D \varepsilon_{t+h-i}, \tag{1.7}\]

\(^5\) In practice, I use Cholesky decomposition following Francis et al. [2007] or Barsky and Sims [2010] for obtaining \( \tilde{A}_0 \). This decomposition ensures that the technology shock is orthogonal to other shocks in the system.
where $E_{t-1}$ is the expectation operator at time $t - 1$.

The share of the $h$-step-ahead forecast error variance for a variable $j$ attributable to structural shock $k$ is:

$$\omega_{jk}(h) = \frac{\epsilon_j' \left( \sum_{i=0}^{h} B_i \hat{A}_0 D e_k e_k' D' \hat{A}_0' B_i' \right) e_j}{\epsilon_j' \left( \sum_{i=0}^{h} B_i \Sigma B_i' \right) e_j} = \frac{\sum_{i=0}^{h} B_{j,i} \hat{A}_0 \gamma' \hat{A}_0' B_{j,i}}{\sum_{i=0}^{h} B_{j,i} \Sigma B_{j,i}}, \quad (1.8)$$

where $e_j$ is an $n \times 1$ indicator vector which selects $\gamma$, the $k$th column of $D$.

This identification method chooses an impulse vector, $\gamma$, which maximizes the forecast error variance as much as possible over $h$ horizon. The impulse response generating matrix is $B_i \hat{A}_0 \gamma$.

I identify a productivity shock by solving following maximization problem:

$$\max_{\gamma} \omega_{1k}(h) \quad (1.9)$$

subject to

$$\gamma' \gamma = 1 \quad (1.10)$$

The maximization constraint, (1.10), is to ensure that the technology shocks have unit variance. In practice\textsuperscript{6}, this maximization problem is to solve the eigenvector associated with the maximum eigenvalue of a weighted sum of $(B_{1,i} \hat{A}_0)' \left( B_{1,i} \hat{A}_0 \right)$.

1.2.2 The Data

In order to identify the technology shock to the US and estimate the impulse responses of the terms of trade, I use following quarterly data. The sample covers the post-Bretton Woods period 1973Q1-2010Q2. For the US labor productivity, I use output per hour in the nonfarm business sector obtained from the website of the

Bureau of Labor Statistics. To construct the US terms of trade, I divide the implicit deflator of imported goods by the implicit deflator of exported goods, obtained from the website of the Bureau of Economic Analysis. I also include US net exports, US consumption relative to that of an aggregate of other G7 countries, and US output relative to that of an aggregate of other G7 countries. To construct the US net exports, I obtain data on nominal exports, imports and GDP from the website of the Bureau of Economic Analysis. I first subtract the value of nominal imports from nominal exports and divide this by nominal GDP. For relative US consumption, I use data from SourceOECD. I construct an aggregate consumption of the rest of the world using private consumption data of the G7 countries except the US (Canada, France, Germany, Italy, Japan and UK) weighted by each country’s GDP share in the total GDP of the G7 countries. I construct an aggregate output of the rest of the world in a similar way. All the variables are converted to log levels except net exports. In order to construct a stationary time series, I detrended the data by linear and quadratic detrending method.

1.2.3 Empirical Results

Figure 1.1 shows the impulse responses using MFEV identification. Following a positive technology shock to US labor productivity, the US terms of trade significantly appreciates on impact. US net exports decrease, although the initial response is not significant. Relative consumption and output tend to increase and exhibit hump-shaped responses.

1.3 The Model

In this section, I propose a two-country model in which firms have a heterogeneous firm-specific productivity and endogenously determine firm-specific markup. The basic framework is based on Ghironi and Melitz [2005] which features heterogeneous
productivity. However, I incorporate non-homothetic consumer preference a l’a Melitz and Ottaviano [2008]. Unlike Melitz and Ottaviano [2008], I do not incorporate an external homogeneous goods sector in order to incorporate the income effect fully in a general equilibrium model\(^7\).

1.3.1 Household’s Utility and Demand for Variety

The economy consists of two countries, Home and Foreign. Foreign variables are denoted with stars. A representative household maximizes

\[
E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, 1 - H_t),
\]

where \( \beta \) is a discount factor, \( C_t \) is total consumption of the household and \( H_t \) is the total hours worked.

For the instantaneous utility, I assume a Cobb-Douglas function as follows:

\[
U(C_t, 1 - H_t) = \frac{C_t^\kappa (1 - H_t)^{1-\kappa}}{1 - \sigma}.
\]

Following Ottaviano et al. [2002] and Melitz and Ottaviano [2008], \( C_t \) is given by:

\[
C_t = \omega \int_{i \in \Omega} q_{it} di - \frac{1}{2} \gamma \int_{i \in \Omega} (q_{it})^2 di - \frac{1}{2} \eta \left( \int_{i \in \Omega} q_{it} di \right)^2,
\]

where \( q_{it} \) is the amount of consumption of each variety \( i \), and \( \Omega \) denotes the possibly-consumed set of goods. \( \omega, \gamma \) and \( \eta \) are positive parameters; \( \omega \) expresses the intensity of the preference for differentiated products, \( \gamma \) is the index of the degree of product differentiation between varieties and \( \eta \) is the index of the pattern of substitution. A large \( \eta \) means closer substitution between varieties.

\(^7\) This approach is similar to Goksel [2011] or Neary [2003].
Solving the expenditure-minimization problem, the demand function for each variety $i$ is derived as:

$$q_t(i) = \frac{1}{\gamma} \left( \omega - \frac{1}{\lambda_t} p_t(i) - \eta Q_t \right),$$

where $Q_t = \int_q q_d di$ and $\lambda_t$ is the Lagrangian multiplier of the expenditure minimization problem.

Integrating over all the varieties consumed, the average consumption of the variety, $\bar{q}_t$, can be written as:

$$\bar{q}_t = \frac{\omega - \frac{1}{\gamma} \bar{p}_t}{\gamma + \eta N_t}$$

where $\bar{p}_t$ is the average price and $N_t$ is the measure of consumed varieties.

When the demand for variety $i$ is zero, the maximum price the firm can set, $\hat{p}_t$, can be derived using (1.13) and (1.14) as:

$$\hat{p}_t = \frac{\omega \gamma \lambda_t + \eta N_t \bar{p}_t}{\gamma + \eta N_t}.$$  

1.3.2 Firms

There is a continuum of firms which produce different varieties $i$. I assume that production requires only labor. Firms face aggregate labor productivity, $Z_t$. Each firm is identical prior to entry. They face a sunk cost of $f_E$ effective labor units, which is $w_t f_E / Z_t$. They also have a firm-specific productivity, $z$, which is revealed after they enter the market. Following Ghironi and Melitz [2005], it is assumed that $z$ follows a Pareto distribution, $G(z) = 1 - \left( \frac{z_{min}}{z} \right)^\theta$, with a lower bound $z_{min}$.

I assume that $N_p$ firms possibly produce. Every period each firm faces a death shock with probability $\delta$, following Ghironi and Melitz [2005].
Firms Serving Domestic Sales

Each firm with firm-specific productivity $z$ serving in the domestic market maximizes:

$$\max \pi_{Dt}(z) = p_{Dt}(z)q_{Dt}(z) - MC_t(z)q_{Dt}(z), \quad (1.16)$$

where $\pi_{Dt}(z)$ is the profit earned from domestic sales, $p_{Dt}(z)$ is the price charged for domestic sales, and $q_{Dt}(z)$ is the quantity of domestic sales. $MC_t(z)$ is the marginal cost for the firm with productivity $z$, which is equal to $\frac{W_t}{z_t}$.

The demand function for a good produced by a firm with productivity $z$ is written using (1.13) as:

$$q_{Dt}(z) = \frac{1}{\gamma} \left( \omega - \frac{1}{\lambda_t} p_{Dt}(z) - \eta N_t q_t \right). \quad (1.17)$$

Each firm serving the domestic market maximizes (1.16) subject to (1.17).

By solving the above profit maximization problem, I obtain the following equation that determines the optimal price charged by the firm:

$$q_{Dt}(z) = \frac{1}{\gamma \lambda_t} \left[ p_{Dt}(z) - MC_t(z) \right] \quad (1.18)$$

Let $z_{Dt}$ be the cutoff productivity with which the firm has positive sales. Therefore, $p_{Dt}(z_{Dt}) = MC_t(z_{Dt}) = \hat{p}_t$ and the demand level is $q_{Dt}(z_{Dt}) = 0$. Equating (1.17) and (1.18) and using (1.14), the optimal price can be further written using $z_{Dt}$ as:

$$p_{Dt}(z) = \frac{1}{2} MC_t(z) + \frac{1}{2} MC_t(z_{Dt}). \quad (1.19)$$

Using $z_{Dt}$, the optimal output level, $q_{Dt}(z)$, markup, $\mu_{Dt}(z)$, and the profit level, $\pi_{Dt}(z)$ can be written as:

$$q_{Dt}(z) = \frac{1}{\gamma \lambda_t} \left[ \frac{1}{2} MC_t(z_{Dt}) - \frac{1}{2} MC_t(z) \right] \quad (1.20)$$
\begin{align}
\mu_{Dt}(z) &= \frac{1}{2}MC_{t}(z_{Dt}) - \frac{1}{2}MC_{t}(z) \quad (1.21) \\
\pi_{Dt}(z) &= \frac{1}{4\gamma\lambda_{t}} [MC_{t}(z_{Dt}) - MC_{t}(z)]^{2}. \quad (1.22)
\end{align}

Importantly, firms with lower cost or higher firm-specific productivity set lower prices and enjoy higher markups and profits. The prices and markups also depend on the cutoff productivity in the market, \( z_{Dt} \).

**Firms Serving Export Sales**

The profit maximization problem for a firm with productivity \( z \) serving export sales can be written as:

\[
\max \pi_{Xt}(z) = p_{Xt}(z)q_{Xt}(z) - \tau_{t}MC_{t}(z)q_{Xt}(z) 
\]  

(1.23)

where \( \pi_{Xt}(z) \) is the profit earned from export sales, \( p_{Xt}(z) \) is the price charged for export sales, and \( q_{Xt}(z) \) is the quantity of the export sales.

The demand function associated with export sales can be written using (1.13) as:

\[
q_{Xt}(z) = \frac{1}{\gamma} \left( \omega - \frac{1}{\lambda_{t}^{s}} p_{Xt}(z) - \eta N_{t}^{s} \tilde{q}_{t}^{s} \right). \quad (1.24)
\]

By solving this profit maximization problem, the optimal price for export sales can be derived using the following equation:

\[
q_{Xt}(z) = \frac{1}{\gamma\lambda_{t}^{s}} [p_{Xt}(z) - \tau_{t}MC_{t}(z)]. \quad (1.25)
\]

Let \( z_{Xt} \) be the cutoff productivity with which the firm obtains positive sales out of exporting. Therefore, \( p_{Xt}(z_{Xt}) = \tau_{t}MC_{t}(z_{Xt}) = \hat{p}_{t}^{s} \) and the demand is \( q_{Xt}(z_{Xt}) = 0 \). Equating (1.24) and (1.25) and using the foreign counterpart of (1.14), the optimal price can be derived as:

\[
p_{Xt}(z) = \frac{1}{2}\tau_{t}MC_{t}(z) + \frac{1}{2}\tau_{t}MC_{t}(z_{Xt}). \quad (1.26)
\]
The optimal output level, markup, and the profit level for export sales can be written as:

\[ q_{Xt}(z) = \frac{1}{\gamma \lambda_t^*} \left[ \frac{1}{2} \tau_t MC_t(z_{Xt}) - \frac{1}{2} \tau_t MC_t(z) \right] \]  
(1.27)

\[ \mu_{Xt}(z) = \frac{1}{2} \tau_t MC_t(z_{Xt}) - \frac{1}{2} \tau_t MC_t(z) \]  
(1.28)

\[ \pi_{Xt}(z) = \frac{1}{4\gamma \lambda_t^*} \left[ \tau_t MC_t(z_{Xt}) - \tau_t MC_t(z) \right]^2. \]  
(1.29)

As in the case of firms serving domestic sales, I can infer from these equations that firms with lower cost have lower prices and enjoy higher markups and profits. Prices and markups depend on the cutoff productivity which determines the exportability, \( z_{Xt} \).

1.3.3 Firm Averages

Given a distribution of firm-specific productivity, \( G(z) \), we can solve for the average values of price, output levels, and markups. For any function of \( z \), \( a_{jt}(z) \), where \( j = D, X \), the average value \( \bar{a}_{jt} \) is given by \( \bar{a}_{jt} = \frac{1}{1-G(z)} \int_{z_{jt}}^{z_t} a_{jt}(z) dG(z) \).

Then the average prices satisfy:

\[ \bar{p}_{Dt} = \frac{2\theta + 1}{2(\theta + 1)} \frac{W_t}{Z_t z_{Dt}} \]  
\[ \bar{p}_{Xt} = \frac{2\theta + 1}{2(\theta + 1)} \frac{\tau_t W_t}{Z_t z_{Xt}} \]

\[ \bar{q}_{Dt} = \frac{1}{2\gamma(\theta + 1) \lambda_t} \frac{W_t}{Z_t z_{Dt}} \]  
\[ \bar{q}_{Xt} = \frac{1}{2\gamma(\theta + 1) \lambda_t^*} \frac{\tau_t W_t}{Z_t z_{Xt}} \]

\[ \bar{\mu}_{Dt} = \frac{1}{2(\theta + 1)} \frac{W_t}{Z_t z_{Dt}} \]  
\[ \bar{\mu}_{Xt} = \frac{1}{2(\theta + 1)} \frac{\tau_t W_t}{Z_t z_{Xt}} \]

The foreign average variables can be written analogously.
1.3.4 Free Entry Condition

Following Ghironi and Melitz [2005], I assume a time-to-build lag such that the firms entering at time $t$ start producing from time $t + 1$. The present discounted value of the stream of expected profits after period $t + 1$ can be written as:

$$v_t = E_t \sum_{s=t+1}^{\infty} [\beta (1 - \delta)]^{s-t} \frac{U_c(C_{t+s}, 1 - H_{t+s})}{U_c(C_t, 1 - H_t)} \pi_s$$

(1.30)

where $\delta$ is the exogenous death rate of the firm and $\pi_t$ is the one-period expected profit of the firm, $\pi_t$ is the sum of the expected profit from domestic sales, $\pi_{Dt}$, and and export sales, $\pi_{Xt}$:

$$\pi_t = \pi_{Dt} + \pi_{Xt}.$$  

(1.31)

$\pi_{Dt}$ and $\pi_{Xt}$ can be written as a function of the cutoff productivity as:

$$\pi_{Dt} = \int_{z_{Dt}}^{\infty} \pi_{Dt}(z)dG(z) = \frac{z_{\text{min}}^\theta \left( \frac{W_t}{Z_t} \right)^2}{2\gamma (\theta + 1)(\theta + 2)\lambda_t} z_{Dt}^{\theta - 2}$$

(1.32)

$$\pi_{Xt} = \int_{z_{Xt}}^{\infty} \pi_{Xt}(z)dG(z) = \frac{z_{\text{min}}^\theta t^2 \left( \frac{W_t}{Z_t} \right)^2}{2\gamma (\theta + 1)(\theta + 2)\lambda_t^2} z_{Xt}^{\theta - 2}.$$  

(1.33)

The foreign average variables can be derived analogously.

The free entry condition can be written using the discounted value of future expected profit after $t + 1$, $v_t$, as:

$$v_t = \frac{W_t f_{Et}}{Z_t}.$$  

(1.34)

1.3.5 The Cutoff Productivity

In this section, I characterize the cutoff productivity, $z_{Dt}$ and $z_{Xt}$. By construction, the firm with cutoff productivity exhibits zero sales. In order to have a positive profit
in the domestic market, the firm with cutoff productivity, \(z_{Dt}\), must satisfy the following condition:

\[
\frac{\omega \gamma \lambda_t + \eta N_t \bar{p}_t}{\gamma + \eta N_t} = \frac{W_t}{Z_t z_{Dt}}
\]  
(1.35)

where \(N_t\) is the total number of firms selling in the home economy.\(^8\) This condition is derived from the fact that at the cutoff productivity, \(z_{Dt}\), \(p_{Dt}(z_{Dt}) = \bar{p}_t = MC_t(z_{Dt})\) holds.

Similarly, the cutoff productivity, \(z_{Xt}\), will satisfy

\[
\frac{\omega \gamma \lambda_t^* + \eta N_t^* \bar{p}_t^*}{\gamma + \eta N_t^*} = \tau_t \frac{W_t}{Z_t z_{Xt}}
\]  
(1.36)

where \(N_t^*\) is the total number of firms selling in the foreign economy. This condition is derived from \(p_{Xt}(z_{Xt}) = \bar{p}_t^* = \tau_t MC_t(z_{Xt})\).

### 1.3.6 Number of the Firms

Under the assumption of firm-specific productivity, \(G(z) \equiv 1 - \left(\frac{z_{\min}}{z}\right)^\theta\) and defining the pool of existing firms, \(N_p\), I can write the number of domestic firms producing as:

\[
N_{Dt} = N_{pt} \left(\frac{z_{\min}}{z_{Dt}}\right)^\theta,
\]  
(1.37)

\[
N_{Xt} = N_{pt} \left(\frac{z_{\min}}{z_{Xt}}\right)^\theta.
\]  
(1.38)

Foreign variables can be written analogously.

---

\(^8\) Therefore \(N_t = N_{Dt} + N_{Xt}^*\), where \(N_{Dt}\) is the number of home firms selling in the home economy and \(N_{Xt}^*\) is the number of foreign firms selling in the home economy. Similarly, \(N_t^* = N_{Dt}^* + N_{Xt}\), where \(N_{Dt}^*\) is the number of foreign firms selling in the foreign economy and \(N_{Xt}\) is the number of home firms selling in the foreign economy.
Since there is a death shock each period with a probability $\delta$ and given that I assume a one-period time-to-build lag for new entrants, the evolution of $N_{pt}$ becomes

$$N_{pt+1} = (1 - \delta)(N_{pt} + N_{Et})$$

(1.39)

where $N_{Et}$ is the number of entrants.

1.3.7 Asset Market Structures

In this section, I discuss three cases of asset market structures. Later I compare the responses of the terms of trade for these three cases. In my model, the implications of an aggregate productivity shock crucially vary across different asset market structures.

Case 1: Financial Autarky and Balanced Trade Assumption

First I assume a financial autarky and a balanced trade assumption to see the adjustment in the terms of trade. The setup assumed here is similar to the one in Ghironi and Melitz [2005]. Under this assumption, the value of exports equals the value of imports as:

$$N_{Xt} \frac{1}{1 - G(z_{Xt})} \int_{z_{Xt}}^{\infty} p_{Xt}(z) q_{Xt}(z) dG(z) = N_{Xt}^* \frac{1}{1 - G(z_{Xt}^*)} \int_{z_{Xt}}^{\infty} p_{Xt}^*(z) q_{Xt}^*(z) dG(z).$$

This equation is simplified to:

$$\frac{N_{Xt} \tau_t^2 M \bar{C}_{t}^2 z_{Xt}^{-2}}{\lambda_t^*} = \frac{N_{Xt}^* \tau_t^2 M \bar{C}_{t}^* z_{Xt}^* - 2}{\lambda_t}. \hspace{1cm} (1.40)$$

Under this assumption, there is no bond trading across countries and thus there is no international risk sharing. The consumption becomes equal to the value of the output.

Although the household in each country does not hold bonds traded internationally, I assume that a share of mutual fund of domestic firms and domestic risk-free
bonds are held by the household. During period $t$, the household buys $x_{t+1}$ shares of the mutual fund of domestic firms already operating at time $t$, $N_{pt}$, and the new entrants, $N_{Et}$. Since I assume one-period time-to-build lag in the production and the exogenous death shock, only $(1 - \delta)(N_{pt} + N_{Et})$ firms will produce at time $t + 1$. However, following Ghironi and Melitz [2005], I assume that the household does not know the firms will be hit by the exogenous death shock until the very end of period $t$. Therefore, the household finances $N_{pt} + N_{Et}$ firms in total. Using the value of expected profit after $t + 1$, $v_t$, the total payment of the household at period $t$ to the mutual fund is $x_{t+1}(N_{pt} + N_{Et})v_t$. The value that the household will receive from the dividend and selling the initial position is $x_t(1 - \delta)(N_{pt-1} + N_{Et-1})(\pi_t + v_t)$. The household has bond sharing, $B_t$ at period $t$ and buys $B_{t+1}$ bonds. Then the budget constraint of the household at period $t$ can be written as:

$$P^c_t C_t + x_{t+1}(N_{pt} + N_{Et})v_t + P^e_t B_{t+1} = W_t H_t + x_t(1 - \delta)(N_{pt-1} + N_{Et-1})(\pi_t + v_t) + (1 + r_t)P^e_t B_t, \quad (1.41)$$

where $r_t$ is the interest rate on bond holding.

The household maximizes the lifetime utility function, (1.11), subject to (1.41). Using Lagrangian multiplier, $\mu_t$, the optimality condition for the household’s consumption and hours worked can be written as:

$$U_C(C_t, 1 - H_t) = P^e_t \mu_t, \quad (1.42)$$

and

$$U_H(C_t, 1 - H_t) + \mu_t W_t = 0. \quad (1.43)$$

The Euler equation for the share holding can be written as:

$$\beta \mu_{t+1}(1 - \delta)(\pi_{t+1} + v_{t+1}) = \mu_t v_t. \quad (1.44)$$
The Euler equation for the bond holding can be written as:

$$\beta \mu_{t+1}(1-\delta)(\pi_{t+1} + v_{t+1}) = \mu_t v_t.$$ (1.45)

At the equilibrium under the assumption of a financial autarky ($B_t = B_{t+1} = 0$) and the assumption of the household’s full ownership of the firms ($x_t = x_{t+1} = 1$), the market clearing condition can be derived from the budget constraint, (1.41):

$$P_t^c C_t + N_{Et} v_t = W_t H_t + N_{mt} \pi_t.$$ (1.46)

**Case 2: Incomplete Asset Market Assumption**

Next, I assume an incomplete asset market. Under this assumption, the representative household trades home bonds and foreign bonds. There are costs of adjusting holdings of home and foreign bonds. I follow the setting used in Ghironi and Melitz [2005].

In this case, the budget constraint of the household can be rewritten as:

$$P_t^c B_{t+1} + P_t^{cs} B_{st+1} + P_t^c \frac{\nu}{2} (B_{t+1})^2 + P_t^{cs} \frac{\nu}{2} (B_{st+1})^2 + P_t^c C_t + N_{Et} v_t$$

$$= (1 + r_t) P_t^c B_t + (1 + r_t^s) P_t^{cs} B_{st} + T_t + W_t H_t + N_{mt} \pi_t,$$

where $B_{t+1}$ is holdings of home bonds, $B_{st+1}$ is holdings of foreign bonds, $\frac{\nu}{2} (B_{t+1})^2$ is the cost of adjusting the holdings of home bonds, and $\frac{\nu}{2} (B_{st+1})^2$ is the cost of adjusting the holdings of foreign bonds. $T_t$ is the rebate to the household, which is equal to $P_t^{c} \frac{\nu}{2} (B_{t+1})^2 + P_t^{cs} \frac{\nu}{2} (B_{st+1})^2$ at equilibrium. We assume $\nu$, the parameter that determines the cost of adjusting the holdings of bonds, to be positive.

The representative foreign household has a similar budget constraint, as:

$$P_t^c B_{t+1}^s + P_t^{cs} B_{st+1}^s + P_t^c \frac{\nu}{2} (B_{t+1}^s)^2 + P_t^{cs} \frac{\nu}{2} (B_{st+1}^s)^2 + P_t^c C_t^s + N_{Et}^s v_t^s$$

$$= (1 + r_t) P_t^c B_t^s + (1 + r_t^s) P_t^{cs} B_{st}^s + T_t^s + W_t^s H_t^s + N_{mt}^s \pi_t^s.$$
where $B_{t+1}$ is the holdings of home bonds, $B_{st+1}$ is the holdings of foreign bonds, \(\frac{\nu}{2}(B_{t+1})^2\) is the cost of adjusting the holdings of home bonds, and \(\frac{\nu}{2}(B_{st+1})^2\) is the cost of adjusting the holdings of foreign bonds. $T_t^*$ is the rebate to the household, which is equal to $P_{t} \frac{\nu}{2}(B_{t+1})^2 + P_{t} \frac{\nu}{2}(B_{st+1})^2$ at equilibrium.

The first order conditions for the choice of bond holdings, i.e., Euler equations for bond holdings for the representative home household are:

\[
\mu_t(1 + \nu B_{t+1}) = \beta (1 + r_{t+1}) E_t \{ \mu_{t+1} \}
\]

\[
\mu_t(1 + \nu B_{st+1}) = \beta (1 + r_{t+1}) E_t \left\{ \frac{RER_{t+1}}{RER_t} \mu_{t+1} \right\}
\]

where $RER_t$ is the real exchange rate defined using the consumer price index, i.e., $RER_t = \frac{P_{c,t}}{P_{c,t}}$.

For the foreign household,

\[
\mu_t^*(1 + \nu B_{t+1}^*) = \beta (1 + r_{t+1}) E_t \left\{ \frac{RER_t}{RER_{t+1}} \mu_{t+1}^* \right\}
\]

\[
\mu_t^*(1 + \nu B_{st+1}^*) = \beta (1 + r_{t+1}) E_t \{ \mu_{t+1}^* \}.
\]

At equilibrium, home and foreign bonds should be in zero net supply:

\[
B_{t+1} + B_{t+1}^* = 0 \tag{1.47}
\]

\[
B_{st+1} + B_{st+1}^* = 0. \tag{1.48}
\]

At equilibrium, the rebates to households satisfy $T_t = P_{t} \frac{\nu}{2}(B_{t+1})^2 + P_{t} \frac{\nu}{2}(B_{st+1})^2$ and $T_t^* = P_{t} \frac{\nu}{2}(B_{t+1}^*)^2 + P_{t} \frac{\nu}{2}(B_{st+1}^*)^2$. Therefore, the aggregate accounting for the Home and Foreign economy can be written as:

\[
P_t B_{t+1} + P_{t} c B_{st+1} + P_t c C_t + N_{Et} \nu_t
\]

\[
= (1 + r_t) P_t B_t + (1 + r_{t}^*) P_{t} c B_{st} + W_t H_t + N_{pt} \pi_t \tag{1.49}
\]

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and
\[ P^c_t B^*_t + P^c_t B^*_t + P^c_t C^*_t + N^*_e v^*_t \]
\[ = (1 + r_t) P^c_t B^*_t + (1 + r^*_t) P^c_t B^*_t + W^*_t H^*_t + N^* \pi^*_t \] (1.50)

Deducting (1.50) from (1.49) and using the bond market equilibrium, (1.47) and (1.48), I obtain:
\[ P^c_t B_t + P^c_t B_t + \frac{1}{2} (P^c_t C_t - P^c_t C_t) + \frac{1}{2} (N^*_e v_t - N^*_e v_t) \]
\[ = (1 + r_t) P^c_t B_t + (1 + r^*_t) P^c_t B_t + \frac{1}{2} (W_t H_t - W^*_t H^*_t) \]
\[ + \frac{1}{2} (N^*_e \pi_t - N^*_e \pi_t) \]. (1.51)

Labor market clearing conditions of the home and the foreign economy are\(^9\):
\[ H_t = \frac{\theta}{2(\gamma + 1)(\gamma + 2)\lambda_t W_t} N^*_e MC^*_t \pi_t^2 + \frac{\theta}{2(\gamma + 1)(\gamma + 2)\lambda_t W_t} N^*_e \pi_t^2 MC^*_t \pi_t^2 \]
\[ + \frac{N^*_e \pi_t}{Z_t} \] (1.52)

and
\[ H^*_t = \frac{\theta}{2(\gamma + 1)(\gamma + 2)\lambda_t W_t} N^*_e MC^*_t \pi_t^2 + \frac{\theta}{2(\gamma + 1)(\gamma + 2)\lambda_t W_t} N^*_e \pi_t^2 MC^*_t \pi_t^2 \]
\[ + \frac{N^*_e \pi_t}{Z^*_t} \]. (1.53)

\(^9\) Here, \(H_t = N^*_e MC^*_t \pi_t^2 + N^*_e \pi_t^2\). \(H^*_t\) can be derived as:
\[ \Gamma^*_t = \left[ \frac{1}{1 - G(z^*_t)} \int_{z^*_t}^{z^*_t} p_{D_t}(z) q_{D_t}(z) dG(z) - \frac{1}{1 - G(z^*_t)} \int_{z^*_t}^{z^*_t} \pi_{D_t}(z) dG(z) \right] / W_t. \]
\(\Gamma^*_t\) can be derived in a similar way.
Case 3: Complete Market Assumption

Finally, I consider the case with a complete market, where the representative household trades a complete set of state-contingent securities in the international asset market.

The household’s period budget constraint can be written as follows:

\[ P^c_t C_t + \sum_{s_{t+1}} Q_t(s^t, s_{t+1}) B_{t+1}(s^t, s_{t+1}) + N_{E_t} v_t = W_t H_t + B_t(s^t) + N_{pi} \pi_t, \quad (1.54) \]

where \( Q_{t,t+1} \) is the stochastic discount factor to price the state-contingent security, \( B_{t+1} \) and \( v_t \) is the post-entry average value of the firm.

Under this assumption, balanced trade is not necessary in an outcome. The trade balance can be written as:

\[ TB_t = \frac{N_{Xt} \frac{1}{1-G(z_{Xt})} \int_{z_{Xt}}^{\infty} p_{Xt}(z) q_{Xt}(z) \, dG(z) - N_{Xt} \frac{1}{1-G(z_{Xt})} \int_{z_{Xt}}^{\infty} p^*_X(z) q^*_X(z) \, dG(z)}{N_{Dt} \frac{1}{1-G(z_{Dt})} \int_{z_{Dt}}^{\infty} p_{Dt}(z) q_{Dt}(z) \, dG(z) + N_{Xt} \frac{1}{1-G(z_{Xt})} \int_{z_{Xt}}^{\infty} p_X(z) q_X(z) \, dG(z)} \]

\[ = \frac{N_{Xt} \tau^2 M^2 t^2 z_{Xt}^2}{2 \gamma(\theta+2) \lambda_t^2} - \frac{N_{Xt} \tau^2 M^2 t^2 z_{Xt}^2}{2 \gamma(\theta+2) \lambda_t^2} \]

\[ = \frac{N_{Xt} \tau^2 M^2 t^2 z_{Xt}^2}{2 \gamma(\theta+2) \lambda_t^2} + \frac{N_{Xt} \tau^2 M^2 t^2 z_{Xt}^2}{2 \gamma(\theta+2) \lambda_t^2} \]

\[ = \frac{N_{Xt} \tau^2 M^2 t^2 z_{Xt}^2}{2 \gamma(\theta+2) \lambda_t^2} + \frac{N_{Xt} \tau^2 M^2 t^2 z_{Xt}^2}{2 \gamma(\theta+2) \lambda_t^2} \]

\[ = \frac{N_{Xt} \tau^2 M^2 t^2 z_{Xt}^2}{2 \gamma(\theta+2) \lambda_t^2} + \frac{N_{Xt} \tau^2 M^2 t^2 z_{Xt}^2}{2 \gamma(\theta+2) \lambda_t^2} \]

Under the complete asset market assumption, the international risk sharing condition holds as follows:

\[ \frac{U_{C^*} (C^*_t, 1 - H^*_t)}{U_C (C_t, 1 - H_t)} = \frac{P^c_{t^*}}{P^c_t}. \quad (1.56) \]

1.3.8 Shocks

In order to close the model, I specify the shock process of productivity. Following Backus, Kehoe and Kydland (1992), I assume a standard bivariate AR(1) process
for home and foreign productivity:

\[
\begin{bmatrix}
Z_t \\
Z^*_t
\end{bmatrix} = \begin{bmatrix}
\phi_Z & \phi_{ZZ^*} \\
\phi_{Z^*Z} & \phi_{Z^*}
\end{bmatrix} \begin{bmatrix}
Z_{t-1} \\
Z^*_{t-1}
\end{bmatrix} + \begin{bmatrix}
\xi_t \\
\xi^*_t
\end{bmatrix}.
\] (1.57)

1.4 Calibration

I calibrate the parameters as follows. I set the discount factor as \( \beta = 0.99 \) and exogenous probability of firm death is set as \( \delta = 0.025 \), following Ghironi and Melitz [2005]. For the basic set of calibration, I assume parameters that characterize non-homothetic preference as \( \omega = 10 \), \( \gamma = 0.5 \) and \( \eta = 1 \) following Rodriguez-Lopez [2006]. I assume the value of the iceberg cost, \( \tau \), to be 1.734, following Alessandria and Choi [2010]. I assume the fixed entry cost as \( f_E = 0.1 \). I normalize the lower bound of productivity as \( z_{\text{min}} = 0.1 \) without loss of generality.\(^{10}\) The parameter characterizing the shape of Pareto distribution \( G(z) \) is set as \( \theta = 3.4 \) following Ghironi and Melitz [2005]. For the parameters that govern the Cobb-Douglas utility, I first set \( \sigma \) to 2. Then \( \kappa \), which determines the weight of consumption and leisure in the Cobb-Douglas utility, is set so that the steady state value of hours worked becomes \( H = 0.2 \). For the case of an incomplete asset market, I assume the bond adjustment cost parameter to be \( \nu = 0.0001 \), which is a small number commonly assumed in previous literature.

Following Backus et al. [1992], I assume \( \phi_Z = \phi_{Z^*} = 0.906, \phi_{ZZ^*} = \phi_{Z^*Z} = 0.088 \).

1.5 The Roles of the Income Effect and the Markup Effect

In this section, before I summarize the results of the impulse response analysis in the next section, I explain the potential roles of the income effect and the markup effect that drives the dynamics of the terms of trade. In this analysis, I assume there is a 1 percent increase in home aggregate productivity, \( Z \). The increase in \( Z \) has

\(^{10}\) This choice of \( z_{\text{min}} \) makes sure the resulting steady state of \( z_{Dt} \) is higher than \( z_{\text{min}} \).
implications for the terms of trade through two effects, the income effect and the markup effect.

The underlying mechanism is as follows. The terms of trade, $TOT_t$, can be decomposed into two parts as follows:

$$ TOT_t = \frac{p_{Xt}^*}{p_{Xt}} = \left( \frac{\tau_t W_t^*}{Z_t^*} \right) \left( \frac{z_{Xt}}{z_{Xt}^*} \right) $$

where $p_{Xt}^*$ is the average price of an imported good and $p_{Xt}$ is the average price of an exported good of the home economy. These are derived in Section 3.3. For simplicity, I do not assume any exogenous change in $\tau_t$ or $\tau_t^*$ here.

If there is a 1 percent increase in the home aggregate productivity, $Z$, the home income increases. This induces the increase in demand for varieties and thus even less productive foreign firms can enter the market, which decreases the cutoff productivity of foreign firms exporting to the home economy, $z_{Xt}^*$. This induces an increase in the relative cutoff productivity, which is the second factor in (1.58). This effect works to depreciate the terms of trade. I call this effect the "income effect" on the cutoff productivity of foreign exporting firms.

If I assume a positive diffusion of the home aggregate productivity to foreign aggregate productivity as in Section 1.3.8, there is the income effect on the cutoff productivity of domestic exporting firms as well as on that of foreign exporting firms. The increase in the home aggregate productivity induces an increase in $Z^*$ as well. In this case, the income of the foreign economy increases and there is an increase in demand for varieties in the foreign economy, which decreases the cutoff productivity of domestic exporting firms, $z_X$. The relative importance of this effect differs across different asset market assumptions, as I discuss in the following sections in detail.
However, another effect through relative cutoff productivity comes into play. If there is a 1 percent increase in $Z$, the cost of producing is reduced in the home economy and more firms enter in the home market. Then the markups charged by the firms serving the home market decrease and thus only more productive foreign firms can enter the market. Therefore, $z_Xt$ increases. This induces an decrease in the relative cutoff productivity in (1.58) and this effect appreciates the terms of trade. I call this effect as the "markup effect" on the cutoff productivity of foreign exporting firms.

As I discuss in the following sections in detail, the relative importance of these two effects, income effect and markup effect, differ across different asset market structures: financial autarky, incomplete asset market, and complete asset market.

1.6 Impulse Response Analysis: The Important Role of Markup Effect Through Variable Markup

In this section, I explain the implications of financial openness to the relative importance of two effects, income effect and markup effect, which works through the channel of relative cutoff productivity in (1.58).

1.6.1 Under Financial Autarky Assumption

Figure 1.2 displays the results under financial autarky. Under this assumption, there is no risk sharing across countries.

The positive labor productivity shock increases $Z_t$. Then the real business cycle effect emerges, i.e., the marginal product of labor increases and thus the wage, $W_t$, increases. Since under the common assumption of Cobb-Douglas utility function, the labor supply is elastic and thus the effective wage, $W_t/Z_t$, decreases. This channel increases the first factor in (1.58), the relative cost of units of effective labor at period 0. Through this effect, the terms of trade depreciates. However, after the one-period
time-to-build lag, new entrants start producing and this surges the increase of the wage, $W_t$ and the subsequent decrease of the first factor in (1.58) occurs. However, this is not enough to appreciate the terms of trade.

The positive labor productivity shock has the extensive margin effect as well as the common real business cycle effect. It increases the Home income and thus the demand for the varieties increases. Then even less productive foreign firms can enter the market, which decreases $z_{Xt}$. This is called income effect. $z_{Xt}$ initially decreases since the effective wage, which is the production cost for the firms, decreases initially. However, it increases in later periods since the increase of the wage makes it difficult for the relatively less-productive firms to enter the market. Therefore, the second factor in (1.58), the relative cutoff productivity, shows a hump-shaped increase over the periods after the shock and this depreciates the terms of trade through the second factor in (1.58).

1.6.2 Under Incomplete Asset Market Assumption

Next I analyze the case of the incomplete asset market. In this case the state non-contingent bonds are traded across countries. Therefore, the international risk sharing across countries occurs to some extent, however, it is not as perfect as the complete asset market case.

Figure 1.3 shows the impulse responses. In this case, the positive labor productivity shock induces an increase in the demand for variety, but less so compared to the case of financial autarky since the household has the demand for buying bonds under this asset market assumption. Therefore, the income effect is mitigated compared to the case of financial autarky.

In this case, the markup effect comes into play. In response to a positive labor productivity shock, Home firms can produce more goods at lower cost and more Home firms enter the home market. Therefore, the number of home firms serving
the home market, $N_{Dt}$, increases. This means that the home market becomes more competitive and the average markup charged, $\bar{\mu}_{Dt}$, decreases. Foreign firms exporting to the home market face this higher competition and thus they need to decrease their markup as well. Therefore, $\bar{\mu}_{Xt}$, also decreases. However, this generates a decrease in the expected profit. The average profit of the foreign firms exporting to the home market, $\pi_{Xt}$, decreases. This means that Foreign firms which have relatively higher firm-specific productivity can enter the Home market, i.e., $z_{Xt}$ increases. $z_{Xt}$, the cutoff productivity of Home firms exporting to Foreign economy, decreases more than the case of financial autarky since the Foreign demand for the varieties of goods more than the case of financial autarky because of the wealth transfer to the Foreign economy. Thus, the relative cutoff productivity, $\frac{z_{Xt}}{z_{Xt}}$, decreases in this case and thus the terms of trade still appreciates. Thus, it is shown that the markup effect through variable markup is important in this case.

1.6.3 Under the Complete Asset Market Assumption

Finally, I analyze the case of the complete asset market assumption. Figure 1.4 displays the results. Under this assumption, the household trades state-contingent claims and the international risk sharing across countries is complete.

In this case, the income effect on $z_{Xt}$ is mitigated much more compared to the case of an incomplete asset market and thus the terms of trade appreciates more than in the case of an incomplete asset market. The mechanism that induces the appreciation is the same as in the case of an incomplete asset market.

The striking feature in this result is that the terms of trade appreciates even under the assumption of a complete asset market. It is known that under a complete asset market it is difficult to generate appreciation of the terms of trade. For instance, Enders and Müller [2009] used a conventional two country real business cycle model without heterogeneity in firm productivity and showed that the appreciation of the
terms of trade is hard to reconcile without the assumption of an incomplete asset market. However, in my model, using the markup effect explained above, it is possible to explain the appreciation of terms of trade even without an incomplete asset market. This resolution does not resort to strong assumptions regarding the labor market, home bias, elasticity of substitution between goods, and the persistence of productivity that previous studies have imposed.

1.7 Comparing the Data and the Model Response of the Terms of Trade

In this section, I compare the average impulse response of the terms of trade from the VAR estimation performed in Section 1.2 and that from theoretical model. By feeding the empirical response of US labor productivity obtained in the VAR analysis into the theoretical model under the assumption of complete market, I calculate the response from the model. Then I calculate the average impulse responses over 4, 8, 12, 16 periods and compare with the responses from the data. In this exercise, I use the assumption of incomplete asset market.

Before comparing the theoretical and empirical impulse responses, I estimate \( \theta, \eta, \gamma, \omega \) by matching the model-based impulse responses with the empirical impulse responses. First, I collect the empirical impulse responses to the vector in \( IR^{data} \) and choose \( \Phi \) to be a diagonal matrix with the variance of impulse responses along its diagonal. The parameters are estimated using the following minimization problem:

\[
\min_{\Theta} \left( IR(\Theta) - IR^{data} \right)' \Phi^{-1} \left( IR(\Theta) - IR^{data} \right)
\]

11 In the analysis in this section, I do not assume productivity diffusion to the Foreign economy which was assumed in (1.3.8) since the empirical response of the rest-of-the-world labor productivity is difficult to estimate because of the availability of the data.

12 When I conduct the estimation, I set following minimum boundaries for the parameters to facilitate the estimation. Minimum boundaries for \( \Theta = \{ \theta, \eta, \gamma, \omega \} \) are \( \{1, 0.00001, 0.00001, 1\} \).
where $\Theta = \{\theta, \eta, \gamma, \omega\}$. $IR(\Theta)$ denotes a vector that consists of model-based impulse responses. I match impulse responses of the terms of trade and relative consumption for 10 quarters. Estimated parameters are listed in Table 1.8.

The main challenge in the previous literature has been to explain the appreciation of the terms of trade in response to a positive productivity shock. Backus et al. [1994] fails to tackle this challenge, i.e., the terms of trade depreciates in their standard real business cycle model. This is because the relative price of goods produced domestically decreases since there is an increase in supply of goods. However, the model presented in Section 1.3 is able to account for the appreciation of the terms of trade as shown in Table 1.8.

1.8 Conclusion

In this paper, I revisited the problem of the anomaly of terms of trade dynamics. Using non-homothetic preference a lá Melitz and Ottaviano [2008], I explained the dynamics of terms of trade in response to a positive aggregate productivity shock. Using a model with endogenous markup and heterogeneous firm-specific productivities, the appreciation in the terms of trade can be generated even under the complete asset market assumption.

Unlike previous studies, I explained the dynamics of the terms of trade through a new channel, which is the channel of relative cutoff firm-specific productivity that determines the optimal export decisions of firms. This resolution does not resort to any strong assumptions regarding the labor market, home bias, elasticity of substitution between goods and the persistence of productivity that previous studies have imposed on their models. Depending on the asset market structure, two competing effects, i.e., the income effect and the markup effect, have different implications for the terms of trade dynamics.

Under the assumption of financial autarky, the income effect is bigger than the
markup effect and the terms of trade depreciates in response to a positive aggregate productivity shock. However, if we allow for the trade of state-contingent or non-state contingent bonds, the markup effect also comes into play and the terms of trade appreciates, which is in line with the empirical findings.

This paper opens up a new research avenue for understanding the relationship between the asset market integration and the terms of trade. The theoretical analyses conducted in this paper suggest that the terms of trade movement varies across different stages of asset market integration. Another possible future work will involve understanding international co-movements of macroeconomic variables. The model I use in this paper is rich enough to understand the moments of consumption and production. In addition, analyzing optimal monetary policy using this type of model will be a promising avenue for future research.
Figure 1.1: Effects of a Positive US Technology Shock

Table 1.1: Estimated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimated value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$</td>
<td>20.05</td>
<td>Shape parameter of Pareto distribution</td>
</tr>
<tr>
<td>$\eta$</td>
<td>3.92e-005</td>
<td>Index of the pattern of substitution between varieties</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.45</td>
<td>Degree of product differentiation</td>
</tr>
<tr>
<td>$\omega$</td>
<td>1.00</td>
<td>Intensity of the preference for differentiated products</td>
</tr>
</tbody>
</table>
Table 1.2: Average Responses of the Terms of Trade (TOT) in the Data and the Model

<table>
<thead>
<tr>
<th>Periods</th>
<th>TOT response from data VAR</th>
<th>TOT response from the model</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>-0.77</td>
<td>-0.41</td>
</tr>
<tr>
<td>8</td>
<td>-0.63</td>
<td>-0.34</td>
</tr>
<tr>
<td>12</td>
<td>-0.38</td>
<td>-0.30</td>
</tr>
<tr>
<td>16</td>
<td>-0.19</td>
<td>-0.26</td>
</tr>
</tbody>
</table>

Figure 1.2: Effect of Home Positive Aggregate Productivity Shock (1 Percent Increase) in a Model with Financial Autarky
Figure 1.3: Effect of Home Positive Aggregate Productivity Shock (1 Percent Increase) in a Model with Incomplete Asset Market

Notes: Blue lines: under financial autarky, red lines: under an incomplete asset market.
Figure 1.4: Effect of Home Positive Aggregate Productivity Shock (1 Percent Increase) in a Model with Complete Market

Notes: Red lines: under an incomplete asset market, black lines: under a complete market.
News-Driven International Business Cycles

2.1 Introduction

This paper studies the international transmission effects of the news about the Total Factor Productivity (TFP) of the US to the Canadian and Japanese economy. Recent studies, e.g., Beaudry and Portier [2006], Beaudry et al. [2009, 2011], Christiano et al. [2008], Jaimovich and Rebelo [2008, 2009], Schmitt-Grohe and Uribe [2008], and Barsky and Sims [2010] suggest that business cycles can be explained using the news about future productivity. 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 et al. [2009] provide evidence that 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 and Japanese macroeconomic variables to the news shock of TFP in the US. This estimation method is based on Beaudry and Portier [2006] and Beaudry et al. [2009]. Beaudry and Portier [2006] estimates the impulse responses of US macroeconomic variables to the news shock of TFP in the US. Whereas Beaudry et al. [2009] 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 they do. I find that Canadian and Japanese TFP significantly responds to US news shock. Next, I develop and estimate a two-country RBC model with a preference of the type suggested by Jaimovich and Rebelo [2008, 2009] and an investment adjustment cost to generate booms in Canadian and Japanese 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 can be generated by the news about future TFP in the US. Using a counterfactual analysis, I show that the response of Canadian and Japanese TFP to a US news shock is important in order to generate the boom observed in the empirical analysis. The 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 an open economy setting.

It is widely known that the standard real business cycle model does not account for comovements in either a closed or an open economy. A positive news shock increases consumption because of the wealth effect. The wealth effect increases leisure and labor hours decrease. The decrease in 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 et al. [2009, 2011] 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 [2008, 2009] emphasized the importance of the preference structure. Since the 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 the adjustment costs of investment and labor are important.

This paper contributes to the 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 the 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 and Japanese 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 the 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 has not been considered by the previous literature on the transmission of news.

The organizations of this paper is as follows. In Section 2.2, I present empirical evidence using the VECM model to estimate the responses of Canadian and Japanese variables to the US news shock. Section 2.3 presents the model. Section 2.4 shows
the results of quantitative analysis in which I compare the empirical and theoretical impulse responses. Section 2.5 concludes.

2.2 Empirical Evidence

The goal of this section is to provide the empirical evidence of international spillover of the news about the US TFP to the macroeconomic variables of Canada and Japan. The identification and estimation methods follow and extend Beaudry and Portier [2006] and Beaudry et al. [2009].

2.2.1 Data

US Data

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

The US TFP series is defined as

\[
\log TFP_t = \left[ \log Y_t - s_h \log H_t - (1 - s_h) \log K_t \right] / s_h
\]  

(2.1)

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). The output measure for calculating TFP (\( Y \)) is the quarterly real GDP of the non-farm business sector. The capital series (\( K \)) is the real capital input in the private business sector. Since the original series of the real capital input is available only at an annual frequency, I interpolate to obtain a quarterly series. The measure of hours worked (\( H \)) is the hours index in the 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 B for more details.

**Canadian Data**

I construct the Canadian TFP series in the same way as (2.1)\(^1\). All the Canadian data except hours worked and capital series are over the period 1961Q1 to 2006Q4. Hours worked is over the period 1966Q1 to 2006Q4 and the capital series is over the period 1961Q4 to 2006Q4. The output measure is real GDP and the capital measure is the real capital series constructed by the Bank of Canada. I calculate the measure of hours worked using data from the Bank of Canada\(^2\).

In higher dimension systems, I also use consumption, investment, exports, imports, the trade balance and terms of trade. For the consumption measure, I use real 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 the import price deflator divided by the export price deflator. For the trade balance, in order to incorporate the effect of the terms of trade, I first multiply the series of real imports by the terms of trade, subtract this series from real exports, and then divide by real GDP. This definition is consistent with that of the model I describe in Section 2.3.

**Japanese Data**

I construct the Japanese TFP series in the same way as (2.1). All the Japanese data except the hours worked series are collected over the period 1955Q2 to 2006Q4. Hours worked is over the period 1960Q1 to 2006Q4. The output measure is real

---

\(^1\) Rhys Mendes (Bank of Canada) kindly gave me the dataset for the Canadian economy.

\(^2\) 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 the 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.
GDP and the capital measure is the gross capital stock of private enterprises. Hours worked series is the aggregate weekly hours worked.

As in the Canadian case, I also use consumption, investment, exports, imports, the trade balance and terms of trade in higher dimension systems. For the consumption measure, I use real private consumption. For the investment measure, I use real non-residential investment. Exports, imports, terms of trade and the trade balance measure are defined in the same way as in the Canadian case.

2.2.2 Identification of the News Shock: Evidence from the Bivariate VECM of TFP and SP

In this subsection, I identify the news shock that 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. An 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 the 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 the likelihood ratio test.

I estimate the following VECM model using Johansen’s maximum likelihood pro-

---

3 See Appendix for the explanation of data in detail.

4 See page 143 of Lütkepohl [2005] for detail.
Following Beaudry and Portier [2006], I identify the news shock by the sequential scheme. We can write the above VECM model using the following Wold representation:

\[
\begin{bmatrix}
\Delta TFP_{t}^{US} \\
\Delta SP_{t}
\end{bmatrix} = \begin{bmatrix}
\gamma_1 \\
\gamma_2
\end{bmatrix} + \begin{bmatrix}
\zeta_1^0 & \zeta_2^0 \\
\zeta_1^2 & \zeta_2^2
\end{bmatrix} \begin{bmatrix}
\Delta TFP_{t-1}^{US} \\
\Delta SP_{t-1}
\end{bmatrix}
\]

\[
+ \begin{bmatrix}
\zeta_{11}^1 & \zeta_{12}^1 \\
\zeta_{21}^1 & \zeta_{22}^1
\end{bmatrix} \begin{bmatrix}
\Delta TFP_{l-1}^{US} \\
\Delta SP_{l-1}
\end{bmatrix}
\]

\[
+ \cdots \cdots
\]

\[
+ \begin{bmatrix}
\zeta_{11}^k & \zeta_{12}^k \\
\zeta_{21}^k & \zeta_{22}^k
\end{bmatrix} \begin{bmatrix}
\Delta TFP_{l-k}^{US} \\
\Delta SP_{l-k}
\end{bmatrix} + \begin{bmatrix}
u_{1t} \\
u_{2t}
\end{bmatrix}
\]

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. First, the short-run identification scheme has a Wold (MA) representation as:

\[
\begin{bmatrix}
\Delta TFP_{t}^{US} \\
\Delta SP_{t}
\end{bmatrix} = \begin{bmatrix}
u_{1t} \\
u_{2t}
\end{bmatrix}
\]

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. First, the short-run identification scheme has a Wold (MA) representation as:

\[
\begin{bmatrix}
\Delta TFP_{t}^{US} \\
\Delta SP_{t}
\end{bmatrix} = \Gamma(L) \begin{bmatrix}
\epsilon_{1t} \\
\epsilon_{2t}
\end{bmatrix}
\]

where \(\Gamma(L) = \sum_{i=0}^{\infty} \Gamma_i L^i\) and \(\epsilon_t = [\epsilon_{1t} \epsilon_{2t}]^\prime\) 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 a shock on \(SP\), \(\epsilon_{2t}\), does not have any short-run impact on \(TFP\).

\[\text{See Hansen [2000] for the explanation of the derivation of the Wold representation in the case of the VECM model.}\]
Second, the long-run identification scheme has a Wold representation as follows:

\[
\begin{pmatrix}
\Delta TFP^{US}_t \\
\Delta SP_t
\end{pmatrix} = \tilde{\Gamma}(L) \begin{pmatrix}
\tilde{\epsilon}_{1t} \\
\tilde{\epsilon}_{2t}
\end{pmatrix}
\]  

(2.4)

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., the 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 2.1. The top graph presents the impulse response of \( TFP \) corresponding to the \( \epsilon_{2t} \) shock (from short-run identification) and the \( \tilde{\epsilon}_1 \) shock (from long-run identification). As can be seen from this figure, the responses from these two identification schemes have highly similar dynamics. On the one hand, the shock on \( SP \), \( \epsilon_2 \), which does not have a contemporaneous impact on \( TFP \), has a 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 2.1 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 plots of \( \epsilon_2 \) and \( \tilde{\epsilon}_1 \) are shown in Figure 2.2. 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.

This 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 in-
formation 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].

2.2.3 Empirical Evidence of International Spillover of the News About the US TFP to the Canadian and Japanese TFP

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

The data on the Canadian TFP is constructed only from 1966Q1 since the data of hours worked is available only from that quarter. Figure 2.3 plots the TFP processes in log for the US and Canada. The likelihood ratio test on cointegration does not reject the hypothesis of cointegration. The series of Japanese TFP is from 1960Q1. Figure 2.4 plots the TFP processes in log for the US and Japan. Again, the result of the likelihood ratio test on cointegration does not reject the hypothesis of cointegration. Therefore we assume that the processes are cointegrated and use the VECM
model for the estimation. I set up a three-variable VECM equation as follows.

\[
\begin{bmatrix}
\Delta TFP^US_t \\
\Delta SP_t \\
\Delta TFP^i_t
\end{bmatrix} =
\begin{bmatrix}
\tilde{\gamma}_1 \\
\tilde{\gamma}_2 \\
\tilde{\gamma}_3
\end{bmatrix} +
\begin{bmatrix}
\tilde{\gamma}^{(0)}_1 \\
\tilde{\gamma}^{(0)}_2 \\
\tilde{\gamma}^{(0)}_3
\end{bmatrix}
\begin{bmatrix}
\zeta_{11} & \zeta_{12} & 0 \\
\zeta_{21} & \zeta_{22} & 0 \\
\zeta_{31} & \zeta_{32} & \zeta_{33}
\end{bmatrix}
\begin{bmatrix}
TFP^US_{t-1} \\
SP_{t-1} \\
TFP^i_{t-1}
\end{bmatrix}
\]

\[
+ \begin{bmatrix}
\tilde{\gamma}^{(1)}_1 \\
\tilde{\gamma}^{(1)}_2 \\
\tilde{\gamma}^{(1)}_3
\end{bmatrix}
\begin{bmatrix}
\zeta_{11} & \zeta_{12} & 0 \\
\zeta_{21} & \zeta_{22} & 0 \\
\zeta_{31} & \zeta_{32} & \zeta_{33}
\end{bmatrix}
\begin{bmatrix}
\Delta TFP^US_{t-1} \\
\Delta SP_{t-1} \\
\Delta TFP^i_{t-1}
\end{bmatrix}
\]

\[
+ \ldots
\]

\[
+ \begin{bmatrix}
\tilde{\gamma}^{(k)}_1 \\
\tilde{\gamma}^{(k)}_2 \\
\tilde{\gamma}^{(k)}_3
\end{bmatrix}
\begin{bmatrix}
\zeta_{11} & \zeta_{12} & 0 \\
\zeta_{21} & \zeta_{22} & 0 \\
\zeta_{31} & \zeta_{32} & \zeta_{33}
\end{bmatrix}
\begin{bmatrix}
\Delta TFP^US_{t-k} \\
\Delta SP_{t-k} \\
\Delta TFP^i_{t-k}
\end{bmatrix}
\]

\[
+ \begin{bmatrix}
u_{1t} \\
u_{2t} \\
u_{3t}
\end{bmatrix},
\]

(2.5)

where \( TFP^US \) is the US TFP series, \( SP \) is the stock price in the US and \( TFP^i \) is the Canadian or Japanese TFP series.

Since the available samples for the Canadian TFP and Japanese TFP are much shorter than that of the US TFP, I use following procedure to estimate the response of the Canadian or Japanese TFP to the US news shock so that I can utilize more information on the news of the US TFP. First, I impose the upper 2 by 2 matrices in the coefficient matrices in (2.5) to be equal to the coefficients obtained from the bivariate VECM with the US TFP and stock price in (2.2).

Next, I regress \( \Delta TFP^i_t \) on all other variables as follows and load the obtained coefficients in (2.5). Here I assume the cointegrating relationship between the US TFP and Canadian or Japanese TFP to be \( [1, -1] \). Therefore, we estimate the
following equation using OLS:

\[
\Delta TFP_t^i = \gamma_3 + \left[ \tilde{\zeta}_0 \ \tilde{\zeta}_2 \ \tilde{\zeta}_3 \right] \begin{bmatrix} TFP_{US, t-1}^i \\ SP_{t-1}^i \\ TFP_{t-1}^i \end{bmatrix} + \left[ \tilde{\zeta}_1 \ \tilde{\zeta}_2 \ \tilde{\zeta}_3 \right] \begin{bmatrix} \Delta TFP_{US, t-1}^i \\ \Delta SP_{t-1}^i \\ \Delta TFP_{t-1}^i \end{bmatrix} + \ldots + \left[ \tilde{\zeta}_0 \ \tilde{\zeta}_2 \ \tilde{\zeta}_3 \right] \begin{bmatrix} \Delta TFP_{t-k}^i \\ \Delta SP_{t-k}^i \\ \Delta TFP_{t-k}^i \end{bmatrix} + u_{3t} \tag{2.6}
\]

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

Figure 2.5 shows the first 40-period responses of US and Canadian TFP to the news about future TFP in the US. Figure 2.7 shows only the response of the Canadian TFP to news with a 90% confidence band constructed using a bootstrap of 1000 replications. The immediate response of the US TFP to news is bigger compared to that of the Canadian TFP. The Canadian TFP is responding slowly at the beginning and converge slowly to the same level as the US TFP over time.

Figure 2.6 shows the responses of the US and Japanese TFP to the news about the future TFP in the US. Figure 2.8 shows only the response of the Japanese TFP. The immediate response of the Japanese TFP to the news is nearly zero, however, it has a persistent and significant increase over time. This converges slowly to the same level as the US TFP.

2.2.4 Empirical Evidence on the International Transmission of US News Shock

In order to obtain further insight, I also study the international transmission effects of the news shock. The variables of interest are consumption, investment, hours, and
output as well as the trade variables (export, import, trade balance and the terms of trade) of Canada and Japan.

*Estimated Responses of Canadian and Japanese Macroeconomic Variables to a US News Shock*

I estimate a higher dimensional system using US productivity ($TFP_{US}$), US stock prices ($SP$) and other macroeconomic variables of interest. I first estimate an 8-variable system with $TFP_{US}$, $SP$, Canadian or Japanese output, consumption, investment, hours worked, terms of trade and the trade balance. I also estimate the responses of exports and imports. When I estimate the responses of exports and imports, I replace the trade balance and the terms of trade with these variables. The results are robust in various other specifications of the system\(^\text{6}\).

Figure 2.9 shows the point estimates of the responses of Canadian 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 exhibits a persistent rise, but initially it has a different dynamic. It has a boom until period 4 and becomes flatter after that. Investment also has a pattern of persistent rise. The investment boom lasts until period 4 after the shock and it exhibits a flatter pattern after period 4.

Figure 2.10 shows the responses of Canadian exports, imports, terms of trade and the 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 the terms of trade, which is defined

\(^{6}\text{I also estimate other specifications of the system for use in an impulse response matching estimation in Section 2.4.3. I choose 5 lags for Canada and 3 lags for Japan using the likelihood ratio test.}\)
as the import price divided by the export price, has a pattern of persistent decline, although it is not significant. The trade balance has a slightly hump-shaped pattern. It initially has a big boom and becomes persistent later.

Figure 2.11 shows the responses of the Japanese output, consumption, investment and hours worked. The shapes of the responses of the Japanese variables have important differences compared to the Canadian responses. Output, consumption and investment do not have immediate booms after the shock occurs. The impact effect is nearly zero, however, their responses rise persistently later on. Hours worked exhibits an initial boom. It peaks at period 3 and persistently declines after that.

Figure 2.12 shows the responses of Japanese exports, imports, terms of trade and the trade balance. Exports and imports do not have an immediate response, however, exhibits a persistent rise. The terms of trade declines persistently. The initial response of the terms of trade is significantly negative. The response of the trade balance is not significant, however, the point estimate has a slightly positive response to the news.

Estimated responses of US Macroeconomic Variables to US News Shock

Although the main focus of this paper is the response of Canadian variables, I also estimated the responses of US variables to a US news shock. I estimate a 6-variable system with $TFP$, $SP$, output, consumption, investment and hours worked. Figure 2.13 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.
2.3 The Model

This section describes the model economy. The model is a two-country model based on Backus et al. [1994] augmented with a different country size, the preference of the type suggested by Jaimovich and Rebelo [2008, 2009], and investment adjustment cost. Two countries are indexed by \( i = \{1, 2\} \). All the variables are in per capita terms unless otherwise noted. Each country is the economy which consists of a representative household, an intermediate good sector and a final good sector. The household has preference over consumption and leisure. The intermediate goods sector produces goods using capital and labor. The final goods sector produces final goods using intermediate goods. The shocks to the economy are the productivity shocks of Country 1 (Canada or Japan) and Country 2 (the US) driven by news about future productivity in the US, which are identified in the previous section.

2.3.1 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 the consumption of country \( i \) and \( N_{it} \) is the hours worked in country \( i \). For the function \( U(C_{it}, 1 - N_{it}, S_{it}) \), following Jaimovich and Rebelo [2008, 2009], I assume the preference as:

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

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 the GHH
preference, which was named after Greenwood et al. [1988]. On the other hand, when \( \kappa = 1 \), this preference becomes the KPR preference, which was named after King et al. [1988]. With \( \kappa = 0 \) (GHH preference), there is no wealth effect on hours worked. However, with \( \kappa = 1 \) (KPR preference), a wealth effect on hours worked emerges.

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

\[
C_{1t} + X_{1t} + q_{1t}^{a}E_{t}Q_{t,t+1}B_{1t+1} = q_{1t}^{a}(W_{1t}N_{1t} + r_{1t}^{b}K_{1t}) + q_{1t}^{a}B_{1t},
\]

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:

\[
C_{2t} + X_{2t} + q_{2t}^{b}E_{t}Q_{t,t+1}B_{2t+1} = q_{2t}^{b}(W_{2t}N_{2t} + r_{2t}^{b}K_{2t}) + q_{2t}^{b}B_{2t}.
\]

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

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

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 the adjustment cost for investment. By introducing this, we can rule out an overshooting of the investment possibly caused by the shocks.

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

\[
U_{c} (C_{1t}, 1 - N_{1t}, S_{1t}) - \eta_{1t}\kappa C_{1t}^{\kappa - 1} S_{1t-1}^{1-\kappa} = \lambda_{1t},
\]

\( \kappa = 0 \) 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.
The optimal conditions for the households in Country 2 can be written in a similar fashion.

2.3.2 Intermediate Goods Sector

The 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:

$$Y_{it} = Z_{it}^{1-\theta} K_{it}^\theta N_{it}^{1-\theta},$$

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

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

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

\[ U_n(C_{1t}, 1 - N_{1t}, S_{1t}) + \lambda_{1t} q_{1t}^a W_{1t} = 0, \quad (2.11) \]

\[ \beta E_t \lambda_{1t+1} q_{1t+1}^a = \lambda_{1t} E_t Q_{t+1} q_{1t}^a, \quad (2.12) \]

\[ \beta E_t \lambda_{1t+1} q_{1t+1}^a + \beta \mu_{1t+1} (1 - \delta) - \mu_{1t} = 0, \quad (2.13) \]

\begin{align*}
&-\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 \quad (2.14) \end{align*}

\[ U_s(C_{1t}, 1 - N_{1t}, S_{1t}) + \eta_{1t} - \beta E_t [\eta_{1t+1} C_{1t+1}^{\nu_1} (1 - \kappa) S_{1t}^{-\nu_2}] = 0 \quad (2.15) \]
The optimal conditions for the intermediate sector are:

\[ r_{it} = \theta Z_{it}^{1-\theta} \left( \frac{K_{it}}{N_{it}} \right)^{\theta-1}, \]  

(2.17)

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

\[ w_{it} = (1 - \theta) Z_{it}^{1-\theta} \left( \frac{K_{it}}{N_{it}} \right)^{\theta}, \]  

(2.18)

where \( w_{it} \) is the real wage in Country \( i \). Capital and labor are assumed to be immobile.

### 2.3.3 Final Goods Sector

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

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

(2.19)

and

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

(2.20)

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

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

\[
\max_{a_{it}, b_{it}} F_i - q_i^a a_{it} - q_i^b b_{it} 
\]

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

The optimal conditions for the final goods sector are:

\[ a_{1t} = (q_{1t}^a)^{-\sigma} \omega_1 F_{1t} \]  

(2.21)
\begin{equation}
b_{1t} = (q_{1t}^b)^{-\sigma} (1 - \omega_1) F_{1t}
\end{equation}

\begin{equation}
a_{2t} = (q_{2t}^a)^{-\sigma} (1 - \omega_2) F_{2t}
\end{equation}

\begin{equation}
b_{2t} = (q_{2t}^b)^{-\sigma} \omega_2 F_{2t}
\end{equation}

2.3.4 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 the following international risk sharing condition under the complete market assumption:

\begin{equation}
\frac{U_c(C_{2t}, 1 - N_{2t}, S_{2t})}{U_c(C_{1t}, 1 - N_{1t}, S_{1t})} = RER_t.
\end{equation}

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

2.3.5 Market Clearing Conditions

Market clearing for the intermediate goods sector is:

\begin{equation}
\Pi_1 Y_{1t} = \Pi_1 a_{1t} + \Pi_2 a_{2t},
\end{equation}

and

\begin{equation}
\Pi_2 Y_{2t} = \Pi_1 b_{1t} + \Pi_2 b_{2t}.
\end{equation}

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

For the final goods market,

\begin{equation}
F_{1t} = C_{1t} + X_{1t}
\end{equation}

and

\begin{equation}
F_{2t} = C_{2t} + X_{2t}
\end{equation}
2.3.6 Other Variables of Interest

The terms of trade for Country 1 is defined as the relative price of imported goods and exported goods:

\[ TOT_t = \frac{q_{1t}^b}{q_{1t}^a}. \] (2.30)

The trade balance of Country 1 over the GDP of Country 1 is defined as

\[ TB_{1t} = \frac{\Pi_2 a_{2t} - \Pi_1 \left( \frac{q_{1t}^b}{q_{1t}^a} \right) b_{1t}}{\Pi_1 Y_{1t}}. \] (2.31)

2.3.7 The Choice of the Processes of TFP

In this model, I take the TFP processes of Country 1 (Canada or Japan) 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 (2.2) and (2.5) in the VECM estimation discussed in Section 2.2.

My approach here is motivated by two facts about actual TFP processes. First, what the empirical analysis in Section 2.2 shows is that the TFP processes are driven by the 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 that 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 result makes sense in light of the slow adoption of technological innovation. Second, according to the estimation results in Section 2.2.3, there is a significant international spillover effect of the news. In the previous theoretical literature such as Beaudry et al. [2009, 2011], foreign TFP is not positively affected by the domestic TFP process driven by the news. However, in my paper, since there is strong
empirical evidence of this, I feed the estimated TFP processes of Canada or Japan into the model as well. In Section 2.4.4, using a counterfactual experiment, I show the importance of feeding the TFP processes of Canada or Japan 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.

### 2.3.8 Competitive Equilibrium

The competitive equilibrium in this model consists of sequences of allocations for $i = 1, 2, \{C_{it}, S_{it}, X_{it}, K_{it+1}, B_{it+1}, Y_{it}, F_{it}, a_{it}, b_{it}\}_{t=0}^{\infty}$ and prices $\{w_{it}, r_{it}, q_{it}^a, q_{it}^b\}_{t=0}^{\infty}$ 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 the households’ problem.
- $\{Y_{it}, F_{it}, a_{it}, b_{it}\}_{t=0}^{\infty}$ solves the firms’ problem.
- Market clearing conditions and the resource constraint are satisfied.

### 2.4 Quantitative Analysis

#### 2.4.1 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, $b_{\text{Can}}$, for Canada is set to 0.32, the degree of openness, $1 - \omega_1$, is also calibrated to be 0.32. Since I assume that the Canadian population at the steady state is 1/10 that of the US, the steady state imported goods share for the US, $1 - \omega_2$, is calibrated to 0.032. The imported goods share for Japan, $b_{j}$, is set to 0.1.\(^9\) This means $1 - \omega_1$ is

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\(^8\) This value is taken from Raffo [2006].

\(^9\) This value is calculated using the data on share of real import in real GDP.
also 0.1 in the case of the two-country model of the US and Japan. I assume that
the Japanese population at steady state is half of that of the US, $1 - \omega_2$ is calibrated
to 0.05 in the case of the two-country model of the US and Japan.

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.

For $\kappa$, $\phi$ and $\sigma$, I take two different approaches. In the first approach, I assume
hypothetical values for these parameters. For the GHH-type preference, I set $\kappa$ equal
to 0.001, which is very small. Under this parameter, the wealth effect on the labor
supply is very small or negligible. For the KPR-type preference, I assume $\kappa = 1$.
Under this type of preference, there is a substantial wealth effect on labor supply.
For $\phi$, the investment adjustment cost parameter, I use either $\phi = 0$ (no adjustment
cost) , $\phi = 5$ (with adjustment cost) or $\phi = 500$ (with adjustment cost in Japan)$^{10}$
. The latter value is the estimated value in Schmitt-Grohe 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 the standard assumption) or $\sigma = 0.3$ (for low elasticity of substitution). The former value is used
in Backus et al. [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 an impulse response matching estimation, which I explain in a later section.

$^{10}$ For the two-country model of the US and Japan, it is hard to generate positive investment response with $\phi = 5$. 
2.4.2 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, $\kappa$, the investment adjustment cost parameter, $\phi$ and the elasticity of substitution between domestically and foreign produced intermediate goods, $\sigma$, in order to obtain intuitions. Figures 2.14 and 2.15 display these model-based impulse responses for Canadian variables assuming different sets of parameter values along with empirical responses which I described in an earlier section. Figure 2.16 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.

A line with diamonds denotes the response of the variable in the case of a standard KPR preference ($\kappa = 1$), no investment adjustment cost ($\phi = 0$) and the elasticity of substitution between domestically and foreign produced goods under the 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 the US TFP, the price of intermediate goods produced in the US declines, which means an appreciation of the terms of trade.

A line with crosses denote the response of the variable in the case of the standard KPR preference ($\kappa = 1$), investment adjustment cost ($\phi = 5$) and the elasticity of substitution between domestically and foreign produced goods under the 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 a 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 the 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 the Canadian intermediate goods firm is producing more goods. The response of US imports becomes correspondingly positive. Canadian imports of intermediate goods has a larger positive response 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 the Canadian trade balance is positive.

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

Figures 2.17 and 2.18 display the results of the Japanese variables. Similar to the case of Canada, in the case of the standard KPR preference ($\kappa = 1$), no investment adjustment cost ($\phi = 0$) and the elasticity of substitution between domestically and foreign produced goods under the standard assumption ($\sigma = 1.5$), as expressed in the line with diamonds, the immediate responses of investment, hours, and thus output are negative, while the response of consumption is positive because of the wealth effect.

Then I further assume a GHH preference (line with squares). Then hours worked
exhibits a positive response and thus generates a positive response of output. However, the response of the trade balance is still far from the point estimate obtained in the empirical analysis. Assuming low elasticity of substitution between domestically and foreign produced goods (line with circles), the response of exports becomes close to the point estimate and the response of the trade balance becomes positive. However, it comes with the cost of worsening the match of terms of trade.

2.4.3 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 the following minimization problem:

$$\min_{\Theta} (IR(\Theta) - IR_{data})' W^{-1} (IR(\Theta) - IR_{data}).$$

(2.32)

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 lag responses of Canadian output, consumption, investment hours worked, terms of trade and the 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. For Japan, the estimated values are $\kappa = 0.01$ (std.error 0.001), $\phi = 3045.6$ (std.error 7347.7), $\sigma = 0.68$ (std.error 0.006) and $\nu = 2.08$ (std.error 0.106). The results are presented in Figures 2.19, 2.20 and 2.23. A line with stars denotes 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 the
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 eliminating 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 the standard assumption (\( \sigma = 1.5 \)). Lower
elasticity means there is a complementarity between domestically and foreign pro-
duced intermediate goods. As can be seen in the previous subsection, this also helps
to explain the domestic boom.

For Japan, the results are presented in Figures 2.21 and 2.22. In the Japanese
case, the model does not match the empirical response of investment. Therefore,
the estimated parameter of investment adjustment cost becomes arbitrarily large.
However, the responses of output, consumption and hours worked are qualitatively
the same as the empirical response. The model replicates the appreciation of the
terms of trade.

2.4.4 A Counterfactual Experiment Where the Canadian or Japanese TFP Does
Not Respond to a US News Shock

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

The results are presented in Figures 2.19, 2.20, 2.21 and 2.22. A dashed line
denotes 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, then the responses of
output, consumption, investment and hours are much lower than the point estimates. The Japanese TFP process is also important to explain the response of output and consumption. Therefore, the response of the Canadian or Japanese TFP to a US news shock is important to match the empirical responses.

2.5 Conclusion

In this paper, I study the international transmission effects of news about US Total Factor Productivity (TFP) using the Canadian and Japanese data. Using the Vector Error Correction Model (VECM), I estimate the impulse responses of the macroeconomic variables of Canada and Japan to the news shock of a US TFP. I find that the Canadian TFP responds to the US news positively and significantly. Japanese TFP exhibits a significant and persistent rise after the shock. 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 transmission effects can be generated by the news about future TFP in the US. In order to generate the comovements to match 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 the Canadian TFP or Japanese TFP to US news shock is important.
Figure 2.1: Identification of the US News Shock

Note: The blue line with circles denotes the impulse response estimated using a short-run identification. The red line with stars denotes the impulse response estimated using a long-run identification. This corresponds to the response of $TFP^US$ to $\epsilon_{2t}$. This corresponds to the response of $TFP^US$ to $\tilde{\epsilon}_{1t}$. The black lines indicate a 90% confidence band using a short-run identification.
Figure 2.2: A Scatter Plot of $\epsilon_2$ against $\tilde{\epsilon}_1$
Figure 2.3: The US and Canadian TFP Processes
Figure 2.4: The US and Japanese TFP Processes
Figure 2.5: The Responses of the US TFP and Canadian TFP to a News About Future US TFP

Note: The line with circles is the impulse response of the US TFP and the line with stars is the impulse response of the Canadian TFP to a US news shock.
Figure 2.6: The Response of the US TFP and Japanese TFP to a News About Future US TFP

Note: The line with circles is the impulse response of the US TFP and the line with stars is the impulse response of the Japanese TFP to a US news shock.
Figure 2.7: The Estimated Response of the Canadian TFP to a News About Future US TFP

Note: The solid lines and the shaded regions are the point estimate and 90% confidence bands.
Figure 2.8: The Estimated Response of the Japanese TFP to a News About Future US TFP

Note: The solid lines and the shaded regions are the point estimate and 90% confidence bands.
Figure 2.9: The Estimated Responses of the Canadian Variables to a News About Future US TFP

Note: The solid lines and the shaded regions are the point estimate and 90% confidence bands.
Figure 2.10: The Estimated Responses of the Canadian Variables to a News About Future US TFP

Note: The solid lines and the shaded regions are the point estimate and 90% confidence bands.
Figure 2.11: The Estimated Responses of the Japanese Variables to a News About Future US TFP

Note: The solid lines and the shaded regions are the point estimate and 90% confidence bands.
Figure 2.12: The Estimated Responses of the Japanese Variables to a News About Future US TFP

Note: The solid lines and the shaded regions are the point estimate and 90% confidence bands.
Figure 2.13: The Estimated Responses of the US Variables to a News About Future US TFP

Note: The solid lines and the shaded regions are the point estimate and 90 % confidence bands.
Figure 2.14: The Responses of the Canadian Variables to a News About Future US TFP in the Model

Notes: The solid lines and the shaded regions 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). A line with diamonds denotes the response of the variable in the case of the KPR preference ($\kappa = 1$) and no investment adjustment cost ($\phi = 0$). A line with crosses denotes the case with the KPR preference ($\kappa = 1$) and investment adjustment cost ($\phi = 5$). A line with squares denotes the case with the GHH preference ($\kappa = 0.001$) and the investment adjustment cost ($\phi = 5$). A line with circles denotes the case with GHH preference ($\kappa = 0.001$), the investment adjustment cost ($\phi = 5$), and low elasticity of substitution between domestically produced and foreign produced intermediate goods ($\sigma = 0.3$).
Figure 2.15: The Responses of the Canadian Trade Variables to a News about Future US TFP in the model

Notes: The solid lines and the shaded regions 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). A line with diamonds denotes the response of the variable in the case of the KPR preference ($\kappa = 1$) and no investment adjustment cost ($\phi = 0$). A line with crosses denotes the case with the KPR preference ($\kappa = 1$) and the investment adjustment cost ($\phi = 5$). A line with squares denotes the case with the GHH preference ($\kappa = 0.001$), the investment adjustment cost ($\phi = 5$), and low elasticity of substitution between domestically produced and foreign produced intermediate goods ($\sigma = 0.3$).
**Figure 2.16:** The Responses of the US variables to a News About Future US TFP in the Model

**Notes:** The solid lines and the shaded regions 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). A line with diamonds denotes the response of the variable in the case of the KPR preference ($\kappa = 1$) and no investment adjustment cost ($\phi = 0$). A line with crosses denotes the case with the KPR preference ($\kappa = 1$) and the investment adjustment cost ($\phi = 5$). A line with squares denotes the case with the GHH preference ($\kappa = 0.001$) and the investment adjustment cost ($\phi = 5$). A line with circles denotes the case with the GHH preference ($\kappa = 0.001$), the investment adjustment cost ($\phi = 5$), and low elasticity of substitution between domestically produced and foreign produced intermediate goods ($\sigma = 0.3$).
Figure 2.17: The Responses of the Japanese Variables to a News About Future US TFP in the Model

Notes: The solid lines and the shaded regions 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). A line with diamonds denotes the response of the variable in the case of the KPR preference ($\kappa = 1$) and no investment adjustment cost ($\phi = 0$). A line with crosses denotes the case with the KPR preference ($\kappa = 1$) and the investment adjustment cost ($\phi = 5$). A line with squares denotes the case with the GHH preference ($\kappa = 0.001$) and the investment adjustment cost ($\phi = 5$). A line with circles denotes the case with the GHH preference ($\kappa = 0.001$), the investment adjustment cost ($\phi = 5$), and low elasticity of substitution between domestically produced and foreign produced intermediate goods ($\sigma = 0.3$).
Figure 2.18: The Responses of the Japanese Trade Variables to a News About Future US TFP in the Model

Notes: The solid lines and the shaded regions 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). A line with diamonds denotes the response of the variable in the case of the KPR preference ($\kappa = 1$) and no investment adjustment cost ($\phi = 0$). A line with crosses denote the case with the KPR preference ($\kappa = 1$) and the investment adjustment cost ($\phi = 5$). A line with squares denote the case with the GHH preference ($\kappa = 0.001$) and the investment adjustment cost ($\phi = 5$). A line with circles denotes the case with the GHH preference ($\kappa = 0.001$), the investment adjustment cost ($\phi = 5$), and low elasticity of substitution between domestically produced and foreign produced intermediate goods ($\sigma = 0.3$).
Figure 2.19: The Responses of the Canadian Variables to News About Future US TFP in the Model with Estimated Parameters

Notes: The solid lines and the shaded regions are the point estimate and 90% confidence bands for the empirical impulse response. A line with stars denotes the model-based response with estimated parameters and feeding both the Canadian and US TFP processes driven by a US news shock. The dashed line denotes the model-based response from counterfactual experiment without feeding the Canadian TFP process driven by a US news shock.
Figure 2.20: The Responses of the Canadian Trade Variables to a News About Future US TFP in the Model with Estimated Parameters

Notes: The solid lines and the shaded regions are the point estimate and 90% confidence bands for the empirical impulse response. A line with stars denotes the model-based response with estimated parameters and feeding both the Canadian and US TFP processes driven by a US news shock. The dashed line denotes the model-based response from counterfactual experiment without feeding the Canadian TFP process driven by a US news shock.
Figure 2.21: The Responses of the Japanese Variables to a News About Future US TFP in the Model with Estimated Parameters

Notes: The solid lines and the shaded regions are the point estimate and 90% confidence bands for the empirical impulse response. A line with stars denote the model-based response with estimated parameters and feeding both the Japanese and US TFP processes driven by a US news shock. The dashed line denotes the model-based response from counterfactual experiment without feeding the Japanese TFP process driven by a US news shock.
Figure 2.22: The Responses of the Japanese Trade Variables to a News About Future US TFP in the Model with Estimated Parameters

Notes: The solid lines and the shaded regions are the point estimate and 90% confidence bands for the empirical impulse response. A line with stars denote the model-based response with estimated parameters and feeding both the Japanese and US TFP processes driven by a US news shock. The dashed line denotes the model-based response from counterfactual experiment without feeding the Japanese TFP process driven by a US news shock.
Figure 2.23: 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.
Appendix A

Appendix to Chapter 1

A.1 Equilibrium Conditions

In this section, I list the equilibrium conditions in the DSGE model under three assumptions of asset market structures.

A.1.1 Under the Financial Autarky Assumption

- Average prices

\[ \bar{p}_{Dt} = \frac{2\theta + 1}{2(\theta + 1)} MC_t z_{Dt}^{-1} \]  \hspace{1cm} (A.1)

\[ \bar{p}_{St} = \frac{2\theta + 1}{2(\theta + 1)} MC_t z_{St}^{-1} \]  \hspace{1cm} (A.2)

\[ \bar{p}_{Xt} = \frac{2\theta + 1}{2(\theta + 1)} \tau_t MC_t z_{Xt}^{-1} \]  \hspace{1cm} (A.3)

\[ \bar{p}_{St} = \frac{2\theta + 1}{2(\theta + 1)} \tau_t^{*} MC_t z_{Xt}^{-1} \]  \hspace{1cm} (A.4)
\[ p_t = \frac{1}{N_t} (N_{Dt} p_{Dt} + N_{Xt} p_{Xt}) \]  
(A.5)

\[ \bar{p}_t^* = \frac{1}{N_t^*} (N_{Dt}^* p_{Dt}^* + N_{Xt}^* p_{Xt}^*) \]  
(A.6)

• Average markups

\[ \bar{\mu}_{Dt} = \frac{1}{2(\theta + 1)} \frac{MC_t}{\bar{z}_{Dt}^{-1}} \]  
(A.7)

\[ \bar{\mu}_{Dt}^* = \frac{1}{2(\theta + 1)} \frac{MC_t^*}{\bar{z}_{Dt}^{*-1}} \]  
(A.8)

\[ \bar{\mu}_{Xt} = \frac{1}{2(\theta + 1)} \frac{\tau_t MC_t}{\bar{z}_{Xt}^{-1}} \]  
(A.9)

\[ \bar{\mu}_{Xt}^* = \frac{1}{2(\theta + 1)} \frac{\tau^* t MC_t^*}{\bar{z}_{Xt}^{*-1}} \]  
(A.10)

• Expected profits

\[ \pi_{Dt} = \frac{z_{\min}^\theta MC_t^2 \bar{z}_{Dt}^{\theta - 2}}{2\gamma(\theta + 1)(\theta + 2) \lambda_t} \]  
(A.11)

\[ \pi_{Dt}^* = \frac{z_{\min}^\theta MC_t^* \bar{z}_{Dt}^{\theta - 2}}{2\gamma(\theta + 1)(\theta + 2) \lambda_t^*} \]  
(A.12)

\[ \pi_{Xt} = \frac{z_{\min}^\theta \tau_t^2 MC_t \bar{z}_{Xt}^{\theta - 2}}{2\gamma(\theta + 1)(\theta + 2) \lambda_t^*} \]  
(A.13)

\[ \pi_{Xt}^* = \frac{z_{\min}^\theta \tau^* \tau_t^2 MC_t^* \bar{z}_{Xt}^{\theta - 2}}{2\gamma(\theta + 1)(\theta + 2) \lambda_t^*} \]  
(A.14)

\[ \pi_t = \pi_{Dt} + \pi_{Xt} \]  
(A.15)

\[ \pi_t^* = \pi_{Dt}^* + \pi_{Xt}^* \]  
(A.16)
• Cutoff productivities

\[
\frac{\omega \gamma \lambda_t + \eta N_t \bar{p}_t}{\gamma + \eta N_t} = \frac{MC_t z_{Dt}^{-1}}{}
\]  
(A.17)

\[
\frac{\omega \gamma \lambda_t^* + \eta N_t^* \bar{p}_t^*}{\gamma + \eta N_t^*} = \frac{MC_t^* z_{D*}^{-1}}{}
\]  
(A.18)

\[
\frac{\omega \gamma \lambda_t + \eta N_t \bar{p}_t}{\gamma + \eta N_t} = \tau_t^s MC_t z_{Xt}^{-1}
\]  
(A.19)

\[
\frac{\omega \gamma \lambda_t^* + \eta N_t^* \bar{p}_t^*}{\gamma + \eta N_t^*} = \tau_t^s MC_t^* z_{X*}^{-1}
\]  
(A.20)

• Number of firms

\[N_t = N_{Dt} + N_{Xt}^*
\]  
(A.21)

\[N_t^* = N_{Dt}^* + N_{Xt}
\]  
(A.22)

• Factor prices

\[\overline{MC_t} = \frac{W_t}{Z_t}
\]  
(A.23)

\[\overline{MC_t^*} = \frac{W_t^*}{Z_t^*}
\]  
(A.24)

• Free entry

\[v_t = \overline{MC_t f_{Et}}
\]  
(A.25)

\[v_t^* = \overline{MC_t^* f_{Et}^*}
\]  
(A.26)
• $N_{Dt}$, $N^*_t$, $N_{Xt}$ and $N^*_t$

\[ N_{Dt} = N_{pt} \left( \frac{z_{min}}{z_{Dt}} \right)^\theta \]  
(A.27)

\[ N^*_t = N^*_{pt} \left( \frac{z_{min}}{z^*_t} \right)^\theta \]  
(A.28)

\[ N_{Xt} = N_{pt} \left( \frac{z_{min}}{z_{Xt}} \right)^\theta \]  
(A.29)

\[ N^*_t = N^*_{pt} \left( \frac{z_{min}}{z^*_t} \right)^\theta \]  
(A.30)

• Evolution of total pool of firms

\[ N_{pt} = (1 - \delta)(N_{pt-1} + N_{Et-1}) \]  
(A.31)

\[ N^*_{pt} = (1 - \delta)(N^*_{pt-1} + N^*_{Et-1}) \]  
(A.32)

• Optimality conditions for household’s consumption and hours worked

\[ U_C(C_t, 1 - H_t) = P^c_t \mu_t \]  
(A.33)

\[ U_{C^*}(C^*_t, 1 - H^*_t) = P^*_{ct} \mu^*_t \]  
(A.34)

\[ U_H(C_t, 1 - H_t) + \mu_t W_t = 0 \]  
(A.35)

\[ U_{H^*}(C^*_t, 1 - H^*_t) + \mu^*_t = 0 \]  
(A.36)
• First order conditions for shares

\[ \beta \mu_{t+1}(1 - \delta)(\pi_{t+1} + v_{t+1}) = \mu_t v_t \]  
(A.37)

\[ \beta \mu^*_{t+1}(1 - \delta)(\pi^*_{t+1} + v^*_{t+1}) = \mu^*_t v^*_t \]  
(A.38)

• Aggregate accounting

\[ P^c_t C_t + N_{Et} v_t = W_t H_t + N_{pt} \pi_t \]  
(A.39)

\[ P^{*c}_t C^*_t + N^*_{Et} v^*_t = H^*_t + N^*_{pt} \pi^*_t \]  
(A.40)

• Balanced trade assumption

\[ \frac{N_t \pi_t^{2} M C_t^{2} z_{t}^{2}}{\lambda^*_t} = \frac{N^*_t \pi^*_t^{2} M C^*_t^{2} z^*_t^{2}}{\lambda^*_t} \]  
(A.41)

• Consumer price index

\[ P^c_t C_t = \frac{MC_t^{2} N_t z_{Dt}^{2}}{2 \gamma (\theta + 2) \lambda_t} \]  
(A.42)

\[ P^{*c}_t C^*_t = \frac{MC^*_t^{2} N^*_t z^*_t^{2}}{2 \gamma (\theta + 2) \lambda^*_t} \]  
(A.43)

• Consumption index

\[ C_t = \frac{\omega N_t M C_t z_{Dt}^{-1}}{2 \gamma (\theta + 1) \lambda_t} - \frac{N_t M C_t^{2} z_{Dt}^{-2}}{4 \gamma (\theta + 1) (\theta + 2) \lambda_t^2} - \frac{\eta}{2} \left( \frac{N_t M C_t z_{Dt}^{-1}}{2 \gamma (\theta + 1) \lambda_t} \right)^2 \]  
(A.44)

\[ C^*_t = \frac{\omega N^*_t M C^*_t z^*_t^{2-1}}{2 \gamma (\theta + 1) \lambda^*_t} - \frac{N^*_t M C^*_t^{2} z^*_t^{2-2}}{4 \gamma (\theta + 1) (\theta + 2) \lambda^*_t^2} - \frac{\eta}{2} \left( \frac{N^*_t \pi^*_t z^*_t^{2-1}}{2 \gamma (\theta + 1) \lambda^*_t} \right)^2 \]  
(A.45)
A.1.2 Under the Incomplete Asset Market Assumption

Under the incomplete asset market assumption, (A.39), (A.40) and (A.41) are replaced with the following equations:

\[
H_t = \frac{\theta}{2\gamma(\theta + 1)(\theta + 2)\lambda_t W_t} N_{Dt}MC_t^2 z_{Dt}^{-2} + \frac{\theta}{2\gamma(\theta + 1)(\theta + 2)\lambda_t W_t} N_{Xt}r_t^2 MC_t^2 z_{Xt}^{-2} \\
+ \frac{N_{Etf_{Et}}}{Z_t}, \tag{A.46}
\]

\[
H_t^* = \frac{\theta}{2\gamma(\theta + 1)(\theta + 2)\lambda_t^* W_t^*} N_{Dt}MC_t^{*2} z_{Dt}^{-2} + \frac{\theta}{2\gamma(\theta + 1)(\theta + 2)\lambda_t W_t} N_{Xt}r_t^2 MC_t^2 z_{Xt}^{-2} \\
+ \frac{N_{Etf_{Et}}^*}{Z_t^*}, \tag{A.47}
\]

\[
P_t^c B_{t+1} + P_t^{ca} B_{st+1} + \frac{1}{2} (P_t^c C_t - P_t^{ca} C_t^*) + \frac{1}{2} (N_{Et} v_t - N_{Et} v_t^*) \\
= (1 + r_t) P_t^c B_t + (1 + r_t^*) P_t^{ca} B_{st} + \frac{1}{2} (W_t H_t - W_t^* H_t^*) \\
+ \frac{1}{2} \left( N_{pt} \tilde{\pi}_t - N_{pt} \tilde{\pi}_t^* \right). \tag{A.48}
\]

A.1.3 Under the Complete Asset Market Assumption

Under the complete asset market assumption, (A.39), (A.40) and (A.41) are replaced with (A.46), (A.47) and

\[
\frac{U_{C^*}(C_t^*, 1 - H_t^*)}{U_C(C_t, 1 - H_t)} = \frac{P_t^{ac}}{P_t^{cc}}. \tag{A.49}
\]
Appendix B

Appendix to Chapter 2

B.1 Data Sources

B.1.1 US Data

- For US working age population, I use the data from The U.S. Government Printing Office. The original data is taken from Department of Commerce (Bureau of Census).

- Real GDP is obtained from Bureau of Economic Analysis (hereafter BEA) NIPA Table (Series ID: GDPC1).

- Real personal consumption expenditure is obtained from St. Louis Fed FRED database (Series ID: PCECC96).

- Real fixed private investment is obtained from St. Louis Fed FRED database (Series ID: FPIC1).

- Real capital input of the private business sector is obtained from Bureau of Labor Statistics (hereafter BLS).
• Total nonfarm employment is obtained from BLS (Series ID: CES0000000001).

• For nominal stock price, I use Standard & Poors 500 composite stock prices index downloaded from Global Financial Database.

• Deflator (price index of business sector) is obtained from BEA (from Price Indexes for Gross Value Added by Sector).

• Hours index of non-farm business sector is obtained from BLS (Series ID: PRS85006033).

• To calculate the series of TFP, I use capital services index of private business sector is obtained from BLS.

• The series of real exports of goods and services is obtained from St. Louis Fed FRED database.

• The series of real imports of goods and services is obtained from St. Louis Fed FRED database.

B.1.2 Canadian Data

• For Canadian population (15 years over), I use the data from CANSIM database, Statistics Canada (Series ID: V2091030).

• Real GDP is obtained from CANSIM database (Series ID: V1992067).

• Real consumption is obtained from CANSIM database (Series ID: V1992044).

• Real investment in non-residential structures and equipment is obtained from Statistics Canada.

• To calculate hours worked, using the population data above, 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\(^1\).

- Real exports is obtained from CANSIM database (Series ID: V1992060).
- Real imports is obtained from CANSIM database (Series ID: V1992063).
- Canadian terms of trade is calculated as import deflator divided by export deflator obtained from sourceOECD database.

### B.1.3 Japanese Data

- For Japanese working population (15 years over), I obtain the series from the Statistics Bureau, Ministry of Internal Affairs and Communications.
- Real GDP is obtained from SNA Statistics, Cabinet Office.
- Real private consumption is obtained from SNA Statistics, Cabinet Office.
- Real private non-residential investment is obtained from SNA Statistics, Cabinet Office.
- Real net exports is obtained from SNA Statistics, Cabinet Office.
- Hours is the aggregate weekly hours worked obtained from Roudouryoku Chosa (Annual Report on the Labour Force Survey), Statistics Bureau.
- Real exports is obtained from SNA Statistics, Cabinet Office.
- Real imports is obtained from SNA Statistics, Cabinet Office.
- Japanese terms of trade is calculated as import deflator divided by export deflator obtained from sourceOECD database.

\(^1\) Rhys Mendes (Bank of Canada) kindly gave me the dataset.


J. P. Neary. Globalisation and market structure. DNB Staff Reports (discontinued) 100, Netherlands Central Bank, 2003.


Biography

Michiru Sakane was born in Tokyo, Japan on February 15th, 1983. She received B.A. and M.A. in Commerce from Hitotsubashi University in 2005 and 2006, respectively. She earned M.A. in Economics from Duke University in 2008. She is graduating from Duke University with Ph.D. degree in Economics in spring of 2011.