A Two-Sector International Real Business Cycles Model with Investment-Specific Technology Shocks*

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Abstract

Can investment-specific technology (IST) shocks explain two of the international business cycles puzzles - the consumption/output anomaly and the international co-movement puzzle? I construct a new set of international business cycles facts which are comparable with the moments calculated from the simulated data of an international real business cycles (IRBC) model with investment-specific technology shocks. I develop two-country, two-good and two-sector (consumption and investment goods producing sectors) IRBC model with IST and aggregate neutral technology shocks to compare its simulated moments with the new set of international business cycles facts. I use the model to study the roles of IST shocks, aggregate neutral technology shocks and trade in investment goods in explaining the international business cycle facts. In contrast to the existing IRBC models with IST shocks, I find that the aggregate neutral technology shocks are relatively more important in explaining the positive cross-country correlation in output. This is mainly because of the sectoral factor re-allocation effects arising from technology shocks in a two-sector model. IST shocks increases the cross-country correlations in labor input and investment. Trade in investment goods increases the cross-country correlations of output and labor, but it decreases the cross-country correlations of investment. This IRBC model also makes a progress towards solving the consumption/output anomaly and the international co-movement puzzle by explaining the observed strongly positive cross-country correlations in output and labor input.

JEL Classification: E32, F41

Keywords: Investment-Specific Technology Shocks, Aggregate Neutral Technology Shocks, Trade in Investment Goods, International Business Cycles, Consumption/Output Anomaly and International Co-Movement Puzzle.

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1 Introduction

In this paper, I develop two-country, two good and two-sector (consumption and investment goods producing sectors) international real business cycles model with aggregate neutral technology shocks and investment-sector specific technology (IST) shocks. I use the model to study the roles of IST shocks, aggregate neutral technology shocks and trade in investment goods in explaining international business cycle facts. In a two-sector model with IST shocks, the relative price of the investment goods in terms of the consumption good does not remain constant. So, in a two-sector economy, to measure real GDP and other real macro variables, it is reasonable to deflate all nominal variables by a common price deflator. In the theoretical economies, I have used the price of the composite consumption good to deflate the nominal variables. In my data work, I have used a constructed implicit price deflator for consumer nondurable goods and services to deflate the nominal macroeconomic variables. Thus, I have developed a new set of international business cycle facts which are comparable with the IRBC model with IST shocks.

Technology shocks play an important role in explaining aggregate economic fluctuations. In particular, investment specific technology (IST) shocks are the most important technology shocks to explain business cycle fluctuations. This claim is supported by some recent studies on the role of IST shocks to explain long-run growth and business cycle fluctuations. Greenwood, Hercowitz and Krusell (1997) finds that IST shocks can explain about 60% of U.S. postwar growth in output per man-hour. Greenwood, Hercowitz and Krusell (2000) shows that IST shocks is the source of about 30% of U.S. output fluctuations. Recently, Fisher (2006) argues that aggregate neutral technology shocks can account for 6% of the variations in hours worked, whereas, IST shocks account for about 48%. Fisher's findings provide robust evidence against the findings of reduced-form econometric study of Gali (1999) which criticizes the role of technology shocks to explain the business cycle fluctuations. Gali (1999) argues that the neutral technology shocks fail to explain significantly the business cycle variation in aggregate hours. Fisher (2006) argues that Gali's findings are specific to his consideration of only neutral technology shocks. If both IST and neutral technology shocks are considered, then technology shocks become important for explaining the aggregate fluctuations. More recently, Justiniano, Primiceri and Tambalotti (2008)estimates a dynamic stochastic general equilibrium (DSGE) model with various shocks and frictions and finds that IST shocks play the most important role in explaining busniess cycle fluctuations in the U.S. output and hours. In contrast, Canova, Lopez-Salido and Michelacci (2008) agrues by providing structural VAR evidence that aggregate neutral technology shocks explain a smaller portion of per-capita hours fluctuations than IST shocks and IST shocks explain a smaller portion of output fluctuations than aggregate neutral shocks. Acconcia and Simonelli (2008) finds that in an estimated dynamic factor model both the IST shocks and aggregate neutral shocks are quantitatively

important in explaining the observed near-zero correlation between aggregate labor productivity and employment growth rates. In light of this evidence in favor of IST and neutral technology shocks, it makes sense to study its roles in explaining IRBC facts.

Existing international real business cycles (IRBC) literature, starting from the seminal work of Backus, Kehoe and Kydland (1992), consider mainly neutral technology shocks to explain the international business cycle facts. Backus, Kehoe and Kydland (1992, 1994 and 1995) is basically a two-country extension of a standard real business cycle (RBC) model as in Kydland and Prescott (1982). They point out three anomalies in the international business cycles research - the consumption/output anomaly, the price-variability anomaly and the international co-movement puzzle. Consumption/output anomaly refers to the counterfactual prediction of the theoretical economies (Backus, Kehoe and Kydland (1992, 1994 and 1995)) that cross-country consumption correlation is higher than the output correlation. The standard deviation of the terms of trade is 0.48 percent in the BKK (1994) benchmark model, whereas it is 2.92 percent in the U.S. data. This discrepancy between the data and theoretical economies is known as price-variability anomaly. In the Backus, Kehoe and Kydland (1995) data, labor inputs and investments are positively correlated across countries (0.33 and 0.53, respectively). However, the Backus, Kehoe and Kydland (1995) model predicts that they are negatively correlated. This discrepancy between the data and theoretical economies is known as the international co-movement puzzle. Using GMM and quarterly data from twently industrialized countries, Ambler, Cardia and Zimmermann (2004) finds statistically significant evidence in favor of the hypothesis that the average cross-country correlation of output is greater than or equal to that of consumption. They also find a strong evidence that the cross country correlations in investment and labor inputs are small positive.

There is a huge literature which attempts to explain the international business cycle facts. This literature is divided into two broad categories. One is known as international business cycles literature and the other is known as new open economy macroeconomics. The former type of literature has evolved from the seminal work of Backus, Kehoe and Kydland (1992). Some of the works in this class of literature are Backus, Kehoe and Kydland (1992, 1994 and 1995), Devereux, Gregory and Smith (1992), Backus and Smith (1993), Stockman and Tesar (1995), Baxter and Crucini (1995), Kollmann (1996), Arvanitis and Mikkola (1996), Kehoe and Perri (2002), Heathcote and Perri (2002), MacGee(2002), Hairault (2002) and Johri, Letendre and Luo (2007). One of the major features of this class of models is a perfectly competitive traded goods sector. The new open economy macroeconomics has evolved from the pioneering work of Obstfeld and Rogoff (1995). Some of the works in this category of research are Betts and Devereux (1996 and 2000), Lapham (1995), Chari, Kehoe and McGrattan (2002), Lapham and Vigneault (2001), Betts and Kehoe (2001), Corsetti and Dedola (2002) and Corsetti, Dedola and Leduce (2002). One of the major features of this type of models is an imperfectly competitive and differentiated traded goods

sector. None of these above mentioned models studies the role of IST shocks. They all mainly use aggregate neutral technology shocks in explaining IRBC facts. Some of these models achieved partial success in explaining the international business cycles anomalies. Arvantis Mikkola (1996), Hairault (2002) and Johri, Letendre and Luo (2007) were relatively more successful in explaining these puzzles.

Boileau (2002), Basu and Thoenissen (2007) and Raffo (2008) are the only three models in IRBC literature which study the role of IST shocks in explaining IRBC facts. Boileau (2002) studies the role of IST shocks and trade in capital goods for explaining the cross-country correlation of output and the volatility of the terms of trade. He finds that these two features contribute towards explaining high cross-country output correlation and the high volatility of the terms of trade. Raffo (2008) finds that an IRBC model with GHH preferences, neutral technology and IST shocks can explain the negative correlation between real exchange rate and relative consumption (Backus-Smith puzzle), the negative correlation between terms of trade and relative output and the large volatility of the terms of trade and trade flows. Basu and Thoenissen (2007) criticizes the use of the relative price of investment goods for identifying IST shocks. They develop an open economy, flexible price, two-country model with IST and aggregate neutral technology shocks and argue that the main driver of the observed negative correlation between the investment rate and the relative price of investment goods is the aggregate neutral technology shocks not the IST shocks. All of these three models find that IST shocks are relatively more important than aggregate neutral technology shocks in explaining cross-country output correlation. But these three models fail to capture an important sectoral factor reallocation effect which arises from technology shocks in a two-productive sector model. In addition, these models also do not use the international business cycle facts which are comparable with the predictions of an IRBC model with IST shocks.

In contrast to the existing IRBC models with IST shocks, I find that in a two-productive-sector IRBC model IST shocks are relatively less important than aggregate neutral technology shocks in explaining cross-country output correlation due to sectoral factor reallocation effects. I also find that IST shocks increases the cross-country labor input and investment spending correlations and trade in investment goods increases the cross-country correlations in output and labor input. However, in contrast to Boileau (2002), I find that trade in investment goods decreases the cross-country correlations in investment spending. The most preferred version of the model with both aggregate shocks and investment-specific technology shocks and with trade in investment goods predicts that the cross-country correlations of output, consumption, labor and investment are 0.43, 0.68, 0.53 and -0.06, respectively (see Table 3 in the Appendix). This version of the model can partly address the international co-movement puzzle and the consumption/output anomaly. This version of the model can explain positive correlation between consumption and output. This is an improvement over Boileau (2002) model with only IST shocks which counterfactually predicts a

negative correlation between consumption and output.

In my constructed new international business cycle facts I find that the cross-country output correlation is relatively lower in the deflated data than it is in the chained data. In the deflated data, this correlation is 0.48 but in the chained data it is 0.73. In both the chained and deflated data, the cross-country consumption (consumer non-durable goods and services) correlation is 0.45 (see Table 2 in the Appendix). In contrast to BKK (1992), the fact based on deflated data shows that the gap between the cross-country output and consumption correlations is small. Thus, this data work helps to address the consumption/output anomaly to some extent. I also find that the cross-country correlation in the relative price of investment goods is 0.55. In the versions of the model with IST shocks this correlation is 0.36.

One of the main contributions of this study is a new set of IRBC facts which are comparable with a two-sector IRBC model. This study also proposes the first two-productive-sector IRBC model with aggregate technology and IST shocks which shows that aggregate technology shocks is relatively more important than IST shocks in explaining cross-country output correlations. In contrast to the Backus, Kehoe and Kydland (1992) model, the model developed in this paper can predict strongly positive cross-country correlations in output and labor input which are consistent with the data. Thus, this IRBC model also makes a progress towards solving the consumption/output anomaly and the international co-movement puzzle.

2 The Model

2.1 The Economic Environment

I delvelop two-country, two-good and two sector international real business cycles model with both aggregate neutral technology and IST shocks. The two countries- Home and Foreign - are symmetric. Each country is inhabited by a representative agent. Both countries have two production sectors- a consumption good sector and an investment good sector. The consumption goods sector produces a consumption good which can only be used for consumption. The investment goods sector produces an investment good which can be used as capital goods in the production process of both sectors. Home country consumption and investment goods are imperfect substitutes for their counterparts in the foreign country. The representative agent in each country consumes a composite good which consists of the consumption goods from both countries. The capital goods used in the production process of both sectors of each country is a composite investment good consists of the investment goods from both countries. So, both countries involve in exporting and importing both consumption and investment goods.

In each country labor and capital is perfectly mobile across the two sectors. In each country,

both production sectors face country-specific aggregate neutral technology shocks. However, only the investment good sector in each country is subject to IST shocks.

Since both countries are symmetric, the model is described from the home country's point of view. An asterisk $(*)$ stands for foreign country variables.

2.2 Preferences

The preferences of the representative agent in the home country are characterized by an expected utility function of the form

$$= E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, 1 - N_t); \quad 0 < \beta < 1, \tag{1}$$

where, C_t and N_t denotes time t consumption and labor of the agent in home country and $U(C, 1 - N) = \frac{1}{\xi} (C^{\mu}(1 - N)^{1-\mu})^{\xi}$. The total hours available to the agent are constant and normalized to 1. The agent allocates the total hours between labor and leisure (L_t):

$$N_t + L_t = 1. \tag{2}$$

2.3 Technologies

The home country consumption good sector produces a consumption good following a Cobb-Douglas technology using inputs of capital and labor:

$$Y_t = F(K_{Yt}, N_{Yt}) = Z_t K_{Yt}^{\alpha} N_{Yt}^{1-\alpha}, \tag{3}$$

where, Y_t denotes time t production of home consumption good, N_{Yt} denotes the labor hours employed in the consumption good sector in time t, K_{Yt} denotes the stocks of capital in the consumption sector at the beginning of period t, and Z_t denotes the time t aggregate technology shocks. The home consumption good is either used domestically or exported to the foreign country.

$$Y_t = Y_{ht} + X_{Yt} \tag{4}$$

where Y_{ht} is the amount of time t home consumption good used at home and X_{Yt} is the amount of time t home consumption good that is exported to the foreign country.

The home country investment good sector produces an investment good following a similar

Cobb-Douglas technology using inputs of capital and labor:

$$I_t = H(K_{It}, N_{It}) = Z_t Z_{It} K_{It}^{\gamma} N_{It}^{1-\gamma}, \tag{5}$$

where, Y_t denotes time t amount of the production of home investment good, N_{It} denotes the labor hours employed in the investment good sector in time t, K_{It} denotes the stocks of capital in the consumption sector at the beginning of period t, Z_t denotes the time t aggregate technology shocks, and Z_{It} denotes the time t investment sector-specific technology (IST) shocks. The home investment good can also be used domestically or exported to the foreign country.

$$I_t = I_{ht} + X_{It}, \tag{6}$$

where I_{ht} is the amount of time t home investment good used at home and X_{It} is the amount of time t home investment good that is exported to the foreign country.

In the technology functions, $N_t = N_{Yt} + N_{It},\ 0 < \alpha < 0$, and $0 < \gamma < 0$. The home and foreign aggregate and IST technology shocks $(Z_t, Z^*, Z_{It}, Z_{It}^*)$, are assumed to evolve following a vector autoregressive process of order 1 (VAR(1)):

$$Y_{t+1} = \Gamma_A A_t + \varepsilon_{At+1}, \tag{7}$$

where $A = [Z_t, Z^*, Z_{It}, Z_{It}^*]',\ \Gamma_A$ is the matrix of coefficients, and ε_A is the vector of mean zero normal random variables with the contemporaneous covariance matrix $\sum_A$.

The representative agent consumes a composite good that consists of domestic and foreign consumption good. The Armington aggregator is used to aggregate the domestic and foreign consumption good as follows:

$$C_t = G(Y_{ht}, X_{Yt^*}^*) = [w_Y (Y_{ht})^{\eta_c} + (1 - w_Y)(X_{Yt^*}^*)^{\eta_c}]^{\frac{1}{\eta_c}}, \tag{8}$$

where, $X_{Yt^*}^*$ is the export of foreign consumption good (Yt^*) to the home country, which is also the import of foreign consumption good in home country.

Both the consumption good sector and investment good sector use a composite investment good, AI, which consists of domestic and foreign investment good, as capital inputs in their production processes. The Armington aggregator is used to aggregate the domestic and foreign investment good as follows:

$$SI_t = M(I_{ht}, X_{It^*}^*) = [w_I (I_{ht})^{\eta_c} + (1 - w_I)(X_{It^*}^*)^{\eta_I}]^{\frac{1}{\eta_I}}, \tag{9}$$

where, $X_{It^*}^*$ is the export of foreign investment good (I^*) to the home country, which is also the

import of foreign investment good in home country. SI is the final composite investment good which is used as capital inputs in both sectors.

The capital accumulation of the home economy is given by:

$$K_{Yt+1} + K_{It+1} = (1-\delta)(K_{Yt} + K_{It}) + \left(\frac{SI_t}{K_{Yt} + K_{It}}\right)^{\omega} (K_{Yt} + K_{It}), \tag{10}$$

where, $0 \leqslant \delta \leqslant 1$ is the depreciation rate of capital and $0 \leqslant \omega \leqslant 1$ is the capital adjustment cost.

There is no rigidity in the factor markets. Labor and capital are perfectly mobile across the two sectors. Labor and installed capital are immobile across countries.

2.4 Equilibrium

We can solve the equilibrium of the model by solving a planner's problem, that is, by maximizing (1) subject to (2) to (10), a specified VAR(1) process for $(Z_t, Z^*, Z_{It}, Z^*_{It})$,
$K_{Yt}, K_{It}, N_{Yt}, N_{It}, X_{Yt}, X_{It}, X^*_{Yt}, X^*_{It} \geqslant 0$ and
$K_{Y0}, K_{I0}, N_{Y0}, N_{I0}, X_{Y0}, X_{I0}, X^*_{Y0}, X^*_{I0} > 0$ given.

2.5 Measurement of Real GDP and the IST shocks

The gross domestic product (GDP) of the home economy is defined using the product approach of national income accounting. Nominal GDP is the current market value of the amount of consumption good and investment good produced in the current year.

$$\text{Nominal GDP} = P_{Yt}Y_t + P_{It}I_t \tag{11}$$

where, P_{Yt} is the current market price of the home produced consumption good and P_{It} is the current market price of the home produced investment good. To express real GDP in terms of the composite home consumption good we divide nominal GDP by the price index of the composite home consumption good, P_t.

$$\text{Real GDP} = \left(\frac{P_{Yt}Y_t + P_{It}I_t}{P_t}\right) \tag{12}$$

The equation (12) can be written as,

$$\begin{aligned} \text{Real GDP} &= \frac{P_{Yt}}{P_t}Y_t + \frac{P_{It}}{P_{Yt}}\frac{P_{Yt}}{P_t}I_t, \\ \Rightarrow \text{Real GDP} &= \frac{\partial G(Y_{ht}, X^*_{Yt^*})}{\partial Y_{ht}}Y_t + \frac{P_{It}}{P_{Yt}}\frac{\partial G(Y_{ht}, X^*_{Yt^*})}{\partial Y_{ht}}I_t \end{aligned} \tag{13}$$

Since the aggregator, G, is a homogenous function of degree one, $\frac{\partial G(Y_{ht}, X^*_{Yt^*})}{\partial Y_{ht}}$ is nothing but the relative price of home consumption good in terms of the composite home consumption good, $\left(\frac{P_{Yt}}{P_t}\right)$.

In the equilibrium, because of perfect mobility of labor across sectors it must be true that the value of the marginal product of labor in the consumption good sector must be equal to the value of the marginal product of labor in the investment good sector:

$$P_{Yt}\frac{\partial F(K_{Yt}, N_{Yt})}{\partial N_{Yt}} = P_{It}\frac{\partial H(K_{It}, N_{It})}{\partial N_{It}} \tag{14}$$

Equation (14) can be re-arranged as,

$$\frac{P_{It}}{P_{Yt}} = \frac{\partial F(K_{Yt}, N_{Yt})/\partial N_{Yt}}{\partial H(K_{It}, N_{It})/\partial N_{It}} = \frac{1}{Z_{It}} \tag{15}$$

$$\Rightarrow Z_{It} = \frac{P_{Yt}}{P_{It}} \tag{16}$$

Equation (15) shows that in the equilibrium, the relative price of the home investment good in terms of the home consumption good is ratio of marginal product of labor in the consumption good sector to the marginal product of labor in the investment good sector. Equation (16) shows that the home investment-specific technology shocks can be measured by the relative price of the home consumption good in terms of the home investment good. Substituting (15) into the equation (13) we can measure the real GDP in terms of the composite home consumption good as,

$$\text{Real GDP} = \frac{\partial G(Y_{ht}, X^*_{Yt^*})}{\partial Y_{ht}}Y_t + \frac{\partial F(K_{Yt}, N_{Yt})/\partial N_{Yt}}{\partial H(K_{It}, N_{It})/\partial N_{It}}\frac{\partial G(Y_{ht}, X^*_{Yt^*})}{\partial Y_{ht}}I_t. \tag{17}$$

3 New International Business Cycle Facts

In a two-sector model with IST shocks, the relative price of the investment goods in terms of the consumption good does not remain constant. So, in a two-sector economy, to measure real GDP and other real macro variables, it is reasonable to deflate all nominal variables by a common price deflator. In the theoretical economies, I have used the price of the composite consumption good to deflate the nominal variables. In my data work, I have used an implicit price deflator for consumer nondurable goods and services to deflate the nominal macroeconomic variables. Thus, I have developed a new set of international business cycle facts which are comparable with the IRBC model with IST shocks.

I have used quarterly U.S. and Canadian data from 1976 to 2005 to compute a new set of international business cycles facts. I have constructed two set of international business cycles facts.

One is based on the published real data series (chained dollars) and other is based on nominal data series deflated by a constructed chained implicit price deflator for consumer nondurable goods and services. I refer to the facts based on the former data set as "Chained Data" and the facts based on the latter data set as "Deflated Data". For the U.S. real data series, I have used seasonally adjusted and chained 2000 dollars national income and expenditure accounts data constructed by Bureau of Economic Analysis and for Canadian real data series, I have used seasonally adjusted and chained 1997 dollars national income and expenditure accounts data constructed by CANSIM. Since the chained implicit price deflator for consumer non-durable goods and services are not readily available, I have a constructed a chained implicit price deflator for consumer non-durable goods and services applying a geometric average formula on the individual chained implicit price deflators.

In the deflated data, the cross-country output correlation is 0.48 (see Table 2 in the appendix) which is lower than the correlation found in the chained data. In both the chained and deflated data, the cross-country consumption (consumer non-durable goods and services) correlation is 0.45. In contrast to BKK (1992), the fact based on deflated data shows that the gap between the cross-country output and consumption correlations is small. Thus, this data work helps to address the consumption/output anomaly to some extent.

I have included expenditures on consumer durable goods as a part of investment spending. In the deflated data, the cross-country investment correlation is 0.36 which is about the same as the correlation found in the chained data (see Table 2 in the appendix). The cross-country correlations of the relative price of the investment goods (in terms of the non-durable consumption goods and services) and labor hours are 0.55 and 0.76, respectively (see Table 2 in the appendix).

4 Calibration

Most of the parameters of the model are calibrated following Backus, Kehoe and Kydland (1994) and Boileau (2002). I have chosen the value of the capital adjustment cost parameters to match the volatility of the investment spending in the simulated data with the volatility observed in the data as closely as possible. Table 1 in the appendix lists the values of all the calibrated parameters.

For the simulations, the estimate of the aggregate neutral technology shocks process is taken from Backus, Kehoe and Kydland (1992). On the other hand, the estimate of IST shocks process is taken from Boileau (2002). I assume that the technology shocks are not correlated across the

sectors. The matrix of coefficients,

$$\Gamma_A = \begin{bmatrix} 0.906 & 0.088 & 0 & 0 \\ 0.088 & 0.906 & 0 & 0 \\ 0 & 0 & 0.553 & 0.027 \\ 0 & 0 & 0.027 & 0.553 \end{bmatrix}.$$

The contemporaneous covariance matrix of the error terms of the shock process,

$$\Sigma_A = \begin{bmatrix} 0.0000726 & 0.0000187 & 0 & 0 \\ 0.0000187 & 0.0000726 & 0 & 0 \\ 0 & 0 & 0.0001687 & 0.0000582 \\ 0 & 0 & 0.0000582 & 0.0001687 \end{bmatrix}.$$

5 Solution and Simulation Methods

I have used the method of undetermined coefficients to solve and simulate the model. I have used Uhlig's toolkits to run the simulations in Matlab. I have chosen simulation length as 120 quarters to match with the period of the data set which starts at the first quarter of the year 1976 and ends at last quarter of the year 2005. Moments of the simulated data are the average of 500 replications.

6 Simulation Results

6.1 The Effects of the Aggregate Neutral Technology Shocks and IST Shocks

6.1.1 Simple Intuition

In a version of the model with either only aggregate technology shocks or only IST shocks and with no trade in capital goods, if Home is hit by either of these two shocks, we find (See Figure 1 and Figure 3 in the Appendix) that in Home workers will work longer hours (substitution effect is stronger than income effect) and in Foreign workers will work shorter hours (substitution effect is less than income effect). This response is same as BKK(1992). In this version of the model, Home re-allocates more labor and capital in investment goods sector in response to either of the two shocks but Foreign re-allocates more labor and capital in consumption goods sector (See Figure 1 and Figure 3 in the Appendix). This factor re-allocation effect is stronger when Home is hit by only IST shocks rather than only aggregate technology shocks.

When Home is hit by only aggregate technology shocks Home produces more of both goods (due to stronger productivity effect) resulting an increase in Home GDP at the impact of the shock

(See Figure 2 in the Appendix). Foreign will produce more of consumption goods and less of investment goods. However, GDP in foreign country increases at the impact of the shock (See Figure 2 in the Appendix). Thus, this sectoral re-allocation effect helps to generate relatively less negative cross-country correlations in labor and investment and also contributes to generate a positive cross-country output correlations. These results are in contrast to Backus, Kehoe and Kydland (1992) which counterfactually predicts that cross-country correlations in output is negative and cross-country correlations in labor and investment are very strongly negative. In this model we are getting this contrasting result due to the sectoral re-allocation effects which are missing in Backus, Kehoe and Kydland (1992).

When Home is hit by only IST shocks, Home produces more of investment goods and less of consumption goods (due to stronger re-allocation effect and investment sector specific productivity effect) resulting an increase in Home GDP at the impact of the shock (See Figure 4 in the Appendix). Foreign will produce more of consumption goods and less of investment goods. In this case, GDP in foreign country decreases at the impact of the shock. Thus, this stronger factor re-allocation effect helps to generate positive cross-country correlations in labor and investment but also contributes to produce relatively lower positive cross-country output correlations. In a version of the model with only aggregate neutral technology shocks and with no trade in capital goods, the cross country correlations in output is 0.32, whereas in a version of the model with only investment specific technology shocks and with no trade in capital goods the cross country correlations in output is 0.14 (See Table 2 in the Appendix). This shows that aggregate neutral technology shocks is relatively more important than investment-specific technology shocks in explaining cross-country output correlations. This result is in contrast to Boileau (2002) which finds that the IST shocks are relatively more important. In this model we are getting this contrasting result due to the sectoral re-allocation effects which are also missing in Boileau (2002).

6.1.2 Quantity Anomaly

In a version of the model with only aggregate technology shocks and with no trade in investment goods, the cross-country output correlation is 0.32 (see Table 2 in the appendix). If we add investment-specific technology shocks in this version of the model, the cross-country output correlation decreases to 0.27. In a version of the model with only investment-specific technology shocks and with no trade in investment goods, the cross-country output correlation is 0.14. In these three versions of the model, the cross country correlations in output is positive and it is the highest in a version of the model where there is only aggregate technology shocks.

Inclusion of the investment-specific technology shocks in a version of the model with aggregate technology shocks and with no trade in capital goods decreases the cross-county consumption correlation. In the model with only aggregate technology shocks and with no trade in investment

goods, the cross-country consumption correlation is 0.75 (see Table 2 in the appendix). If we add investment-specific technology shocks in this version of the model, the cross-country consumption correlation decreases to 0.73. In the model with only investment-specific technology shocks and with no trade in investment goods, the cross-country consumption correlation is 0.67. In these three versions of the model, the cross country correlations in consumption is counterfactually very strongly positive. This result is very common in an IRBC model with a complete financial market with CES preferences. Since in all the versions of our model consumer has CES preferences and the financial market is complete, it cannot produce a low cross-country correlations in consumption. However, by generating a high cross-country correlations in output, this model reduces the counterfactual gap between the cross-country correlations in output and consumption, and thus we make a progress in solving the quantity anomaly.

6.1.3 International Co-Movement Puzzle

Inclusion of the investment-specific technology shocks in a version of the model with aggregate neutral technology shocks and with no trade in capital goods increases the cross-county labor input correlation. In the model with only aggregate technology shocks and with no trade in capital goods, the cross-country labor input correlation is -0.34 (see Table 2 in the appendix). If we add investment-specific technology shocks in this version of the model, the cross-country labor input correlation increases to 0.13. In the model with only investment-specific technology shocks and with no trade in investment goods, the cross-country labor input correlation is 0.20.

In the absence of any trade in capital goods, investment-specific technology shocks tend to increase the cross-country investment spending correlation. In the model with only aggregate technology shocks and with no trade in capital goods, the cross-country investment spending correlation is -0.90 (see Table 2 in the appendix). If we add investment-specific technology shocks in this version of the model, the cross-country investment spending correlation increases to 0.13. In the model with only investment-specific technology shocks and with no trade in investment goods, the cross-country investment spending correlation is 0.26.

In contrast, inclusion of the investment-specific technology shocks in a version of the model with aggregate neutral technology shocks and with trade in capital goods has negligible effects on the cross-county correlations of output and consumption. However, it tends to increase the cross-county correlations of labor input and investment spending. In the model with only aggregate technology shocks and with trade in capital goods, the cross-country labor input correlation is 0.25 (see Table 3 in the appendix). If we add investment-specific technology shocks in this version of the model, the cross-country labor input correlation increases to 0.53. In the model with only investment-specific technology shocks and with trade in investment goods, the cross-country labor input correlation is 0.56. In the model with only aggregate technology shocks and

with trade in capital goods, the cross-country investment spending correlation is -0.91 (see Table 3 in the appendix). If we add investment-specific technology shocks in this version of the model, the cross-country investment spending correlation increases to -0.06. In the model with only investment-specific technology shocks and with trade in investment goods, the cross-country investment spending correlation is 0.03.

Thus, we find that IST shocks are relatively more important than aggregate neutral technology shocks in explaining cross-country correlations in labor input and investment spending, irrespective of trade in capital goods.

6.1.4 Other Macroeconomic Aggregates

Investment-specific technology shocks increase the volatility of the aggregate output. In the model with only aggregate technology shocks and with no trade in capital goods, the volatility of the aggregate output is 1.19 (see Table 4 in the appendix). If we add investment-specific technology shocks in this version of the model, the volatility of the aggregate output increases to 1.41. In the model with only investment-specific technology shocks and with no trade in capital goods, the volatility of the aggregate output is 0.76.

Most of the models over predict the volatility of consumption. Only exceptions are the models with only investment-specific technology shocks. In the model with only investment-specific technology shocks and with no trade in capital goods, the volatility of consumption relative to the volatility of GDP is 0.53 (see Table 4 in the appendix). On the other hand, in the model with only aggregate technology shocks and with no trade in capital goods, the volatility of consumption relative to the volatility of GDP is 1.03.

All of the models over predict the volatility of investment spending. Investment-specific technology shocks increase the volatility of investment spending. In the model with only aggregate technology shocks and with no trade in capital goods, the volatility of investment spending is 4.73 (see Table 4 in the appendix). If we add investment-specific shocks in this version of the model, the volatility of investment spending relative to the volatility of GDP increases to 14.7. In the model with only investment-specific technology shocks and with no trade in capital goods, the volatility of investment relative to the volatility of GDP is 13.35.

On the other hand, all of the models under predict the volatility of labor input. Investment-specific technology shocks increase the volatility of investment spending. In the model with only aggregate technology shocks and with no trade in capital goods, the volatility of labor input relative to the volatility of GDP is 0.17 (see Table 4 in the appendix). If we add investment-specific shocks in this version of the model, the volatility of labor input relative to the volatility of GDP increases to 0.47. In the model with only investment-specific technology shocks and with no trade in capital goods, the volatility of labor input relative to the volatility of GDP is 0.43.

The models with only aggregate technology shock and with both the aggregate and investment-specific technology shocks can explain a strong positive correlation between consumption and output. Investment-specific technology shocks tend to decrease the correlation between consumption and output. In the model with only aggregate technology shocks and with no trade in capital goods, the correlation between consumption and output is 0.95 (see Table 6 in the appendix). If we add investment-specific shocks in this version of the model, the correlation between consumption and output decreases to 0.63. In the model with only investment-specific technology shocks and with no trade in capital goods, the correlation between consumption and output is -0.19. So, to explain the observed positive correlation between consumption and output we need to have both investment-specific technology shocks and aggregate neutral technology shocks in the model.

The models with only investment-specific technology shocks can predict a strong positive correlation between output and investment spending. In the model with only investment-specific technology shocks and with no trade in capital goods, the correlation of investment spending with output is 0.85 (see Table 6 in the appendix). On the other hand, in the model with only aggregate technology shocks and with no trade in capital goods, the correlation of investment spending with output is 0.73. In the model with both aggregate and investment-specific technology shocks and with no trade in capital goods, the correlation of investment spending with output is 0.64.

Most of the models under-predict the correlation of labor input with output. The model with only aggregate neutral technology unrealistically predicts a negative correlation between labor input and output. Investment-specific technology shocks tend to increase the correlation between labor input and output. In the model with only aggregate technology shocks and with no trade in capital goods, the correlation of labor input with output is -0.08 (see Table 6 in the appendix). If we add investment-specific shocks in this version of the model, the correlation between labor input and output increases to 0.33. In the model with only investment-specific technology shocks and with no trade in capital goods, the correlation of labor input with output is 0.72. So, to explain the observed positive correlation between labor input and output we need to have both investment-specific technology shocks and aggregate neutral technology shocks in the model.

Investment-specific technology shocks tend to make the negative correlation between the output and the relative price of capital goods and output stronger. In the model with only aggregate technology shocks and with no trade in capital goods, the correlation between the relative price of capital goods and output is -0.09 (see Table 6 in the appendix). If we add investment-specific shocks in this version of the model, the correlation between relative price of capital goods and output changes to -0.48. In the model with only investment-specific technology shocks and with no trade in capital goods, the correlation between the relative price of capital goods and output is -0.89.

6.2 The Effects of the Trade in Investment Goods

6.2.1 Simple Intuition

In the versions of the model with trade in investment goods, the direction of the sectoral reallocation effects depends on the type of the technology shocks. When Home is hit by aggregate neutral technology shocks, workers in both Home and Foreign work less (income effect is stronger than substitution effect). Both Home and Foreign re-allocates more labor and capital in the consumption goods sector and consumption spending in both country increases (See Figure 5 and Figure 6 in the Appendix). In Home output in both sectors increases. In Foreign output of consumption goods increases but output of investment goods falls. Overall, Home GDP increases at the impact of the shock (See Figure 6 in the Appendix). Foreign GDP does not change at the impact of the shocks. However, Forign GDP gradually increases after the first period (See Figure 6 in the Appendix). Thus trade in capital goods helps to increase cross-country correlations in labor and output. Home's import of both investment and consumption goods increases at the impact of the shocks. Thus, home investment rises and foreign investment falls at the impact of the shocks. Trade in capital goods reduces cross-country correlations in investment. In the a version of the model with trade in capital goods and with only aggregate neutral technology shocks, the cross country correlations in investment spending is -0.91. This result is in contrast to Boileau (2002) which shows that in a version of this model with only aggregate neutral technology shocks and with trade in capital goods, the cross country correlations in investment spending is 0.27.

When Home is hit by only IST shocks, workers in both Home and Foreign work more (income effect is less than substitution effect). Both Home and Foreign re-allocates more labor and capital in the investment goods sector and consumption spending in both country decreases (See Figure 7 in the Appendix). In Home output of investment goods increases but output of consumption goods falls. In Foreign output of investment goods increases but output of consumption goods falls. Overall, GDP in Home increases but GDP in Foreign slightly decreases at the impact of the shock (See Figure 8 in the Appendix). Due to stronger factor re-allocation effect, this version of the model generates relatively lower cross-country correlations in output and higher cross-country correlations in labor. Home's import of both investment and consumption goods increases. Thus, home investment rises and foreign investment falls at the impact of the shocks. In this case too trade in capital goods also reduces cross-country correlations in investment. In a version of the model with trade in capital goods and with only IST shocks, the cross country correlations in investment spending is 0.03. This result is in contrast to the results of Boileau (2002) which shows that in a version of the model with only investment specific technology shocks and with trade in capital goods, the cross country correlations in investment spending is 0.89.

6.2.2 Quantity Anomaly

In the deflated data the cross-country correlations in output is 0.48. Trade in investment goods contributes to explain this highly positive cross-country output correlation. In the model with only aggregate neutral technology shocks and with no trade in investment goods, the cross-country output correlation is 0.32 (see Table 2 in the appendix). If you allow trade in investment goods in this model, the cross-country output correlation increases to 0.42 (see Table 3 in the appendix). In the model with only investment-specific technology shocks and no trade in investment goods, the cross-country output correlation is 0.14. If you allow trade in investment goods in this version of the model, the cross-country output correlation increases to 0.37. In the model with both aggregate and investment-specific technology shocks and no trade in investment goods, the cross-country output correlation is 0.27. If you allow trade in investment goods in this model, the cross-country output correlation increases to 0.43.

In the deflated data the cross-country correlations in consumption is 0.45. Cross-country consumption correlation predicted by the model is higher than what we find in the data. Trade in investment goods helps to reduce the cross-country consumption correlation to some extent. In the model with only aggregate technology shocks and no trade in investment goods, the cross-country consumption correlation is 0.75 (see Table 2 in the appendix). If you allow trade in investment goods in this model, the cross-country output correlation decreases to 0.67 (see Table 3 in the appendix). In the model with only investment-specific technology shocks and no trade in investment goods, the cross-country consumption correlation is 0.67. If you allow trade in investment goods in this version of the model, the cross-country consumption correlation decreases to 0.65. In the model with both aggregate and investment-specific technology shocks and no trade in investment goods, the cross-country consumption correlation is 0.73. If you allow trade in investment goods in this version of the model, the cross-country consumption correlation decreases to 0.68.

Like the versions of the model with no trade in capital goods, these versions of the model also cannot completely solve the quantity anomaly. But it makes a progress by reducing the counterfactual gap between the the cross-country correlations in output and consumption.

6.2.3 International Co-Movement Puzzle

In the data the cross-country correlations in labor input is 0.76. Trade in investment goods, to some extent, also helps in explaining the high positive cross-country labor input correlation observed in the data. In the model with only aggregate technology shocks and no trade in investment goods, the cross-country labor input correlation is -0.34 (see Table 2 in the appendix). If you allow trade in investment goods in this model, the cross-country labor input correlation increases to 0.25 (see Table 3 in the appendix). In the model with only investment-specific technology shocks and no

trade in investment goods, the cross-country labor input correlation is 0.20. If you allow trade in investment goods in this version of the model, the cross-country labor input correlation increases to 0.56. In the model with both aggregate and investment-specific technology shocks and no trade in investment goods, the cross-country labor input correlation is 0.13. If you allow trade in investment goods in this model, the cross-country labor input correlation increases to 0.53.

In the deflated data, cross-country correlation of investment spending is 0.36. In all versions of the model, trade in investment goods tends to reduce the cross-country correlation of investment spending. In a version of the model with only investment-specific technology shocks and no trade in investment goods, the cross-country investment spending correlation is 0.26 (see Table 2 in the appendix). If you allow trade in investment goods in this version of the model, the cross-country investment correlation decreases to 0.03 (see Table 3 in the appendix). In the model with both aggregate and investment-specific technology shocks and no trade in investment goods, the cross-country investment spending is 0.13. If you allow trade in investment goods in this version of the model, the cross-country investment spending correlation decreases to -0.06.

Thus, all of these versions of the model can partly address the international co-movement puzzle. It can explain the positive comovement in labor input, but it cannot explain the positive comovement in investment spending observed in the data.

6.2.4 Other Macroeconomic Aggregates

In the deflated U.S. data the volatility of consumption relative to the volatility of GDP is 1.42. Trade in investment goods reduces the fluctuations in the aggregate output. In the model with both the aggregate technology shocks and investment-specific technology shocks and with no trade in capital goods, the volatility of the aggregate output is 1.41 (see Table 4 in the appendix). If we allow trade in this version of the model, the volatility of the aggregate output decreases to 1.33 (see Table 5 in the appendix).

In the U.S. data the volatility of consumption relative to the volatility of GDP is 0.54. Most of the versions of the model over predict the volatility of consumption. Only exceptions are the versions of the model with only investment-specific technology shocks. In a version of the model with IST shocks, inclusion of the trade in capital goods slightly increases the relative volatility of consumption. However, in a version of the model with only aggregate technology shocks trade in investment goods tends to decrease the volatility of consumption. In the model with only investment-specific technology shocks and with no trade in capital goods, the volatility of consumption is 0.53. If we allow trade in this version of the model, the volatility of consumption increases marginally to 0.54. However, in the model with only aggregate technology shocks and with no trade in capital goods, the volatility of consumption is 1.01. If we allow trade in this version of the model, the volatility of consumption decreases to 0.90.

In the deflated U.S. data the volatility of investment spending relative to the volatility of GDP is 2.96. All of the versions of the model over-predict the volatility of investment spending. Trade in investment goods explains part of this higher volatility of investment spending. In a version of the model with both the aggregate neutral technology shocks and investment-specific technology shocks and with no trade in capital goods, the volatility of investment spending is 14.7. If we allow trade in this version of the model, the volatility of investment spending increases to 15.49.

In the deflated U.S. data the volatility of labor input relative to the volatility of GDP is 1. On the other hand, all of the models under-predict the volatility of labor input. Trade in capital goods explains part of the lower variability in labor hours. In the model with both the aggregate technology shocks and investment-specific technology shocks and with no trade in capital goods, the relative volatility of labor input is 0.47. If we allow trade in this version of the model, the relative volatility of labor input decreases to 0.40.

In the deflated U.S. data the correlation of consumption with output is 0.82. The versions of the model with only aggregate technology shock and with both the aggregate and investment-specific technology shocks can explain the strong positive correlation between consumption and output. Trade in investment goods tends to increase the correlation of consumption with output. In the model with both the aggregate technology shocks and investment-specific technology shocks and with no trade in capital goods, the correlation of consumption with output is 0.63 (see Table 6 in the appendix). If we allow trade in this version of the model, the correlation of consumption with output increases to 0.7 (see Table 7 in the appendix).

In the deflated U.S. data the correlation of investment spending with output is 0.95. All versions of the model can explain a positive correlation between investment spending and output. However, the version of the model with only investment-specific technology shocks can predict a strong positive correlation between output and investment spending. Trade in capital goods tends to decrease the correlation of investment spending with output. In the model with only investment-specific technology shocks and with no trade in capital goods, the correlation of investment spending with output is 0.85. If we allow trade in this version of the model, the correlation of investment spending with output decreases to 0.79.

In the deflated U.S. data the correlation of labor input with output is 0.86. The version of the model with only IST shocks can explain a positive correlation between labor input and output. However, the version of the model with only aggregate neutral technology shocks unrealistically predicts a negative correlation between labor input and output. Trade in capital goods tends to reduce the correlation of labor input with output. In the model with only investment-specific technology shocks and with no trade in capital goods, the correlation of labor input with output is 0.72. If we allow trade in this version of the model, the correlation of labor input with output decreases to 0.6.

7 Conclusion

In the deflated data, cross-country output correlation between the U.S. and Canada is 0.48, which is not only lower than the cross-country output correlation found in the chained data but it is also closer to the observed cross-country correlation in consumer nondurable goods and services. Thus, this new IRBC fact helps to address the consumption/output anomaly to some extent. Due to the sectoral factor reallocation effects, the model with only aggregate shocks and no trade in investment goods can explain a significant part of the positive cross-country correlation in output. But it can not explain the positive cross-country co-movements in labor and investment. The sectoral factor reallocation effect is stronger in the model with only investment specific technology shocks and no trade in capital goods. It helps to generate a positive cross-country co-movements in labor and investment but it generates relatively smaller amount of positive cross-country correlation in output. Thus, in contrast to the existing IRBC models with IST shocks, I find that in a two-productive-sector IRBC model IST shocks are relatively less important than aggregate neutral technology shocks in explaining cross-country output correlation.

Trade in investment goods changes the sectoral factor reallocation effect. It increases the cross-country correlations in output and labor input. But it decreases the cross-country correlations in investment spending. The most preferred version of the model with both aggregate shocks and IST shocks and with trade in capital goods predicts that the cross-country correlations of output, consumption, labor and investment are 0.43, 0.68, 0.53 and -0.06, respectively (see Table 3 in the Appendix). Thus, this version of the model makes a progress towards solving the international co-movement puzzle and the consumption/output anomaly. To make sure that model does not counter-factually predict a negative correlation between consumption and output, and a negative correlation between labor and output, we have to incorporate both IST shocks and aggregate neutral technology shocks in the model. To make the model realistic, we also need to allow trade in investment goods. In all versions of the model, the cross-country correlations in consumption is counter-factually higher than the the cross-country correlations in output. This is due to the fact that there is a complete financial market in this model which generates a higher degree of risk sharing between Home and Foreign consumers.

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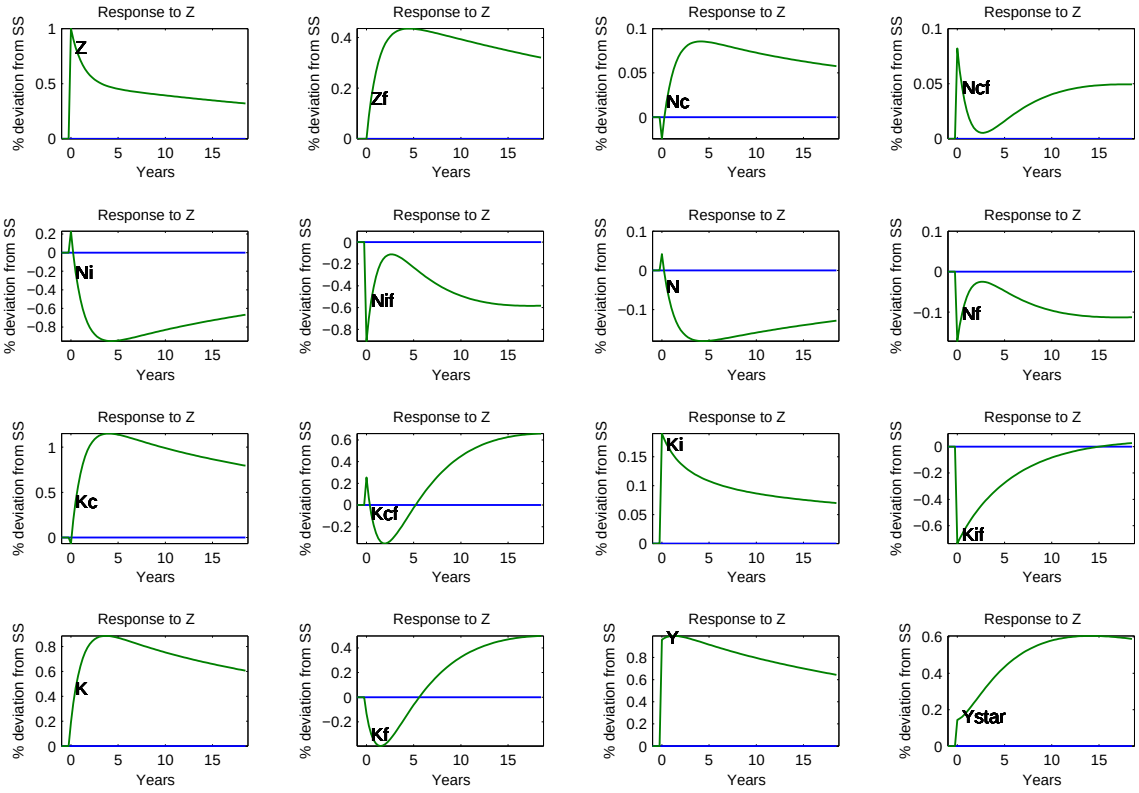
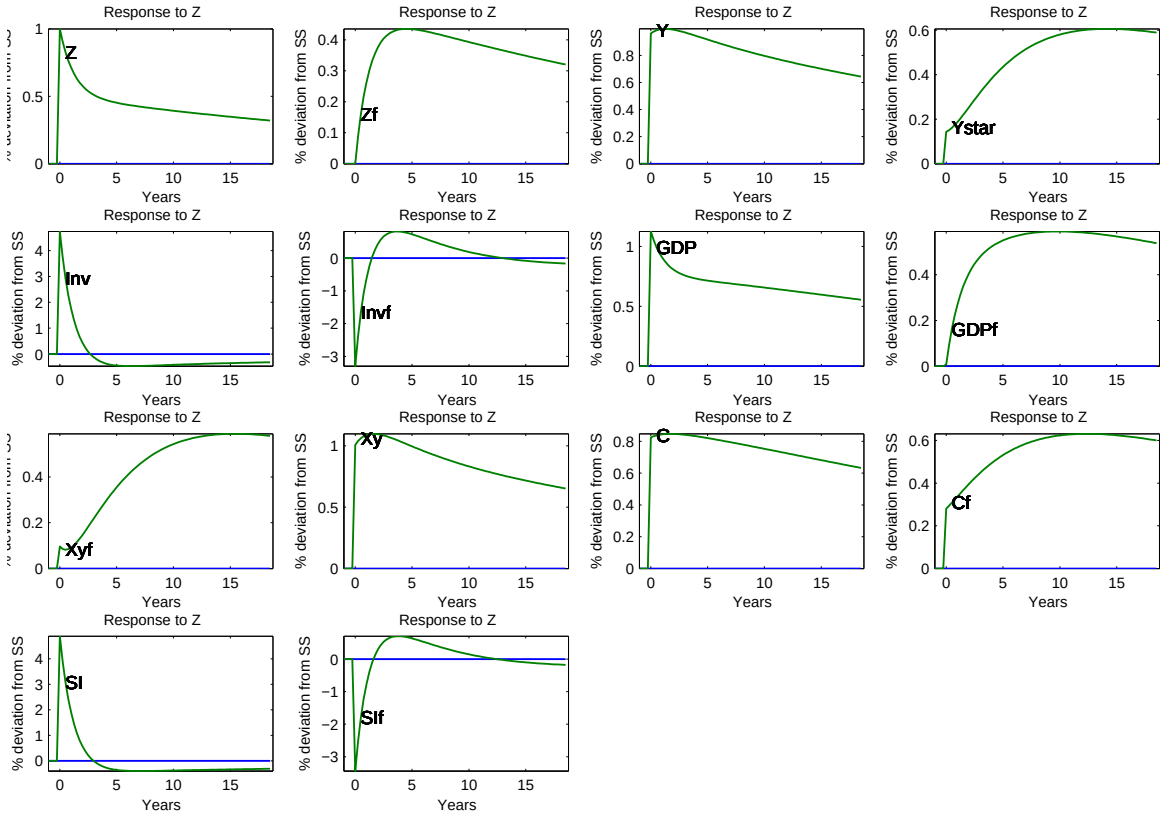
Appendix

Figure 1: Impulse Responses to a Shock in Z for a Model with NO Trade in Investment Goods



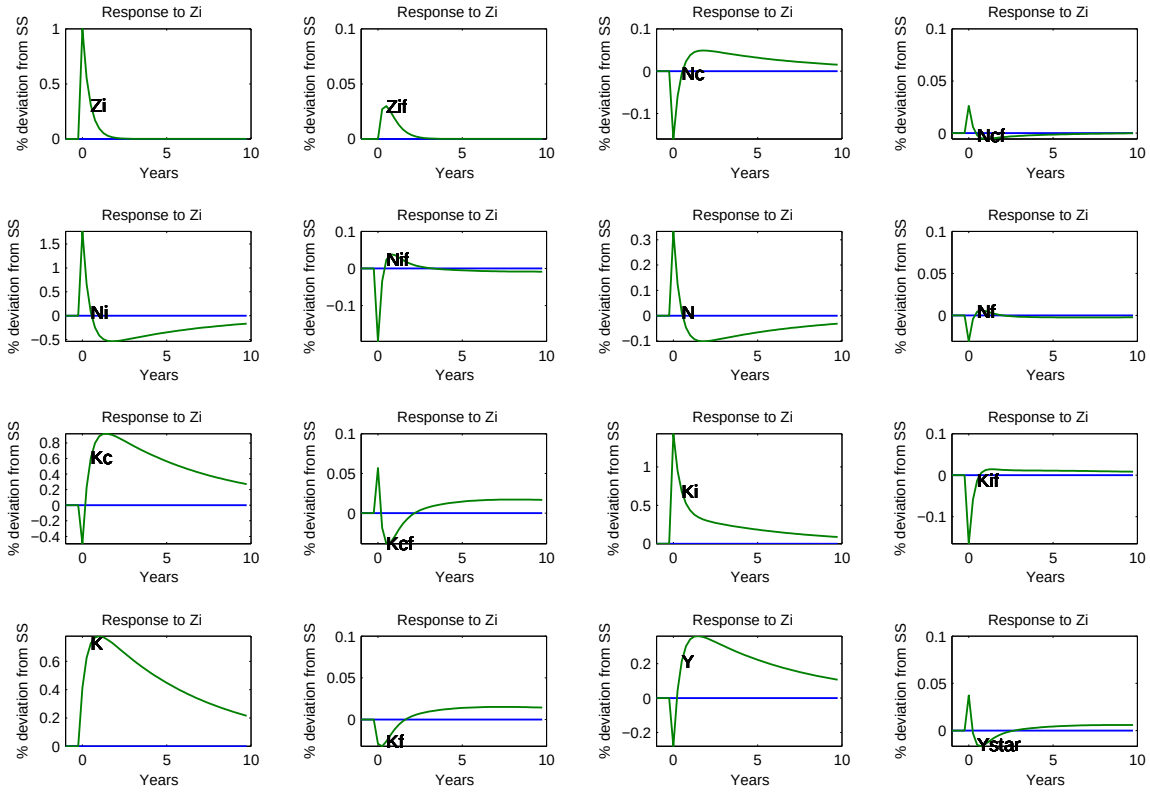
Note: **Z** denotes aggregate neutral technology shock in Home, **Zf** denotes aggregate neutral technology shock in Foreign, **Nc** denotes labor inputs in the consumption goods sector of Home, **Ncf** denotes labor inputs in the consumption goods sector of Foreign, **Ni** denotes labor inputs in the investment goods sector of Home, **Nif** denotes labor inputs in the investment goods sector of Foreign, **N** denotes total labor inputs in Home, **Nf** denotes total labor inputs in Foreign, **Kc** denotes capital in the consumption goods sector of Home, **Kcf** denotes capital in the consumption goods sector of Foreign, **Ki** denotes capital in the investment goods sector of Home, **Kif** denotes capital in the investment goods sector of Foreign, K denotes aggregate capital stock in Home, **Kf** denotes aggregate capital stock in Foreign, **Y** denotes output in the consumption goods sector of Home and **Ystar** denotes output in the investment goods sector of Foreign.

Figure 2: Impulse Responses to a Shock in Z for a Model with NO Trade in Investment Goods



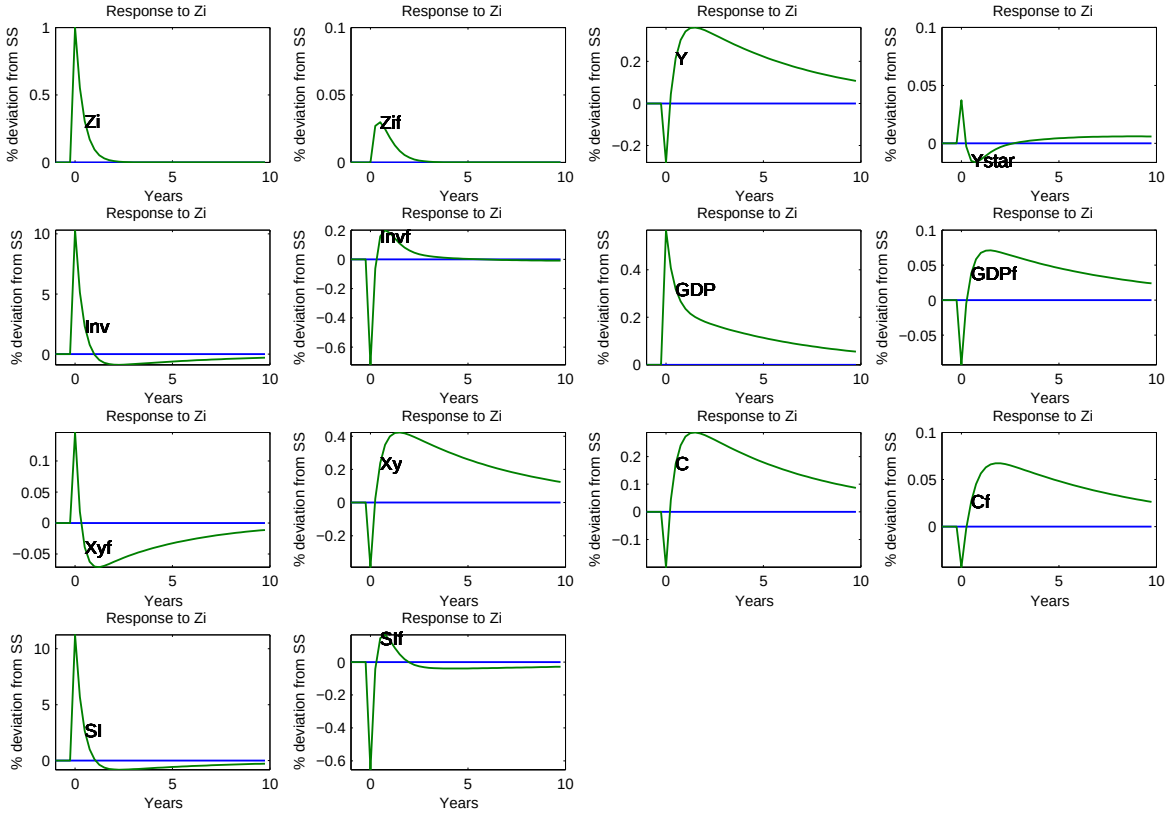
Note: **Z** denotes aggregate neutral technology shock in Home, **Zf** denotes aggregate neutral technology shock in Foreign, **Y** denotes output in the consumption goods sector of Home, **Ystar** denotes output in the investment goods sector of Foreign, **Inv** denotes output in the investment goods sector of Home, **Inv** denotes output in the investment goods sector of Foreign, **GDP** denotes gross domestic products in terms of consumption goods in Home, **GDPf** denotes gross domestic products in terms of consumption goods in Foreign, **Xyf** denotes exports of consumption goods by Foreign, **Xy** denotes exports of consumption goods by Home, **C** denotes total consumption in Home, **Cf** denotes total consumption in Foreign, **SI** denotes aggregate investment spending in terms of consumption goods in Home and **SIf** denotes aggregate investment spending in terms of consumption goods in Foreign.

Figure 3: Impulse Responses to a Shock in Zi for a Model with NO Trade in Investment Goods



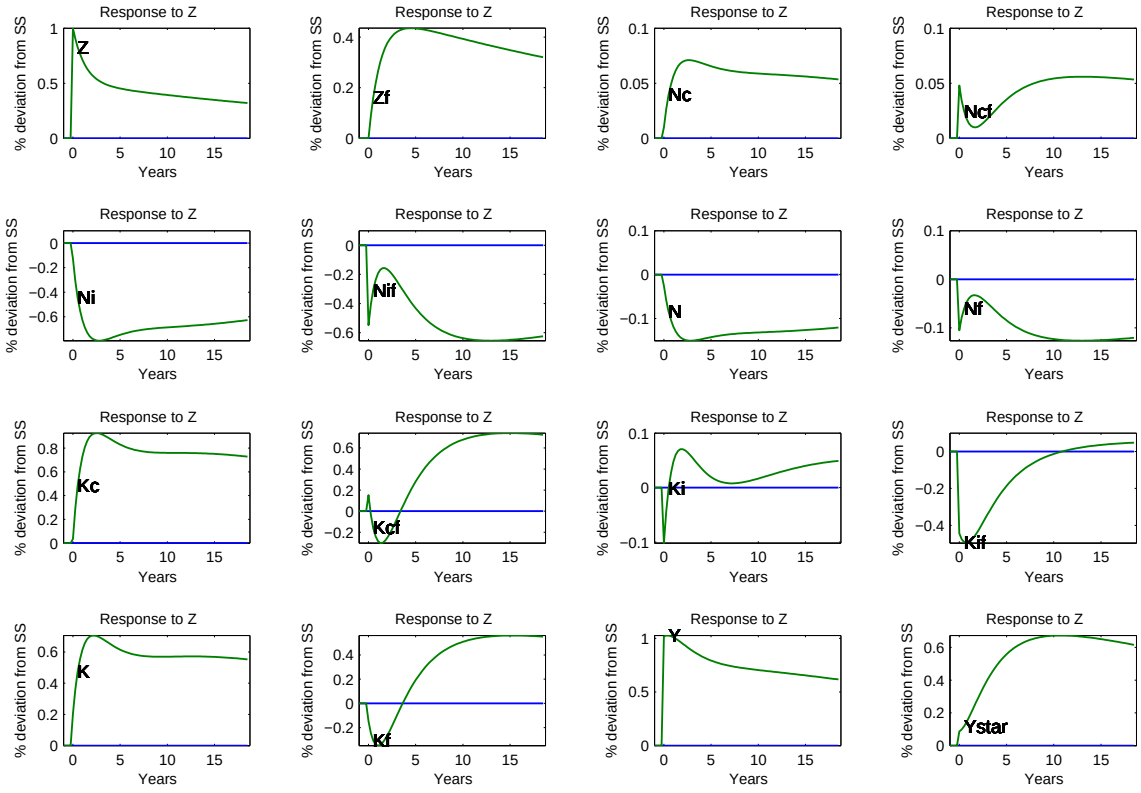
Note: **Zi** denotes investment-specific technology shock in Home, **Zif** denotes investment-specific technology shock in Foreign, **Nc** denotes labor inputs in the consumption goods sector of Home, **Ncf** denotes labor inputs in the consumption goods sector of Foreign, **Ni** denotes labor inputs in the investment goods sector of Home, **Nif** denotes labor inputs in the investment goods sector of Foreign, **N** denotes total labor inputs in Home, **Nf** denotes total labor inputs in Foreign, **Kc** denotes capital in the consumption goods sector of Home, **Kcf** denotes capital in the consumption goods sector of Foreign, **Ki** denotes capital in the investment goods sector of Home, **Kif** denotes capital in the investment goods sector of Foreign, **K** denotes aggregate capital stock in Home, **Kf** denotes aggregate capital stock in Foreign, **Y** denotes output in the consumption goods sector of Home and **Ystar** denotes output in the investment goods sector of Foreign.

Figure 4: Impulse Responses to a Shock in Zi for a Model with NO Trade in Investment Goods



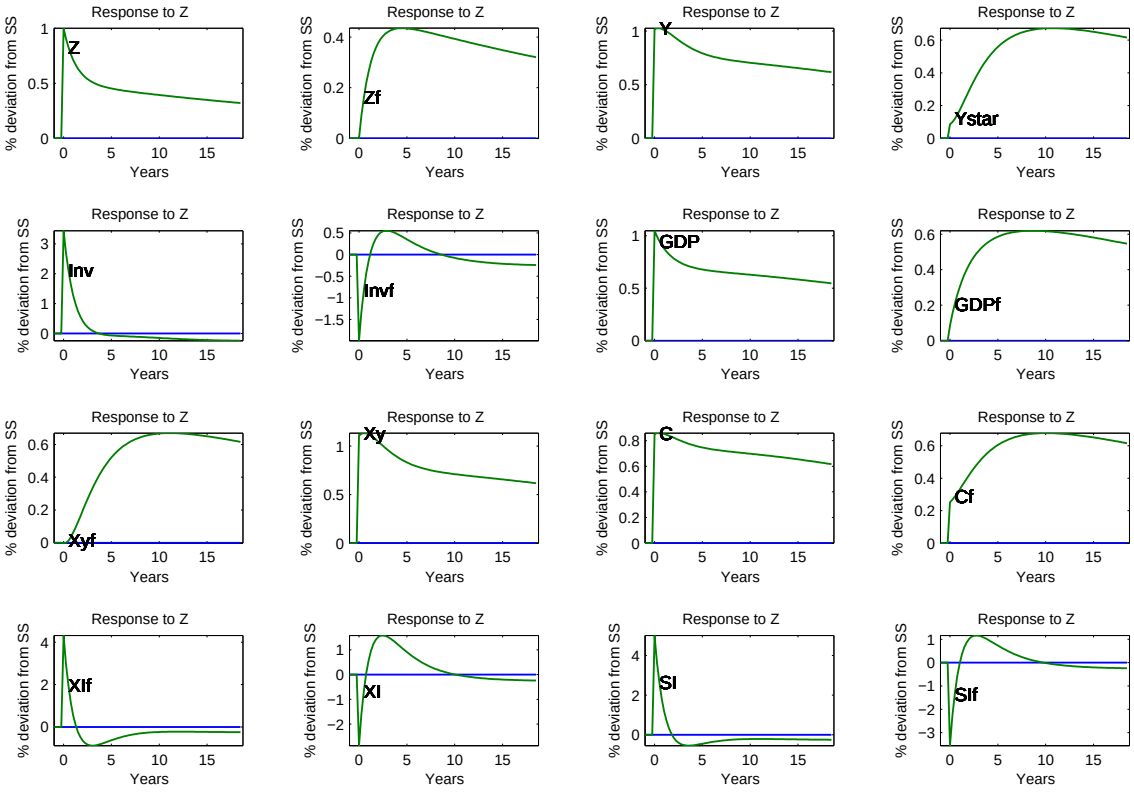
Note: **Zi** denotes investment-specific technology shock in Home, **Zif** denotes investment-specific technology shock in Foreign, **Y** denotes output in the consumption goods sector of Home, **Ystar** denotes output in the investment goods sector of Foreign, **Inv** denotes output in the investment goods sector of Home, **Inv** denotes output in the investment goods sector of Foreign, **GDP** denotes gross domestic products in terms of consumption goods in Home, **GDPf** denotes gross domestic products in terms of consumption goods in Foreign, **Xyf** denotes exports of consumption goods by Foreign, **Xy** denotes exports of consumption goods by Home, **C** denotes total consumption in Home, **Cf** denotes total consumption in Foreign, **SI** denotes aggregate investment spending in terms of consumption goods in Home and **SIf** denotes aggregate investment spending in terms of consumption goods in Foreign.

Figure 5: Impulse Responses to a Shock in Z for a Model with Trade in Investment Goods



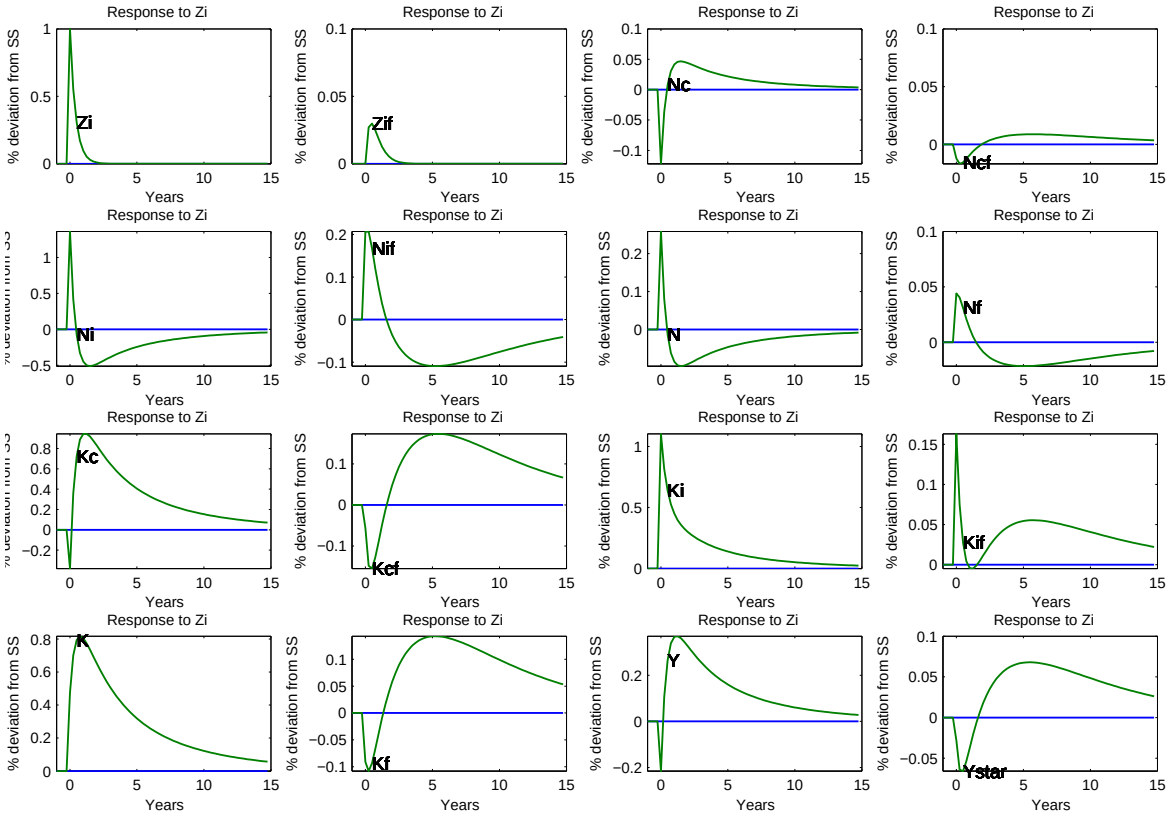
Note: Z denotes aggregate neutral technology shock in Home, Zf denotes aggregate neutral technology shock in Foreign, Nc denotes labor inputs in the consumption goods sector of Home, Ncf denotes labor inputs in the consumption goods sector of Foreign, Ni denotes labor inputs in the investment goods sector of Home, Nif denotes labor inputs in the investment goods sector of Foreign, N denotes total labor inputs in Home, Nf denotes total labor inputs in Foreign, Kc denotes capital in the consumption goods sector of Home, Kcf denotes capital in the consumption goods sector of Foreign, Ki denotes capital in the investment goods sector of Home, Kif denotes capital in the investment goods sector of Foreign, K denotes aggregate capital stock in Home, Kf denotes aggregate capital stock in Foreign, Y denotes output in the consumption goods sector of Home and Ystar denotes output in the investment goods sector of Foreign.

Figure 6: Impulse Responses to a Shock in Z for a Model with Trade in Investment Goods



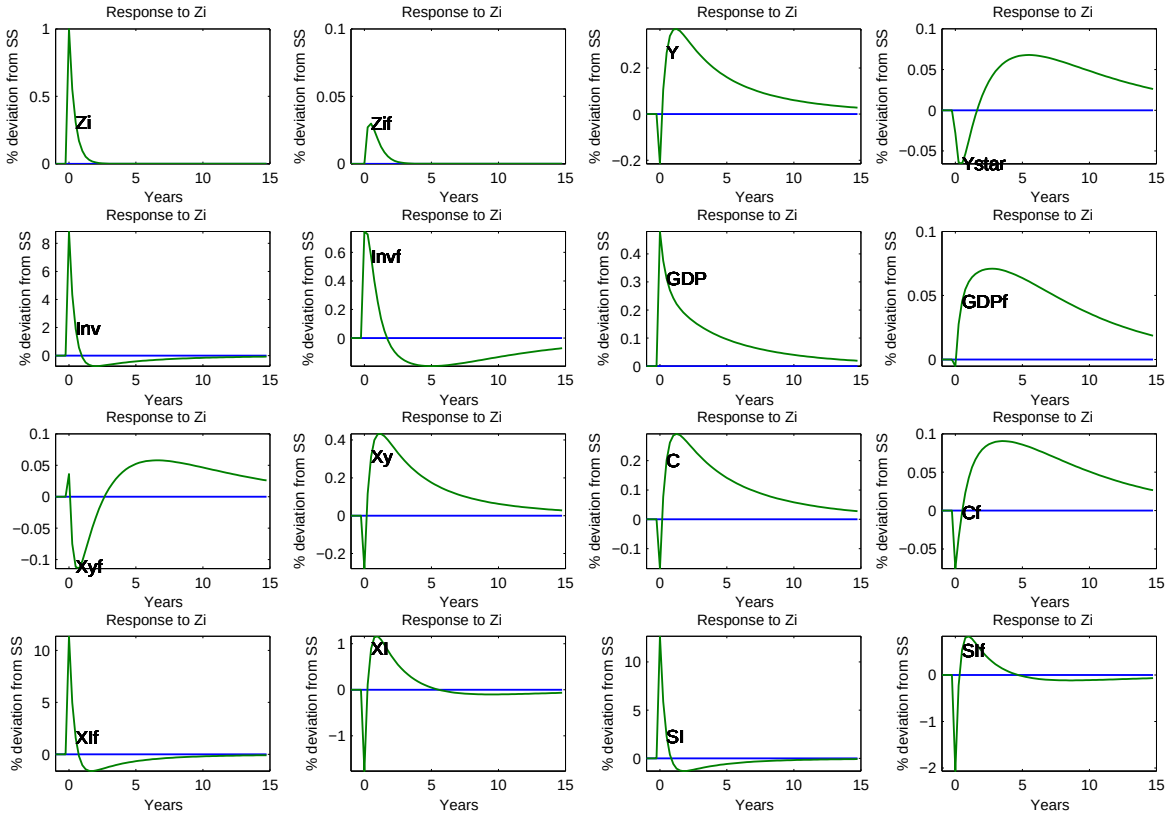
Note: **Z** denotes aggregate neutral technology shock in Home, **Zf** denotes aggregate neutral technology shock in Foreign, **Y** denotes output in the consumption goods sector of Home, **Ystar** denotes output in the investment goods sector of Foreign, **Inv** denotes output in the investment goods sector of Home, **Inv** denotes output in the investment goods sector of Foreign, **GDP** denotes gross domestic products in terms of consumption goods in Home, **GDPf** denotes gross domestic products in terms of consumption goods in Foreign, **Xyf** denotes exports of consumption goods by Foreign, **Xy** denotes exports of consumption goods by Home, C denotes total consumption in Home, **Cf** denotes total consumption in Foreign, **XIf** denotes exports of investment goods by Foreign, **XI** denotes exports of investment goods by Home, **SI** denotes aggregate investment spending in terms of consumption goods in Home and **SIf** denotes aggregate investment spending in terms of consumption goods in Foreign.

Figure 7: Impulse Responses to a Shock in Zi for a Model with Trade in Investment Goods



Note: **Zi** denotes investment-specific technology shock in Home, **Zif** denotes investment-specific technology shock in Foreign, **Nc** denotes labor inputs in the consumption goods sector of Home, **Ncf** denotes labor inputs in the consumption goods sector of Foreign, **Ni** denotes labor inputs in the investment goods sector of Home, **Nif** denotes labor inputs in the investment goods sector of Foreign, **N** denotes total labor inputs in Home, **Nf** denotes total labor inputs in Foreign, **Kc** denotes capital in the consumption goods sector of Home, **Kcf** denotes capital in the consumption goods sector of Foreign, **Ki** denotes capital in the investment goods sector of Home, **Kif** denotes capital in the investment goods sector of Foreign, **K** denotes aggregate capital stock in Home, **Kf** denotes aggregate capital stock in Foreign, **Y** denotes output in the consumption goods sector of Home and **Ystar** denotes output in the investment goods sector of Foreign.

Figure 8: Impulse Responses to a Shock in Zi for a Model with Trade in Investment Goods



Note: **Zi** denotes investment-specific technology shock in Home, **Zif** denotes investment-specific technology shock in Foreign, **Y** denotes output in the consumption goods sector of Home, **Ystar** denotes output in the investment goods sector of Foreign, **Inv** denotes output in the investment goods sector of Home, **Inv** denotes output in the investment goods sector of Foreign, **GDP** denotes gross domestic products in terms of consumption goods in Home, **GDPf** denotes gross domestic products in terms of consumption goods in Foreign, **Xyf** denotes exports of consumption goods by Foreign, **Xy** denotes exports of consumption goods by Home, **C** denotes total consumption in Home, **Cf** denotes total consumption in Foreign, **XIf** denotes exports of investment goods by Foreign, **XI** denotes exports of investment goods by Home, **SI** denotes aggregate investment spending in terms of consumption goods in Home and **SIf** denotes aggregate investment spending in terms of consumption goods in Foreign.

Table 1: Parameter Values

Parameters	Value	Description
β	0.99	Time discount rate
μ	0.34	Preference parameter
ξ	-1.0	Implies a coefficient of relative risk aversion of 1.33
α	0.36	Capital's share in the consumption goods sector
γ	0.36	Capital's share in the investment goods sector
δ	0.025	Quarterly depreciation rate of Capital
$\frac{1}{1-\eta_C}$	0.9	Elasticity of substitution between Home and Foreign consumption goods
$\frac{1}{1-\eta_I}$	0.9	Elasticity of substitution between Home and Foreign investment goods
$\frac{X^*_{Yt^*}}{Yt}$	0.15	Percentage of imported Foreign consumption good out of the total production of Home consumption goods
$\frac{X^*_{It^*}}{It}$	0.23	Percentage of imported Foreign investment good out of the total production of Home investment goods
w_Y	0.87	Share of Home consumption goods in the Armington aggregator for the composite Home consumption good
w_I	0.79	Share of Home investment goods in the Armington aggregator for the composite Home investment good
ω	0.5	Value of the capital adjustment cost parameter

Table 2: Cross-Country Correlations Based on the Simulations of the Models with No Trade in Investment Goods

Variables	Chained Data	Deflated Data	Model with Only Z	Model with Only Z_i	Model with Both Z & Z_i
GDP	0.73	0.48	0.32	0.14	0.27
Consumption	0.45	0.45	0.75	0.67	0.73
Labor	0.76	0.76	-0.34	0.20	0.13
Investment	0.34	0.36	-0.90	0.26	0.13
Relative Price of Invesment Goods	0.55	0.55	–	0.36	0.36

Notes: 1. Data covers the period 1976.1 to 2005.4. Data sources: CANSIM and BEA. 2. Simulated moments are the average over 500 replications of 120 periods each. 3. Variables have been detrended using the Hodrick-Prescott filter.

Table 3: Cross-Country Correlations Based on the Simulations of the Models with Trade in Investment Goods

Variables	Chained Data	Deflated Data	Model with Only Z	Model with Only Z_i	Model with Both Z & Z_i
GDP	0.73	0.48	0.42	0.37	0.43
Consumption	0.45	0.45	0.67	0.65	0.68
Labor	0.76	0.76	0.25	0.56	0.53
Investment	0.34	0.36	-0.91	0.03	-0.06
Relative Price of Invesment Goods	0.55	0.55	–	0.36	0.36

Notes: 1. Data covers the period 1976.1 to 2005.4. Data sources: CANSIM and BEA. 2. Simulated moments are the average over 500 replications of 120 periods each. 3. Variables have been detrended using the Hodrick-Prescott filter.

Table 4: Business Cycles Properties Based on the Simulations of the Models with No Trade in Investment Goods

Standard Deviation (in percentage)	Chained U.S. Data (Canadian Data)	Deflated U.S. Data (Canadian Data)	Model with Only Z	Model with Only Z_i	Model with Both Z & Z_i
GDP	1.41	1.42	1.19	0.76	1.41
	(1.48)	(2.02)			
Relative Price of Invesment Goods	0.77	0.77	0	1.35	1.35
	(1.41)	(1.41)			
Standard Deviation Relative to the Standard Deviation of GDP					
Consumption	0.54	0.54	1.01	0.53	1.03
	(0.62)	(0.45)			
Labor	1.00	1.00	0.17	0.43	0.47
	(1.10)	(0.81)			
Investment	2.96	2.96	4.73	13.35	14.7
	(2.77)	(2.49)			

Notes: 1. Data covers the period 1976.1 to 2005.4. Data sources: CANSIM and BEA. 2. Simulated moments are the average over 500 replications of 120 periods each. 3. Variables have been detrended using the Hodrick-Prescott filter.

Table 5: Business Cycles Properties Based on the Simulations of the Models with Trade in Investment Goods

Standard Deviation (in percentage)	Chained U.S. Data (Canadian Data)	Deflated U.S. Data (Canadian Data)	Model with Only Z	Model with Only Z_i	Model with Both Z & Z_i
GDP	1.41	1.42	1.13	0.69	1.33
	(1.48)	(2.02)			
Relative Price of Invesment Goods	0.77	0.77	0	1.36	1.35
	(1.41)	(1.41)			
Standard Deviation Relative to the Standard Deviation of GDP					
Consumption	0.54	0.54	0.90	0.54	1.05
	(0.62)	(0.45)			
Labor	1.00	1.00	0.13	0.38	0.40
	(1.10)	(0.81)			
Investment	2.96	2.96	4.91	14.8	15.49
	(2.77)	(2.49)			

Notes: 1. Data covers the period 1976.1 to 2005.4. Data sources: CANSIM and BEA. 2. Simulated moments are the average over 500 replications of 120 periods each. 3. Variables have been detrended using the Hodrick-Prescott filter.

Table 6: Correlation with Output Based on the Simulations of the Models with No Trade in Investment Goods

Correlation with Output	Chained U.S. Data (Canadian Data)	Deflated U.S. Data (Canadian Data)	Model with Only Z	Model with Only Z_i	Model with Both Z & Z_i
Consumption	0.80	0.82	0.95	-0.19	0.63
	(0.79)	(0.81)			
Labor	0.91	0.86	-0.08	0.72	0.33
	(0.86)	(0.87)			
Investment	0.93	0.95	0.73	0.85	0.64
	(0.77)	(0.81)			
Relative Price of Invesment Goods	-0.14	-0.003	-0.09	-0.89	-0.48
	(0.57)	(0.68)			

Notes: 1. Data covers the period 1976.1 to 2005.4. Data sources: CANSIM and BEA. 2. Simulated moments are the average over 500 replications of 120 periods each. 3. Variables have been detrended using the Hodrick-Prescott filter.

Table 7: Correlation with Output Based on the Simulations of the Models with Trade in Investment Goods

Correlation with Output	Chained U.S. Data (Canadian Data)	Deflated U.S. Data (Canadian Data)	Model with Only Z	Model with Only Z_i	Model with Both Z & Z_i
Consumption	0.80	0.82	0.98	-0.07	0.7
	(0.79)	(0.81)			
Labor	0.91	0.86	-0.53	0.60	0.15
	(0.86)	(0.87)			
Investment	0.93	0.95	0.65	0.79	0.56
	(0.77)	(0.81)			
Relative Price of Invesment Goods	-0.14	-0.003	0.05	-0.87	-0.45
	(0.57)	(0.68)			

Notes: 1. Data covers the period 1976.1 to 2005.4. Data sources: CANSIM and BEA. 2. Simulated moments are the average over 500 replications of 120 periods each. 3. Variables have been detrended using the Hodrick-Prescott filter.