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Investment Specific Technology Shocks and Emerging Market Business Cycle Dynamics

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Abstract: This article explores the role of investment specific technology shocks for emerging market business cycle fluctuations. The analysis is motivated by two key empirical facts; the presence of investment specific technical change in the post-war US economy together with the importance of investment goods for the emerging market imports. The goal of this paper is to quantify the contribution of the investment specific technical change in the US for the business cycles of an emerging country in the context of a two country, two sector international real business cycle framework with investment and consumption goods sectors. We estimate the model for Mexico and US data and find that a permanent US originating investment specific technology shock is very important in explaining the Mexican output and investment dynamics. This shock explains around 80\% of the investment variability and it accounts for the around 45\% of the output variability. We argue that the model's ability to account for the important business cycle features of the data is dependent on the presence of shocks that capture financial frictions as well as a permanent investment specific technology shock that originates in the US.

JEL Codes: E32, F41, F44, C11.

Keywords: Emerging markets, Investment specific technology shocks, International real business cycles.

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1 Introduction

Business cycle fluctuations of emerging market economies display different characteristics to advanced economies. In emerging market economies, output and trade balance are significantly more volatile while trade balance is much more counter-cyclical. The literature on emerging market business cycles has focused on two main explanations. The first strand of the literature builds on the hypothesis by Aguiar and Gopinath (2007) according to which the business cycle characteristics of these countries can be replicated in a standard real business cycle (RBC) framework when the main driving source of fluctuations is a shock to trend growth. The other strand of the literature, emphasizes the importance of shocks to these countries' risk premium and financial frictions[1]. In this paper, we consider the role of investment specific technology (IST) shocks arising in foreign economies in the context of an international real business cycle (IRBC) framework.

The analysis is motivated by two key empirical facts. First, an important aspect of the post-war US economy is the significant decline in the relative price of investment goods and the increase in the real investment rate[2]. Greenwood et al. (1997) explained this empirical feature by showing the important role of investment technology for US economic growth. Since then, the contribution of IST shocks in driving US business cycle fluctuations has been examined in several papers such as Greenwood et al. (2000), Fisher (2006), Justiniano et al. (2010) and Schmitt-Grohe and Uribe (2011). Second, empirical evidence shows that the imports of emerging market economies are mostly concentrated on investment goods (see Serven (1995) or Mutreja et al. (2014)). Thus, since investment specific technical change is *imported* by emerging markets, IST shocks in the US can generate international spillovers affecting emerging market fluctuations.

We quantify the effect of this channel in a setting of two country, two sector IRBC model with consumption and investment goods sectors. In the model set-up, we allow country size to differ so that we can outline a small open economy with the calibration. The general convention in the business cycle literature is to represent investment goods and consumption goods as output of a single sector while in our model, these are two separate sectors with different technologies. One can think of two explanations for having this structure. First, in an open economy framework, changes in the aggregate investment price index do not necessarily reflect the changes in the domestic productivity of investment goods[3]. Second, the two sector structure allow us to study the effects of technological improvements in the consumption and investment sectors separately. We introduce sector specific total factor productivity (TFP) shocks in both countries. The IST shock is assumed to be non-stationary to capture the trend in the relative price of investment goods. We allow this shock to be persistent in growth rates. The technology shock in the consumption sector, on the other hand, is temporary. The permanent shock in the investment sector is assumed to originate in the developed economy. It then slowly diffuses into the emerging market economy with a slow adjustment process. This formulation implies a cointegration in the long run. Intuitively, we capture the fact that technological improvements usually occur in advanced economies and take time to be acquired and implemented in emerging markets.

[1]See, Neumeyer and Perri (2005) or Garcia-Cicco et al. (2010)

[2]That is, where investment and GDP are deflated by their own prices.

[3]For a detail discussion, see Basu and Thoenissen (2011).

We also take into account the hypothesis on the importance of financial frictions and country risk premium shocks in our theoretical set-up. We incorporate a risk premium shock to the model which is a residual to the uncovered interest rate parity (UIP) condition. We assume that households need to pay a cost to undertake a position in the foreign asset market.

We estimate the model with Bayesian likelihood methods for Mexico and US data since these two countries have strong trade linkages. Using data for Mexico, we find that the share of Mexican exports to the US and Mexican imports from the US are 78% and 49%, respectively. The import share of investment goods is 55% while its export share is 48%[4]. As imports are capital goods intensive, relative price movements of investment goods in the US will transmit into the Mexican economy. This transmission operates through the substitution channel (terms of trade movements), the wealth channel (technological progress) as well as the relative investment absorption of both countries (expenditure on investment goods).

We then evaluate the importance of the US originating IST change for the business cycles of Mexico. We find that the fluctuations in output is mainly driven by sector specific technology shocks. The permanent US originating IST shock explains around 80% of the variability in investment and it accounts for the around 45% of the output variability. On the other hand, the country risk premium shock (UIP shock) accounts for the most of the fluctuations of the trade balance to output ratio and the real exchange rate.

We further asses the model performance in terms of second moments of the data. Our model successfully addresses the volatility and the autocorrelation of the trade balance to output ratio. Although having a risk premium shock is key in fitting the dynamics of trade balance to data as emphasised in for instance Garcia-Cicco et al. (2010), the value of trade elasticities are also crucial. The estimated trade elasticities in the model are around 1.5. We show that lowering the trade elasticity in both sectors to a value lower than 1 would worsen the model performance in accounting for the standard deviation and the autocorrelation of the trade balance. In addition, as observed in the data, our model delivers significant income volatility which is a consequence of the persistence of the technology shocks in the model. Our model performs well along several other dimensions like explaining the persistence of variables of interest and generating substantial investment and real exchange rate volatility. Importantly, the model generated cross-country output correlation is higher than the consumption correlation and also the model generated cross-country investment correlation is very close to the data. Since the IST shock in our model is global it generates significant cross-country investment and output correlation. At the same time, it does not affect the consumption correlation to the same extent as this shock is a shock to the productivity of the investment sector. In this respect, our model addresses important puzzles in the IRBC literature, namely the quantity and the co-movement puzzles. However, in the model relative standard deviation of consumption with respect to output is close to one, which is slightly below the typical findings for emerging markets. It also does not account for the counter-cylicality of the trade balance to output ratio, although the value delivered by the model is very close to zero as it is in our data.

This paper relates to several strands of the international real business cycle literature. As we focus on

[4]We used the data from OECD STAN Bilateral Database. We report the values from 2011 as it is the latest available data.

emerging market business cycles dynamics, our paper builds on that literature. Our paper includes two key driving sources of emerging market business cycle fluctuations that are emphasised in the literature: permanent technology shocks and country risk premium shocks. On the one hand, we show that permanent technology shocks are important for business cycle dynamics of emerging markets as Aguiar and Gopinath (2007) suggested but we find that this permanent shock takes the form of a slowly diffusing permanent IST shock that originates in the US rather than a TFP shock. On the other hand, we show that risk premium shocks are still key in explaining the dynamics of the trade balance. In this respect, the paper relates to the papers by Garcia-Cicco et al. (2010), Neumeyer and Perri (2005), Uribe and Yue (2006) and Chang and Fernandez (2013). As we present a two sector structure with investment and consumption goods, our paper is more closely related to the paper by Alvarez-Parra et al. (2013). They build a small open economy model with durable and non-durable goods augmented by shocks to trend and country risk premium. They calibrate the model to the Mexican economy and they emphasize the importance of shocks that capture financial frictions -a UIP shock- in explaining some important emerging market business cycle features. Our paper confirms their findings on the importance of a UIP shock in an estimated two country, two sector setting, but motivated by the empirical evidence we emphasize the role of a permanent IST shock and show that this shock is important for the overall performance of the model. Although papers that emphasize the role of financial frictions for the emerging market economies mostly include permanent productivity shocks in the theoretical framework, none of them investigated the fall in the relative price of investment goods, hence the role of investment specific technology shocks in their frameworks. The implications of investment specific technology shocks to address different questions in an international dimension have been studied in other papers previously, such as Boileau (2002), Raffo (2010) or Mandelman et al. (2011). This paper is more closely related to Jacob and Peersman (2013). They examined the driving sources of the US trade balance variability and found that the marginal efficiency investment shock -a shock that increases the efficiency of transforming investment goods into physical capital- accounts for most of the US trade balance fluctuations. Finally, since we show that a US originated investment specific technology shock is significantly important for the fluctuations of Mexican output and investment, our paper also relates to the literature that explores the importance of US shocks for the business cycle fluctuations of emerging market countries (see, for instance, Canova (2005) or Mackowiak (2007)). Different from these papers, we analyse the importance of US shocks within a structural model of IRBC and highlight the role of investment specific technical change.

The rest of the paper is structured as follows. We begin by describing the model in Section 2. In Section 3, we outline the Bayesian estimation of the model. We present the results in Section 4 by discussing the second moments, variance decomposition and the impulse response analysis. Finally, we conclude in Section 5.

2 The Model

The model we present here, is a two country, two sector small open economy general equilibrium model. The two countries, Home (H) and Foreign (F), are populated by a mass of infinitely lived households with a fraction of (n) and $(1-n)$ of the world total, respectively. Firms can produce either consumption goods or investment goods and they can sell those goods in the domestic and foreign markets. There are deviations from the purchasing power parity (PPP) through the existence of home bias in preferences which depends on the degree of openness and the country size. We allow for some other real frictions that are common in the literature. Specifically, we introduce external habit formation in consumption, incomplete international asset market structure and investment adjustment costs. There are country and sector specific technology shocks as well as a UIP shock. We assume that the IST shock is non-stationary and cointegrated across economies. We will denote the foreign country variables by an asterisk, (*).

2.1 Households

The preferences over intertemporal decisions are identical across countries. The representative home household, (i), receives utility from consumption (C_t^i), and disutility from supplying labour (L_t^i). The representative home household's, (i), lifetime utility function can be expressed as:

$$U_t^i = E_t \sum_{t=0}^{\infty} \beta^t \left[log(C_t^i - hC_{t-1}) - \frac{(L_t^i)^{1+\eta}}{1+\eta} \right], \quad 0 < \beta < 1 \tag{1}$$

where E_t denotes the expectations operator conditional on time t information, β is the discount factor, h is the degree of external habit formation and the parameter η is the inverse of the Frisch elasticity of labour supply. The log consumption utility ensures the existence of a balanced growth path in the model as there is a permanent IST shock.

Households obtain income through the rent on labour and capital they supply to the domestic firms. Households also receive nominal profits from the ownership of the domestic firms. It is assumed that the international asset markets are incomplete, in the sense that households are able to trade non-state-contingent bonds to invest in new capital and purchase consumption goods. Here, we follow Benigno (2001) to model incomplete asset market structure. Households in the home country can hold two kinds of bonds which are denominated in the units of the home currency and the foreign currency. However, the bonds issued by the home country are not traded internationally. In order to have a stationary distribution of wealth between countries there is an additional cost for the households in the home country when they trade in the foreign asset market. Intuitively, when households at home country borrow from the foreign asset market, they will pay a premium that is charged on the foreign interest rate.

The representative home household, (i), maximises (1) subject to the budget constraint:

$$P_{c,t}C_t^i + P_{x,t}X_t^i + \frac{B_{H,t}^i}{(1+i_t)} + \frac{S_t B_{F,t}^i}{(1+i_t^*)\Theta\left(\dfrac{S_t B_{F,t}}{P_{c,t}}\right)} \leq$$

$$B_{H,t-1}^i + S_t B_{F,t-1}^i + W_t^i L_t^i + P_{x,t} R_t^K K_{t-1}^i + \Pi_t^i \quad (2)$$

where $B_{H,t}^i$ and $B_{F,t}^i$ are the household i's holdings of the domestic and foreign currency denominated nominal risk-free bonds. The nominal interest rates on these bonds in time t are i_t and i_t^* respectively, S_t is the nominal exchange rate defined as the home currency price of buying one unit of foreign currency. $P_{c,t}$ and $P_{x,t}$ are the price of consumption and investment goods respectively, in the home country. The cost function $\Theta(\cdot)$ ensures a well defined steady state and is given for domestic households as it depends on the holdings of foreign currency denominated bonds of the world.[5] W_t^i represents the nominal wage rate, X_t^i is the investment, K_{t-1}^i is the capital stock, R_t^K denotes the real rental rate of capital in investment units and Π_t^i is the profit income from domestic firms.

The law of motion for capital is given by:

$$K_t^i \;=\; (1-\delta^K)K_{t-1}^i \;+\; \left[1 - S\left(\frac{X_t^i}{X_{t-1}^i}\right)\right] X_t^i \quad (3)$$

where δ^K is the capital depreciation rate. The functional form of the investment adjustment cost, $S(\cdot)$, has the following properties as in Christiano et al. (2005): $S(1) = S'(1) = 0$ and $S''(1) > 0$.

The equilibrium conditions of the household in the home country for labour, domestic and foreign bond holdings, capital and investment are characterised by:

$$w_t \;=\; L_t^\eta \left(C_t - hC_{t-1}\right) \quad (4)$$

$$1 = \beta(1+i_t)E_t\left[\left(\frac{C_t - hC_{t-1}}{C_{t+1} - hC_t}\right)\left(\frac{P_{c,t}}{P_{c,t+1}}\right)\right] \quad (5)$$

$$1 = \beta(1+i_t^*)\Theta(S_t B_{F,t}/P_{c,t})E_t\left[\left(\frac{C_t - hC_{t-1}}{C_{t+1} - hC_t}\right)\left(\frac{P_{c,t}}{P_{c,t+1}}\right)\left(\frac{S_{t+1}}{S_t}\right)\right] \quad (6)$$

[5]In order to prevent non-stationarity in the model, we impose the following restrictions on the cost function: $\Theta(\cdot)$ is a differentiable decreasing function in the neighbourhood of steady state level of net foreign assets and when the net foreign assets are in the steady state level ($B_{F,t}^i = 0$), the cost function is equal to 1 ($\Theta(0) = 1$). See Benigno (2001) for details.

$$Q_t = \beta E_t \left[\left(\frac{C_t - hC_{t-1}}{C_{t+1} - hC_t} \right) \left(\frac{P_{x,t+1}}{P_{c,t+1}} R^K_{t+1} + (1 - \delta^K) Q_{t+1} \right) \right] \tag{7}$$

$$\frac{P_{x,t}}{P_{c,t}} - Q_t \left(1 - S\left(\frac{I_t}{I_{t-1}} \right) - \left(\frac{I_t}{I_{t-1}} \right) S'\left(\frac{I_t}{I_{t-1}} \right) \right) = \\ \beta E_t \left[\left(\frac{C_t - hC_{t-1}}{C_{t+1} - hC_t} \right) Q_{t+1} \left(S'\left(\frac{I_{t+1}}{I_t} \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right) \right] \tag{8}$$

where w_t is the real wage in consumption units and Q_t is the shadow price of capital in consumption units. Equation (7) shows that the cost of installing an additional unit of capital is equal to the sum of present discounted future value and the rental rate. Notice that changes in the relative price of investment goods will affect the marginal value of acquiring an extra unit of capital. A fall in the relative price of investment goods will lower the cost of installing an additional unit of capital.

The situation of foreign households is analogous.

2.2 Final Goods Sector

Final goods in both sectors is a combination of home and foreign produced intermediate goods. Countries only trade intermediate goods; final goods can not be traded.

The final good in the home consumption sector consists of home produced consumption goods ($C_{H,t}$) and imported goods ($C_{F,t}$) and in the foreign country, it consists of foreign produced consumption goods ($C^*_{F,t}$) and imported goods ($C^*_{H,t}$). The aggregate consumption index has the following constant elasticity of substitution (CES) aggregation form in the home and foreign country, respectively:

$$C_t = \left(\omega^{\frac{1}{\theta}} (C_{H,t})^{\frac{\theta-1}{\theta}} + (1-\omega)^{\frac{1}{\theta}} (C_{F,t})^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \tag{9}$$

$$C^*_t = \left(\omega^{*\frac{1}{\theta}} (C^*_{F,t})^{\frac{\theta-1}{\theta}} + (1-\omega^*)^{\frac{1}{\theta}} (C^*_{H,t})^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \tag{10}$$

where θ is the elasticity of substitution between home and foreign produced intermediate consumption goods. The parameter that determines the share of foreign produced intermediate goods in the production of the final consumption good at home, $(1-\omega)$, is a function of the degree of openness in the consumption sector, (ρ), and the relative country size, $(1-n)$ [6]: $(1-\omega) = (1-n)\,\rho$. The value of ω determines the degree of home bias in consumption preferences. And in the foreign country, $(1-\omega^*) = n\,\rho^*$.

The final good producers in the consumption sector maximises (9) subject to nominal expenditure which

[6] See, De Paoli (2009) for a similar preference specification in a two country, small open economy general equilibrium framework.

gives the following demand functions for the home and foreign country respectively:

$$C_{H,t} = \omega \left(\frac{P_{H,t}}{P_{c,t}} \right)^{-\theta} C_t \ , \qquad C_{F,t} = (1-\omega) \left(\frac{P_{F,t}}{P_{c,t}} \right)^{-\theta} C_t \tag{11}$$

$$C^*_{F,t} = \omega^* \left(\frac{P^*_{F,t}}{P^*_{c,t}} \right)^{-\theta} C^*_t \ , \qquad C^*_{H,t} = (1-\omega^*) \left(\frac{P^*_{H,t}}{P^*_{c,t}} \right)^{-\theta} C^*_t \tag{12}$$

The corresponding consumer price indices are:

$$P_{c,t} = \left(\omega P_{H,t}^{1-\theta} + (1-\omega) P_{F,t}^{1-\theta} \right)^{\frac{1}{1-\theta}} \tag{13}$$

$$P^*_{c,t} = \left(\omega^* (P^*_{F,t})^{1-\theta} + (1-\omega^*)(P^*_{H,t})^{1-\theta} \right)^{\frac{1}{1-\theta}} \tag{14}$$

We assume that law of one price (LoOP) holds such that: $P_{F,t} = S_t P^*_{F,t}$ and $P^*_{H,t} = P_{H,t}/S_t$. Thus in our framework there are deviations from PPP only through the existence of home bias.

Similarly, the final good in the investment sector is a combination of domestically produced investment goods -$X_{H,t}$ at home, $X^*_{F,t}$ at foreign country- and imported goods -$X_{F,t}$ at home, $X^*_{H,t}$ at foreign country- and has the CES aggregation form:

$$X_t = \left(\nu^{\frac{1}{\alpha}} (X_{H,t})^{\frac{\alpha-1}{\alpha}} + (1-\nu)^{\frac{1}{\alpha}} (X_{F,t})^{\frac{\alpha-1}{\alpha}} \right)^{\frac{\alpha}{\alpha-1}} \tag{15}$$

$$X^*_t = \left({\nu^*}^{\frac{1}{\alpha}} (X^*_{F,t})^{\frac{\alpha-1}{\alpha}} + (1-\nu^*)^{\frac{1}{\alpha}} (X^*_{H,t})^{\frac{\alpha-1}{\alpha}} \right)^{\frac{\alpha}{\alpha-1}} \tag{16}$$

where α is the elasticity of substitution between home and foreign produced intermediate investment goods. The share of foreign produced intermediate goods for the production of the final investment good, $(1-\nu)$, is similarly a function of the degree of openness in the investment sector, (ϕ) and (ϕ^*), and the relative country size, $(1-n)$ and n: $(1-\nu) = (1-n)\,\phi$ and $(1-\nu^*) = n\,\phi^*$. The value of ν and ν^* determines the degree of home bias in the investment sector.

The optimal choice of final good producers in the investment sector yields:

$$X_{H,t} = \nu \left(\frac{P_{x^H,t}}{P_{x,t}} \right)^{-\alpha} X_t \ , \qquad X_{F,t} = (1-\nu) \left(\frac{P_{x^F,t}}{P_{x,t}} \right)^{-\alpha} X_t \tag{17}$$

$$X^*_{F,t} = \nu^* \left(\frac{P^*_{x^F,t}}{P^*_{x,t}} \right)^{-\alpha} X^*_t \ , \qquad X^*_{H,t} = (1-\nu^*) \left(\frac{P^*_{x^H,t}}{P^*_{x,t}} \right)^{-\alpha} X^*_t \tag{18}$$

The corresponding price indices for the investment goods are:

$$P_{x,t} = \left(\nu P^{1-\alpha}_{x^H,t} + (1-\nu) P^{1-\alpha}_{x^F,t} \right)^{\frac{1}{1-\alpha}} \tag{19}$$

$$P^*_{x,t} = \left(\nu^* (P^*_{x^F,t})^{1-\alpha} + (1-\nu^*)(P^*_{x^H,t})^{1-\alpha} \right)^{\frac{1}{1-\alpha}} \tag{20}$$

As a result of LoOP; imported investment good prices will simply be the price that foreign producers set for those goods, corrected by the nominal exchange rate:

$$P_{x^F,t} = S_t P^*_{x^F,t} \ , \qquad P^*_{x^H,t} = P_{x^H,t}/S_t$$

2.3 Intermediate Goods Sector

Here, we describe the production functions and the price setting mechanisms for both sectors. The intermediate good producers in both sectors can sell their goods to the final good producers from the home and foreign country. Firms produce output by using labour and capital and production has the standard constant returns to scale functional form.

The production function of the consumption goods in the home country is given by:

$$Y_{c,t} = K^{\alpha^c}_{c,t-1} (A_{c,t} L_{c,t})^{1-\alpha^c} \tag{21}$$

where $A_{c,t}$ is the sector specific exogenous technology shock, $L_{c,t}$ is the total labour supply employed in the home consumption intermediate sector, $K_{c,t-1}$ denotes the use of capital in the home consumption intermediate sector and finally the parameter α^c is the capital's share of output. The technology shock in the consumption sector has the following stochastic process:

$$ln(A_{c,t}) \ = \ \rho_{a^c} \, ln(A_{c,t-1}) \ + \ \varepsilon_{a^c,t} \tag{22}$$

where $0 \leq \rho_{a^c} < 1$ and $\varepsilon_{a^c,t} \sim N(0, \sigma^2_{a^c})$.

Firms in the intermediate sector maximise the nominal profit function:

$$\Pi_{c,t} = P_{H,t} Y_{c,t} - W_t L_{c,t} - P_{x,t} R^K_t K_{c,t-1} \tag{23}$$

subject to the production function (21).

The first order conditions for the choice of capital and labour are:

$$R_t^K = \alpha^c \left(\frac{P_{H,t}}{P_{x,t}}\right) A_{c,t}^{1-\alpha^c} \left(\frac{L_{c,t}}{K_{c,t-1}}\right)^{1-\alpha^c} \tag{24}$$

$$w_t = (1-\alpha^c) \left(\frac{P_{H,t}}{P_{c,t}}\right) A_{c,t}^{1-\alpha^c} \left(\frac{K_{c,t-1}}{L_{c,t}}\right)^{\alpha^c} \tag{25}$$

And the capital-labour ratio is:

$$\frac{w_t}{R_t^K} = \frac{1-\alpha^c}{\alpha^c} \frac{K_{c,t-1}}{L_{c,t}} \frac{P_{x,t}}{P_{c,t}} \tag{26}$$

The production function of the investment goods sector is similar to the consumption goods one but with an additional non-stationary component:

$$Y_{x,t} = K_{x,t-1}^{\alpha^x} (Z_{x,t} L_{x,t})^{1-\alpha^x} \tag{27}$$

where $L_{x,t}$ is the total labour supply employed, $K_{x,t-1}$ is the use of capital and the parameter α^x is the capital's share of output in the home investment intermediate sector. Different from the consumption sector, the investment specific technology shock assumed to be non-stationary. We discuss how we formalise the permanent investment specific shock in Section 2.5.

As in the intermediate consumption sector, firms maximise the nominal profit function:

$$\Pi_{x,t} = P_{x^H,t} Y_{x,t} - W_t L_{x,t} - P_{x,t} R_t^K K_{x,t-1} \tag{28}$$

subject to the production function (27).

The first order conditions for the choice of capital and labour are:

$$R_t^K = \alpha^x \left(\frac{P_{x^H,t}}{P_{x,t}}\right) (Z_{x,t})^{1-\alpha^x} \left(\frac{L_{x,t}}{K_{x,t-1}}\right)^{1-\alpha^x} \tag{29}$$

$$w_t = (1-\alpha^x) \left(\frac{P_{x^H,t}}{P_{c,t}}\right) (Z_{x,t})^{1-\alpha^x} \left(\frac{K_{x,t-1}}{L_{x,t}}\right)^{\alpha^x} \tag{30}$$

And the capital-labour ratio is:

$$\frac{w_t}{R_t^K} = \frac{1-\alpha^x}{\alpha^x} \frac{K_{x,t-1}}{L_{x,t}} \frac{P_{x,t}}{P_{c,t}} \tag{31}$$

The capital-labour ratio of two sectors imply that capital and labour will be allocated between the two sectors depending on the share of the inputs in the production functions:

$$\frac{1-\alpha^c}{\alpha^c}\frac{K_{c,t-1}}{L_{c,t}}=\frac{1-\alpha^x}{\alpha^x}\frac{K_{x,t-1}}{L_{x,t}} \tag{32}$$

The foreign country's intermediate goods sectors are symmetric to the home country.

2.4 Equilibrium Conditions and the Current Account

We close the model by using the market clearing conditions for each sector. The output of both sectors can be consumed at home and foreign country. Equivalently, the output in the consumption (investment) sector will be equal to the sum of total consumption (investment) at home and the demand for exports minus the imports:

$$\begin{aligned}\frac{P_{H,t}}{P_{c,t}}Y_{c,t}&=\frac{P_{H,t}}{P_{c,t}}C_{H,t}+\left(\frac{1-n}{n}\right)\frac{P_{H,t}}{P_{c,t}}C^*_{H,t}\\&=C_t-\frac{P^*_{F,t}}{P_{c,t}S_t}C_{F,t}+\left(\frac{1-n}{n}\right)\frac{P_{H,t}}{P_{c,t}}C^*_{H,t}\end{aligned} \tag{33}$$

$$\begin{aligned}\frac{P_{x^H,t}}{P_{c,t}}Y_{x,t}&=\frac{P_{x^H,t}}{P_{c,t}}X_{H,t}+\left(\frac{1-n}{n}\right)\frac{P_{x^H,t}}{P_{c,t}}X^*_{H,t}\\&=\frac{P_{x,t}}{P_{c,t}}X_t-\frac{P^*_{x^F,t}}{P_{c,t}S_t}X_{F,t}+\left(\frac{1-n}{n}\right)\frac{P_{x^H,t}}{P_{c,t}}X^*_{H,t}\end{aligned} \tag{34}$$

We measure the total output in the home economy with CPI as we do not have an explicit GDP deflator:

$$Y_t=\frac{P_{H,t}}{P_{c,t}}\,Y_{c,t}+\frac{P_{x^H,t}}{P_{c,t}}\,Y_{x,t} \tag{35}$$

that is, the sum of production in the consumption and investment sectors.

As a results of the incomplete international asset market structure, we can track the dynamics of the current account[7]:

$$\begin{aligned}\frac{S_tB_{F,t}}{P_{c,t}(1+i^*_t)\Theta(\frac{S_tB_{F,t}}{P_{c,t}})}-\frac{S_tB_{F,t-1}}{P_{c,t}}=\left(\frac{1-n}{n}\right)\frac{P_{H,t}C^*_{H,t}}{P_{c,t}}-\frac{P^*_{F,t}S_tC_{F,t}}{P_{c,t}}&\\+\left(\frac{1-n}{n}\right)\frac{P_{x^H,t}X^*_{H,t}}{P_{c,t}}-\frac{P^*_{x^F,t}S_tX_{F,t}}{P_{c,t}}&\end{aligned} \tag{36}$$

[7]To see the fluctuations of the current account, we aggregate the individual budget constraints (2) and plug in the aggregate profits ($\Pi_t=P_{x^H,t}Y_{x,t}-W_tL_{x,t}-P_{x,t}R^K_tK_{x,t}+P_{H,t}Y_{c,t}-W_tL_{c,t}-P_{x,t}R^K_tK_{c,t}$). Then we apply the equilibrium conditions, Equations (33) and (34). We also take into account the assumption that asset markets are complete at domestic level; meaning home bonds are in zero net supply.

Notice that, the right hand side of the current account equation is equivalent to the net exports. It is the exports of both consumption and investment sectors minus the imports of both sectors. We define the trade balance as a ratio of GDP:

$$\frac{TB_t}{Y_t} = \frac{1}{Y_t}\left[\left(\frac{1-n}{n}\right)\frac{P_{H,t}C^*_{H,t}}{P_{c,t}} - \frac{P^*_{F,t}S_tC_{F,t}}{P_{c,t}} + \left(\frac{1-n}{n}\right)\frac{P_{x^H,t}X^*_{H,t}}{P_{c,t}} - \frac{P^*_{x^F,t}S_tX_{F,t}}{P_{c,t}}\right] \tag{37}$$

Finally, the total labour and capital will be:

$$L_t = L_{c,t} + L_{x,t} \tag{38}$$

$$K_t = K_{c,t} + K_{x,t} \tag{39}$$

2.5 The Shock Structure

The technology shock in the investment sector is a permanent shock in both countries. We assume that these two non-stationary shocks are cointegrated across countries. Specifically, we assume that the permanent IST shock in the foreign country carries a unit root while the technology of the investment sector in the home country adjusts to it slowly.

One can think of a permanent IST shock that is persistent in growth rates. This shock assumed to originate in the foreign economy:

$$ln(Z^*_{x,t}) - ln(Z^*_{x,t-1}) = \rho^*_{z^x}(ln(Z^*_{x,t-1}) - ln(Z^*_{x,t-2})) + \varepsilon^*_{z^x,t} \tag{40}$$

However, the technology of the investment sector of the home economy adjusts to this shock slowly:

$$ln(Z_{x,t}) - ln(Z^*_{x,t}) = \rho_{z^x}(ln(Z_{x,t-1}) - ln(Z^*_{x,t-1})) + \varepsilon_{z^x,t} \tag{41}$$

where the parameter ρ_{z^x} is the persistence of adjustment. We introduce a stochastic component ($\varepsilon_{z^x,t}$) to the adjustment of home investment technology to the technological improvement in the foreign country.

To have a stationary equilibrium we transform the trended variables and work with a stationarised model. The derivation of the trends and the de-trending procedure can be found in Appendix A.

Thus, in total there are four technology shocks in the model. As mentioned before, in addition to the IST shocks, there are temporary country specific technology shocks in the consumption sector. We also introduce an exogenous UIP shock to the Equation 6:

$$1 = \beta\zeta_t(1+i^*_t)\Theta(S_tB_{F,t}/P_{c,t})E_t\left[\left(\frac{C_t - hC_{t-1}}{C_{t+1} - hC_t}\right)\left(\frac{P_{c,t}}{P_{c,t+1}}\right)\left(\frac{S_{t+1}}{S_t}\right)\right] \tag{42}$$

where

$$ln(\zeta_t) \;=\; \rho_\zeta \, ln(\zeta_{t-1}) \,+\, \varepsilon_{\zeta,t}\,, \qquad 0 \leq \rho_{a^c} < 1, \quad \varepsilon_{a^c,t} \sim N(0, \sigma^2_{a^c}) \tag{43}$$

The UIP shock can be potentially interpreted as a financial friction shock as in Garcia-Cicco et al. (2010). It is a shock to the premium that households in home country pay to engage in transactions in foreign asset market.

3 Estimation

We use Bayesian estimation methods to estimate the model[8]. The stationary log-linearised model that we use for our estimations can be found in Appendix C. To obtain the posterior distributions, we run four parallel chains of 500000 replications of the Metropolis Hastings algorithm with an acceptance rate around 25%. We discard 25% of the draws. We monitor the convergence by using the Brooks and Gelman (1998) statistics[9].

3.1 Data

We estimate the model for the period 1995:Q1-2016:Q3. We assume that the home country is Mexico and foreign country is the US. We use series on real consumption, the relative price of investment goods for Mexico and the US and the bilateral trade balance to GDP ratio as observables. The trade balance to GDP ratio is the difference between the exports and imports of Mexico and US, divided by the Mexican GDP[10]. Details on the data sources can be found in Appendix D.

We plot the observables in Appendix E where we present the additional tables and figures (see, Figure 3). We take the natural logarithms of all series except for the trade balance to GDP ratio and we then demean all series. Having a permanent shock in the model allows a consistent way of de-trending between the model and the data. As consumption and the relative price of investment good are trended, we measure them in

[8]See, An and Schorfheide (2007) for a detailed description of implementation of Bayesian estimation.

[9]To conduct estimations, we use the MATLAB version of Dynare (see, Adjemian et al. (2011)).

[10]The bilateral export and import data are only available in nominal terms in US dollars. What we observe in the data is then:

$$\frac{TB_t}{Y_t} = \frac{1}{(P_{c,t}/S_t)\,Y_t}\left[\frac{1-n}{n}(P_{H,t}/S_t)C^*_{H,t} - P^*_{F,t}C_{F,t} + \frac{1-n}{n}(P_{x^H,t}/S_t)X^*_{H,t} - P^*_{x^F,t}X_{F,t}\right]$$

This could create measurement issues given that in the model we present all variables in relative prices. But we avoid such problem since the above stated equation is observationally equivalent to the Equation 37.

first differences. To match the data, we define following observables in the model:

$$c_{obs,t} = c_t - c_{t-1} + \alpha \Delta z^*_{x,t} \tag{44}$$

$$c^*_{obs,t} = c^*_t - c^*_{t-1} + \alpha^* \Delta z^*_{x,t} \tag{45}$$

$$rx_{obs,t} = rx_t - rx_{t-1} - (1-\alpha)\Delta z^*_{x,t} \tag{46}$$

$$rx^*_{obs,t} = rx^*_t - rx^*_{t-1} - (1-\alpha^*)\Delta z^*_{x,t} \tag{47}$$

where $\Delta z^*_{x,t}$ is the first difference of the global IST shock, rx_t and $rx^*_{x,t}$ are the relative price of investment goods in the home and foreign country respectively ($rx_t = p_{x,t} - p_{c,t}$, $rx^*_t = p^*_{x,t} - p^*_{c,t}$). As the trade balance is stationary in levels, the demeaned series is equivalent to the model specification. Note that in our calibration, the capital share on the production of intermediate goods is assumed to be symmetric across sectors and countries ($\alpha_c = \alpha_x = \alpha^*_c = \alpha^*_x$).

3.2 Priors and Calibration

Table 2 shows the prior distributions of the estimated coefficients. Our prior choice is standard. We use gamma distribution for the inverse Frisch elasticity of labour supply and trade elasticities for both sectors. We allow for a large standard deviation as the estimates of these parameters vary among studies. We use gamma distribution for the cost of intermediation parameter with a mean of 0.01 and a standard deviation of 0.001. Investment adjustment costs assumed to follow a gamma distribution with a mean of 4 and a standard deviation of 1. We use beta distribution for the parameters that are bounded between zero and one. The prior choice of the consumption habit parameter is standard among estimated general equilibrium models (for instance, see Smets and Wouters (2003)). We set the prior mean of the autoregressive components to 0.75 which implies high persistence. We choose inverse gamma distribution for the standard error of shocks with a mean of 0.1 and standard deviation of 2.

Table 1: Calibrated Parameters

Parameter	Description	Value
β	discount factor	0.99
n	relative country size	0.25
δ^K	depreciation rate	0.025
$\rho = \rho^*$	degree of openness-consumption	0.07
$\phi = \phi^*$	degree of openness-investment	0.16
$\alpha_c = \alpha_x = \alpha^*_c = \alpha^*_x$	capital share	0.36

We calibrate the remaining parameters. We set the discount factor, β, to 0.99 so that the annual steady state interest rate is around 4%. We calculated the relative country size by using the population share.

The depreciation rate, δ^K, is set to 0.025 per quarter, implying a 10% annual depreciation on capital. The share of imported goods in both sectors are country size adjusted in the model: $(1-\omega) = (1-n)\,\rho$ in the consumption goods and $(1-\nu) = (1-n)\,\phi$ in the investment goods. To calculate the degree of openness parameters, we took the data from World Input Output Database and used the national input output tables for Mexico and the US. We set the degree of openness in the consumption sector, ρ to 0.07 and in the investment sector, ϕ to 0.15. These values imply that the size adjusted degree of home bias is higher in the US ($\omega = 0.94$, $\omega^* = 0.98$, $\nu = 0.88$ and $\nu^* = 0.98$) and investment sectors have higher import intensity in both countries but particularly in Mexico[11]. We fix the capital share in each sector and country to 0.36 to be consistent with the literature.

3.3 Posteriors

Table 2 reports the estimation results. We present the posterior mode and the standard deviation along with the mean and the 5th and 95th percentiles of the posterior distribution. The posterior distributions of the estimated parameters can be found in Appendix E (see, Figure 4).

The estimated value of the trade elasticities are in line with the calibrations of this parameter in the IRBC literature. The posterior mean of the trade elasticity in the investment sector is 1.41 and in the consumption sector is 1.65. Most of the papers in the IRBC literature calibrates the trade elasticity to 1.5 (see for instance, Backus et al. (1993)); our estimation results are significantly close to this calibration. Our estimate of the inverse Frisch elasticity is slightly lower than 1. Findings of other studies suggest a smaller elasticity of labour supply compared with our estimate. An important aspect of the posterior distribution is that it is significantly similar to its prior distribution implying identification issues (see, Figure 4). Problems of identification in estimating the Frisch elasticity is common in many other macro studies such as Smets and Wouters (2003). A similar identification issue arises for the parameter of the cost of intermediation in the bond markets. The estimated posterior mean is in fact equal to the prior. We decided to keep this parameter in our estimation since Garcia-Cicco et al. (2010) show that the value of this parameter is crucial for the dynamics of the trade balance. We test the importance of the value of this parameter in our quantitative analysis. Although, we allow the degree of habit formation to be different between the two countries the estimation results indicate very similar habit persistence in the US and Mexico. The posterior distribution shows that consumption habits play a slightly smaller role in Mexico than in the US. The posterior mean

[11] To measure the import share of consumption and investment goods, we used the final consumption expenditure of households and the gross fixed capital formation respectively. We calculated the import shares of each sector for 5 years (2000, 2003, 2006, 2009, 2011) and averaged them. We found the share of imports in investment sector 0.17 and 0.12 in Mexico and US respectively. For consumption goods sector these values are respectively 0.07 and 0.05 for Mexico and US. We fix the value of the degree of openness parameter in the consumption sector to the value that we obtain from the Mexican data as the values are similar between Mexico and the US. In fact, the degree of home bias in the consumption sector in the US is equal to 0.98 with both values. But because this is not the case for the investment goods sector, for the value of the degree of openness in the investment sector, we choose 0.16 as an intermediate value. This value matches the US home bias but it gives a slightly higher home bias for Mexico compared with the data- with the exact data calibration, the degree of home bias in the investment sector in Mexico equals to 0.86 while with our choice it is 0.88.

estimate of investment adjustment cost for Mexico is much higher than it is for the US, $\mu = 6.40, \mu* = 1.76$. The value of the US investment adjustment cost parameter is much lower than estimates of other studies.

Table 2: Prior and Posterior Distributions

Parameter	**Description**	**Prior**			**Posterior**			
		Density	Mean	Std.dev	Mode	Std.dev	Mean	[5,95]
η	inverse frisch elasticity	gamma	1.00	0.25	0.867	0.229	0.961	[0.57, 1.34]
θ	trade elasticity-consumption	gamma	1.00	0.25	1.706	0.296	1.652	[1.18, 2.11]
α	trade elasticity-investment	gamma	1.00	0.25	1.490	0.292	1.419	[0.95, 1.86]
δ	cost of intermediation	gamma	0.01	0.001	0.0099	0.001	0.010	[0.008, 0.011]
μ	investment adjustment costs	gamma	4	1	6.206	1.033	6.401	[4.67, 8.04]
μ^*	investment adjustment costs	gamma	4	1	3.811	0.956	1.766	[0.64, 2.79]
h	consumption habit-Mex	beta	0.70	0.10	0.464	0.054	0.489	[0.40, 0.57]
h^*	consumption habit-US	beta	0.70	0.10	0.481	0.060	0.512	[0.41, 0.61]
ρ_{a^c}	consumption tech. shock-Mex	beta	0.75	0.10	0.885	0.038	0.889	[0.83, 0.95]
$\rho^*_{a^c}$	consumption tech. shock-US	beta	0.75	0.10	0.970	0.011	0.976	[0.96, 0.99]
ρ_ζ	UIP shock	beta	0.75	0.10	0.892	0.040	0.880	[0.81, 0.94]
ρ^x_z	ECM	beta	0.75	0.10	0.836	0.044	0.834	[0.76, 0.90]
$\rho^*_{z^x}$	global IST shock	beta	0.75	0.10	0.443	0.083	0.865	[0.82, 0.94]
ε_{a^c}	consumption tech. shock-Mex	inv.gamma	0.10	2.00	2.25	0.19	2.33	[1.99, 2.66]
$\varepsilon^*_{a^c}$	consumption tech. shock-US	inv.gamma	0.10	2.00	0.92	0.08	0.84	[0.71, 0.97]
ε_ζ	UIP shock	inv.gamma	0.10	2.00	0.54	0.16	0.63	[0.34, 0.89]
ε^x_z	ECM	inv.gamma	0.10	2.00	3.49	0.28	3.53	[3.05, 4.00]
$\varepsilon^*_{z^x}$	global IST shock	inv.gamma	0.10	2.00	1.20	0.10	0.92	[0.69, 1.16]

Note: The standard deviation of shocks are reported in percentages.

We find a fairly high persistence for the consumption sector productivity shocks and for the UIP shock. The posterior mean and the mode of the persistence of the growth rate of permanent IST shock is significantly different; this is related to the long tail of the posterior distribution. The posterior mean of the IST shock indicates a high persistence in growth rates. In terms of the adjustment of Mexican investment technology to the permanent IST shock, the posterior value is quite high ($\rho_z^x = 0.83$), indicating a weak cointegrating relationship between the US and Mexico total factor productivities in the investment sector.

4 Results

4.1 Second Moments

We now turn to analysing the quantitative performance of the model. We present the second moments of key macroeconomic variables and compare them with the ones obtained from the model. Given our interest in the business cycle properties of the data, we HP-filter[12] output, consumption, investment, relative price of investment goods and trade balance series[13]. To have a like for like comparison between the model and the data, we simulated the stationary model and then added back the stochastic trends to the non-stationary variables. We then HP-filter the non-stationary simulated data as we did for the real data[14]. Table 3 presents the standard deviation, autocorrelation and the cross-correlation of some selected variables.

Let us first start with pointing out the main international business cycle features of the data: i. the standard deviation of output is fairly high ii. trade balance to output ratio is very persistent and less volatile than output; iii. trade balance is counter-cyclical; iv. consumption is more volatile than output; iv. the relative real exchange rate volatility is significantly high; v. cross-country output correlation is higher than the cross-country consumption and investment correlations and vi. the real exchange rate and the relative consumption has a negative relationship.

Income in emerging market economies is known to be more volatile than it is in developed countries (see, Aguiar and Gopinath (2007) or Neumeyer and Perri (2005)). Consistently with the data, our model generates significant output volatility. The model generated standard deviation of the Mexican GDP is equal to 1.93% while it is 1.85% in our sample period. The satisfactory performance of the model in accounting for the output volatility is related to the persistence of technology shocks. The estimated persistence of the both consumption technology shocks and the growth rate of permanent IST shock are fairly high. Intuitively, since agents have higher income expectation in the future, consumers borrow today thus smooth consumption and also use the borrowing to invest and accumulate additional capital. This channel in turn increases the volatility of consumption and investment hence the output

Our model does fairly well in matching the relative volatility of the trade balance to GDP ratio[15]. Garcia-Cicco et al. (2010) showed that a standard RBC model fails to explain the volatility and the persistence of

[12]As we are working with quarterly data, we choose 1600 for the smoothing parameter of the HP-filter.
[13]Information on the data sources can be found in Appendix D.
[14]We simulated the model for 100000 periods.
[15]For the rest of the paper, we will refer to the ratio of the trade balance to GDP as trade balance.

Table 3: Selected HP-filtered Moments

	Standard Deviation			**Autocorrelations**	
	Data	Model		Data	Model
TB/Y	0.62	0.56		0.90	0.89
Y	1.85	1.93		0.83	0.77
C	1.13	0.91		0.85	0.81
X	2.09	2.83		0.82	0.94
RER	6.99	3.59		0.91	0.87
PX	1.58	2.00		0.82	0.77

	Cross-Correlations				
	Data	Model		Data	Model
TB/Y-Y	-0.04	0.10	Y-Y*	0.81	0.35
C-Y	0.91	0.75	C-C*	0.75	0.17
X-Y	0.88	0.31	X-X*	0.70	0.77
PX-Y	0.05	0.41	PX-PX*	0.01	0.62
RER-Y	-0.21	0.27	RER-Rel.C	-0.26	0.15

Note: The standard deviation of all variables are divided by the standard deviation of Mexican GDP(Y) except for the standard deviation of output(Y). PX refers to the ratio of investment goods prices to the consumption goods prices. All variables are in logs except for the trade balance to GDP ratio. The data on consumption, output, investment and relative price of investment goods are HP-filtered. We use the Mexican and the US data for the period 1995:Q1-2016:Q2. Mexico is treated as the home economy and the US is the foreign. Details on the bilateral trade balance and the real exchange rate data can be found in Appendix D. The relative consumption is the log difference between the HP-filtered consumption of Mexico and US. The model counterpart of the statics is calculated by using the posterior mean.

the trade balance. They argue that including financial frictions to an otherwise standard RBC model corrects for this failure. Our model incorporates the financial friction channel; Mexican households need to pay a cost to borrow from the US bond market and as in Garcia-Cicco et al. (2010) we include a risk premium shock. Our result show that having financial frictions is very important but not sufficient to account for the observed volatility. The success of our model in accounting for the relative volatility of the trade balance is also result of the theoretical structure rather than being only related to a shock to the uncovered interest rate parity. The estimated trade elasticities imply a substitution between home and foreign produced goods higher than one. This in turn lowers the terms of trade volatility and increase the volatility of the trade balance. When we lower the elasticities to a value lower than one, the model under predicts the standard deviation of the trade balance. In addition, the existence of a global IST shock, reduces the volatility of the trade balance since it is global. In fact, when we shut down the permanent IST shock ($\varepsilon^*_{z^x} = 0$), it's volatility is equal to 0.82 which is higher than the observed value. Hence, although our model confirms the importance of financial frictions to account for the observed relative standard deviation of trade balance with respect to output, this performance also depends on other channels that generate wealth effects[16].

The model accounts for the observed persistence of the trade balance. Garcia-Cicco et al. (2010) showed that a standard RBC model predicts that the autocorrelation function of the trade balance is flat and close to unity while in the data, this function slopes downward. In Figure 1, we show the autocorrelation function of the trade balance that we obtain from the data and the model. The autocorrelation function that the model delivers matches almost perfectly with the first order autocorrelation but then slopes downwards at a slightly faster rate than the data. In this respect, our model performs better than a standard RBC. Garcia-Cicco et al. (2010) argued that model's ability of matching the autocorrelation function of the trade balance is related to the parameterisation of debt elasticity (δ) which provides a stationary distribution of wealth as well as the presence of the UIP and the preference shocks. As our model incorporates the two channels that they pointed out, we check the sensitivity of our results to the value of debt elasticity parameter and to the UIP shock.

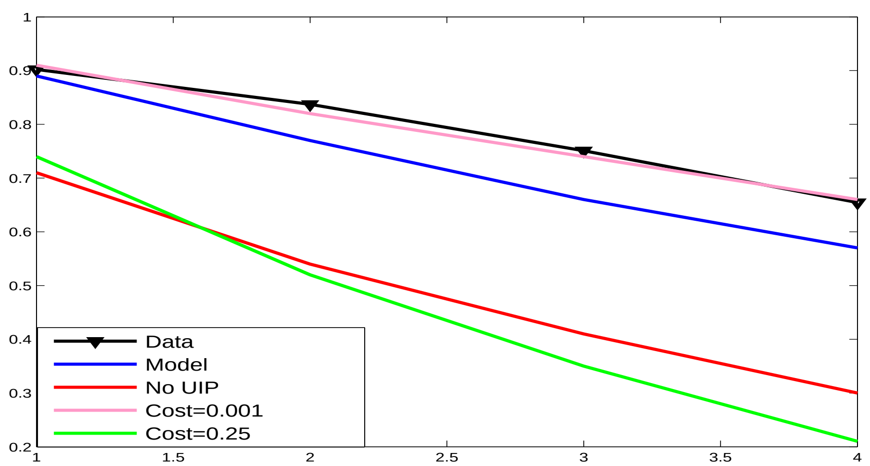
We first test the importance of the existence of a shock to the UIP condition. When we shut down the UIP shock ($\varepsilon_\zeta = 0$), the model under predicts the autocorrelation of the trade balance, although the function slopes downward at a rate very close to data. Hence, as Garcia-Cicco et al. (2010) argue this shock is important for addressing the persistence of the trade balance.

We now check the sensitivity of our results to the parameter value of the cost of intermediation in the international bond market. The standard approach is to fix the value of this parameter to a small value that is sufficient enough to induce stationarity in the model. Garcia-Cicco et al. (2010) show that there exists a small enough value of debt elasticity which ensures stationarity but at the same time results in a flat, close to unity autocorrelation function for the trade balance. To test the sensitivity of our results, to the calibration of δ, we first lower the value to 0.001 which matches the calibration of Garcia-Cicco et al. (2010) in their estimate of a standard RBC model. Interestingly, with this calibration our model matches

[16] The importance of trade in durable goods for replicating trade dynamics was previously explained in Engel and Wang (2011).

the autocorrelation function of the trade balance almost perfectly. On the contrary, when we increase the value of this parameter to 0.25, our model performs poorly; it predicts an autocorrelation which is much lower than what we observe. The reason for having a different result from Garcia-Cicco et al. (2010) is that there are already existing channels in our model that lowers the persistence that model generate for the trade balance. An important parameter for model's ability to account for this feature is the elasticity of substitution between home and foreign produced goods. The estimated trade elasticities help matching the persistence of the trade balance. With elasticities lower than one, in fact, the model predicts a first order autocorrelation of the trade balance equal to 0.98. The impact of trade elasticities transmit to the persistence of the trade balance through the relative price channel. An increase in the trade elasticity lowers the terms of trade volatility and since the terms of trade are mean reverting, a higher elasticity lowers its persistence too.

Figure 1: The Autocorrelation of the Trade Balance to GDP Ratio



The counter-cyclical behaviour of the trade balance is a well known feature of the emerging market economies[17]. Trade balance is also negatively correlated in our data too but it is very close to zero. Our model does not account for this feature although the predicted correlation is fairly low. One important parameter that has an impact on the sign of the correlation between the trade balance and output is the trade elasticity, as the elasticity of substitution parameter determines the dominance of the substitution effect. In our model, the high substitutability between goods increases the impact of the expenditure switching channel. On the other hand, the existence of the UIP shock as well as the incomplete market structure helps obtaining a correlation which is close to zero. When risk is not shared perfectly across countries, unexpected shocks create wealth effects. Hence, the incomplete market structure contributes to the obtained

[17]See, Aguiar and Gopinath (2007).

low correlation.

An important business cycle feature of emerging market countries is that consumption volatility is higher than output volatility. Even though the model does not fit the data perfectly, it generates a volatility that is close to 1. Having a global shock in the model reduces the volatility of consumption and dampens the impact of financial frictions. Garcia-Cicco et al. (2010) argue that having a permanent growth rate shock in the model helps matching the consumption volatility as a result of wealth effects arising from the permanent technology shock. This is not the case in our framework since IST shock is a global shock. In this respect, having a higher persistence of IST shock would help generating a volatility that is higher than output and also increase the volatility of the trade balance.

The model is able to replicate the persistence of other variables of interest. This is a consequence of the rich shock structure along with the external habit formation in consumption. The persistence of the growth rate of the permanent IST shock contributes to the autocorrelations we obtain. However, that comes at a cost; the persistence of IST shock increases the persistence of investment to a level more than it is in the data. The model performs reasonably well in terms of generating significant investment and real exchange rate volatility. Having an IST shock in the model helps generating substantial variability in investment and also in relative price of investment goods. Although the real exchange rate volatility is still less than what we observe in the data, it is fairly high compared with the performance of standard RBC models. The inability of open economy general equilibrium models to account for the volatility of the real exchange rate and the terms of trade is a well-known problem in the literature, labelled as the 'price' puzzle. In our model although a shock the UIP condition helps fitting the moments of the real exchange rate, the global IST shock reduces its volatility. In addition, the estimated value of the elasticity of substitution between consumption goods is higher than one, implying a low terms of trade volatility. The fluctuations of terms of trade have an influence on real exchange rate as long as preferences are biased towards home produced goods. Given the high degree of home bias in our framework, the movements of terms of trade and real exchange rate are highly correlated. Hence, the low terms of trade volatility implies a low real exchange rate volatility as well.

Finally, the model accounts for several other important puzzles in open economy macroeconomics. In data cross-country output correlation is higher than the cross-country consumption correlation while standard international real business cycle models produce higher consumption correlation than the output one (quantity puzzle). Also investment is positively correlated across countries although models predict a negative correlation (co-movement puzzle). Our model successfully account for these features of the data. Since the IST shock in our model is global; it generates significant cross-country investment and output correlation. At the same time, it does not affect the consumption correlation to the same extent as this shock is a shock to the productivity of the investment sector. In this respect, existence of a global investment specific technology shock helps reconcile theory with data. On the other hand, our model does not perform well in terms of matching the correlation of real exchange rate and the relative consumption. International real business cycle models predict a one to one correlation between the relative consumption and the real exchange rate. However, in data real exchange rate and relative consumption are negatively correlated. The inability of models to replicate this feature of data is known as the consumption-real exchange rate anomaly (see, Chari et al. (2002))[18]. Although our model does not predict the sign of the correlation well, it still successively generates a low correlation as international real business cycle models often predict a correlation close to one.

4.2 Variance Decomposition

In this section, we present the variance decomposition and specifically, examine the sources of business cycle fluctuations of Mexican economy. The important result we reach is that although the UIP shock is the main driving source of the fluctuations of international variables, Mexican output growth is mainly driven by technology shocks (see, Table 4).

Global shocks are not expected to contribute to the fluctuations of international variables as they cannot be insured away by countries. Although the IST shock does not have a cross-country symmetric structure in our framework, it still is a global shock. On the other hand, the UIP shock which is a shock to country interest rate differentials account for the 97% of the variability of the trade balance and the 93% of the real exchange rate fluctuations. This shock is also very important for the fluctuations of the growth rate of consumption as it affects the consumption decisions through the risk sharing condition. Although productivity shocks are not as important for consumption dynamics, they still contribute substantially to its fluctuations. The movements in output growth is driven by the combination of stationary consumption technology shock and the US originating IST shock. IST shock explains 82% of the investment fluctuations and it is also key for the movements in the relative price of investment goods.

Table 4: Variance Decomposition (in percentages)

Vbl. Name	ε_{a^c}	$\varepsilon^*_{a^c}$	ε_{uip}	ε_{z^x}	$\varepsilon^*_{z^x}$
TB/GDP	0.17	0.00	97.71	1.92	0.10
Δ GDP	45.73	0.00	17.56	0.52	36.12
Δ Cons.	19.57	0.26	50.48	0.29	29.40
Δ Inv.	0.016	0.00	15.72	2.16	82.10
Δ (P_x/P_c)	14.47	0.04	5.19	12.44	67.86
RER	1.48	4.68	93.21	0.51	1.92

Note: We only present the variance decomposition for Mexico (home country) variables. We report the mean variance decomposition over the estimated parameter draws. Δ refers to the growth rate of the corresponding variable.

Our results are important for understanding the sources of business cycle fluctuations of emerging market

[18] See, Corsetti et al. (2008) for a detailed investigation on lack of international risk sharing in an IRBC framework.

economies. Aguiar and Gopinath (2007) suggested that the business cycle characteristics of these countries can be addressed in a standard RBC framework when the main driving source of fluctuations is a shock to trend growth. Garcia-Cicco et al. (2010) then showed that shocks to country interest rates are the main driving source of the trade balance and investment variability while output and consumption are mostly driven by non-stationary technology shocks. They found virtually no role for permanent shocks in driving the business cycle fluctuations. Our paper relates to the findings of both papers. But we explore the implications of these shocks in a two country, two sector framework. We show that a permanent shock is very important in driving the business cycle fluctuations of output and investment as suggested by Aguiar and Gopinath (2007). We also show that that temporary productivity shocks remain to be important for the movements in output over the business cycle and that UIP shock drives the fluctuations of the trade balance confirming the findings of Garcia-Cicco et al. (2010). We argue that an RBC that is purely driven by permanent shocks or shocks to interest rate differentials across countries is not sufficient to address empirical features of the emerging market economies. But what is essential is to include the combination of these shocks to an encompassing theoretical framework.

Our finding also relates to the literature that explores the importance of US shocks for the business cycle fluctuations of emerging market countries (see, for instance, Canova (2005) or Mackowiak (2007)). Motivated by the empirical regularities of the US economy, we add to the literature by emphasising the role of permanent IST shocks. A permanent supply side improvement in the US investment sector is important for the business cycle fluctuations of Mexico. Our finding proves the significance of trade linkages in the transmission of US shocks.

4.3 Impulse Response Analysis

Given the prominent role of the UIP shock, in this section we analyse the dynamic response of the trade balance when the world is hit by a shock to real interest differential across countries. This will allow us to understand the importance of the two sector, two country structure. A 1% increase in the UIP shock reduces the difference between home and foreign interest rates in our model; in a way the shock lowers the premium on Mexican households when they borrow from the US bond market.

We can decompose the trade balance into its price and quantity components to have a full understanding of the transmission. This decomposition will allow us to disentangle the contribution of each component to trade balance dynamics. By doing so, we can trace whether the dynamic response of the trade balance is dominated by the relative price movements or the quantity components[19]. For tractability we use the log-linearised version of Equation 37. First, we will define the relative prices: $rx_t = p_{x,t} - p_{c,t}$, $rx_t^* = p_{x,t}^* - p_{c,t}^*$, $rx_{H,t} = p_{x^H,t} - p_{c,t}$, $rc_{H,t} = p_{H,t} - p_{c,t}$, $rx_{F,t}^* = p_{x^F,t}^* - p_{c,t}^*$, $rc_{F,t}^* = p_{F,t}^* - p_{c,t}^*$ and $rer_t = p_{c,t}^* + s_t - p_{c,t}$ is the real

[19] Jacob and Peersman (2013) present a very similar trade balance definition to the one we show here. Raffo (2008) decomposes it into demand and price components in a different way. It is not a full decomposition as ours, because in their decomposition, the demand functions are affected by the relative price movements.

exchange rate based on consumer prices. Trade balance to output ratio in linear terms is equal to:

$$tb_t = \frac{1-n}{n}\frac{\tilde{C}^*_H}{\tilde{Y}}(c^*_{h,t} + rc_{H,t}) - \frac{\tilde{C}_F}{\tilde{Y}}(c_{F,t} + rc^*_{F,t} + rer_t) + \frac{1-n}{n}\frac{\tilde{X}^*_H}{\tilde{Y}}(x^*_{h,t} + rx_{H,t}) - \frac{\tilde{X}_F}{\tilde{Y}}(x_{F,t} + rx^*_{F,t} + rer_t) \quad (48)$$

Re-writing this by substituting the optimal demand functions and using steady state conditions yield:

$$tb_t = c\_abs_t + x\_abs_t - tot_{C,t} - tot_{X,t} - rel\_pxpc - wrer_t \quad (49)$$

where

$$c\_abs_t = \frac{\tilde{C}}{\tilde{Y}}(1-\omega)(c^*_t - c_t) \quad (50)$$

$$x\_abs_t = \frac{\tilde{X}}{\tilde{Y}}(1-\nu)(x^*_t - x_t) \quad (51)$$

$$tot_{C,t} = \frac{\tilde{C}}{\tilde{Y}}(1-\omega)(1-\theta)(rc^*_{F,t} - rc_{H,t}) \quad (52)$$

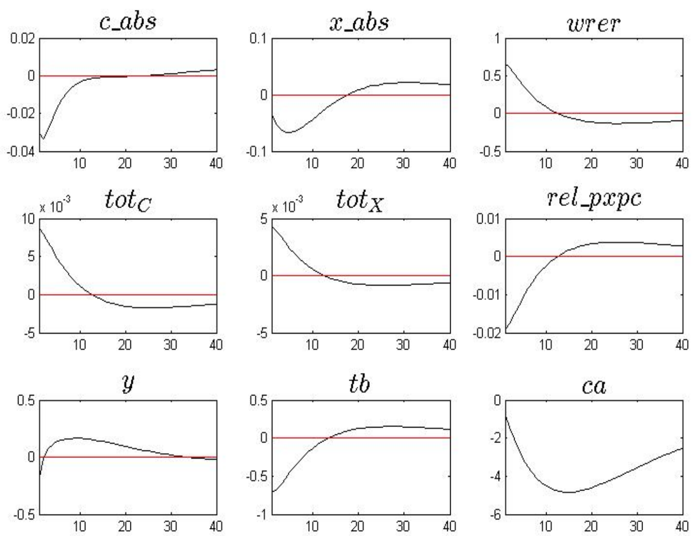
$$tot_{X,t} = \frac{\tilde{X}}{\tilde{Y}}(1-\nu)(1-\alpha)(rx^*_{F,t} - rx_{H,t}) \quad (53)$$

$$rel\_pxpc_t = \frac{\tilde{X}}{\tilde{Y}}(1-\nu)\,\alpha\,(rx_t - rx^*_t) \quad (54)$$

$$wrer_t = \left(\frac{\tilde{C}}{\tilde{Y}}(1-\omega)(1-2\theta) + \frac{\tilde{X}}{\tilde{Y}}(1-\nu)(1-2\alpha)\right) rer_t \quad (55)$$

The first two components of the trade balance, c_abs_t and x_abs_t, reflect the weighted cross-country relative consumption and investment absorptions. Considering the differences in the degree of openness between the two sectors, the weight of consumption and investment sectors will be significantly different. On the other hand, the impact of the terms of trade will also depend on the trade elasticities. With an elasticity higher than one, the substitution effect has a positive impact on the trade balance. Intuitively, when home produced goods become cheaper (terms of trade increase) consumers substitute imports with home produced goods, implying a trade balance improvement. The estimated values for both trade elasticities in our model is higher than one implying a positive relationship between the terms of trade and the trade balance. As a consequence of the two sector structure, the international relative price of investment goods has an influence on the trade dynamics. Notice that in the absence of a separate investment sector, rel_pxpc_t would disappear. The final component, $wrer_t$, is the weighted real exchange rate. The changes in the real exchange rate has a positive impact on the trade balance as a result of the negative value of the weight; a depreciation (increase) of the real exchange rate implies an improvement in the trade balance.

Figure 2: UIP Shock



Now, we can trace the impact of a UIP shock on trade dynamics by looking at the reaction of each component. Figure 2 shows the dynamic response of the current account, trade balance to output ratio, home output along with the response of the components of the trade balance. Following the UIP shock, the interest rate at home falls while it increases in foreign country. This leads to an increase in the expenditure at home and reduction in expenditure at foreign. Foreign country saves and lends to home economy hence the current account falls. The current account deficit implies a trade deficit. At home country, consumption and investment increase by more than the increase in output. This difference is compensated by import demand. On the other hand, output, consumption and investment falls in foreign country. This leads to a fall in the weighted cross-country relative consumption and investment absorptions. A fall in the relative consumption and investment absorptions imply a fall in the trade balance. Notice that the fall in the relative investment absorption is much higher than the consumption absorption for two reasons: first, investment sector has a higher degree of openness; second, investment allows wealth accumulation to home country.

Hence, the contribution of relative investment absorption to the fall in trade balance is much higher than consumption.

As a result of the fall in demand for consumption and investment in foreign economy the prices of foreign produced goods fall while the increased domestic demand at home raises the price of home produced goods. Hence the terms of trade improves in both sectors. The fall in the terms of trade, switches the expenditure towards imported goods leading to a fall in the trade balance[20]. Real exchange rate appreciates as imports are cheaper now, this also lowers the trade balance. Finally, the international relative price of investment goods fall, contributing to the fall in the trade balance. The relative price of investment goods decreases at home and increases at foreign country.

Overall, the response of the trade balance to a risk premium shock is negative. Consistently with the data, output and the trade balance move in opposite directions. In the face of a positive shock to the UIP condition, the aggregate output increase in the domestic economy. Both quantity and relative price components of the trade balance contribute to this counter-cyclicality positively.

5 Conclusion

We explore the role of IST shocks for emerging market business cycle fluctuations. The analysis in this paper is motivated by two key empirical facts. First, there has been a significant decline in the relative price of investment goods and an increase in the investment rate in the post-war US economy, implying investment specific technical progress. Second, the imports of emerging market economies are more intensive in investment goods relative to consumption goods. If so, changes in the relative price of investment goods will have spillover effects on emerging market economies through the trade channel.

To this end, we develop a two country, two sector IRBC model with investment and consumption goods sectors, and estimate it with the data for Mexico and the US. We assume that there is a non-stationary IST shock that originates in the US and that the technology diffuses into the Mexican economy with a gradual speed. We include temporary country specific consumption sector productivity shocks and a risk premium shock (UIP shock). A key finding of the paper is that a two sector, two country IRBC model that incorporates IST shocks does a reasonably good job at explaining the business cycle features of Mexico. Specifically, the model accounts for the volatility and the persistence of the trade balance to output ratio and also produces its downward sloping autocorrelation function. The model successfully delivers substantial income, investment and real exchange rate volatility and account for important puzzles in international macroeconomics like the quantity and co-movement puzzles. We show that the model's ability in accounting for these features is combination of having a permanent IST shock and also a shock to risk premium. The variance decomposition analysis show that while the trade balance dynamics are mainly driven by the country risk premium shock, technology shocks are still the main driving source of output fluctuations. Hence, we argue that both financial

[20] $tot_{C,t}$ and $tot_{X,t}$ are increasing in response to a UIP shock although terms of trade im both sectors fall. This is a consequence of the negative weights.

frictions and shocks to trend growth are crucial in explaining emerging market business cycles.

The result of importance of financial frictions for emerging market business cycles is in line with the findings of Neumeyer and Perri (2005) or Garcia-Cicco et al. (2010). But in our framework shock to trend growth are crucial for investment and output dynamics. This is due to the differences in the formulation of the permanent technological improvement. In our set-up, the permanent productivity shock is a a slowly diffusing IST shock that originates in the US rather than a country specific economy wide productivity improvement. This findings suggest that IST shocks should have a role in the study of the emerging market business cycles.

Appendices

Appendix A Stationarised Model

In this appendix, we first derive the trends of the endogenous variables[21] and then transform them accordingly. We show the de-trending of the foreign country variables as the shock originates in the foreign country.

For convenience we fix the capital's share of output in the two sectors to the same parameter consistently with our calibration: $\alpha^* = \alpha^{x^*} = \alpha^{c^*}$. We will use the sectoral capital-output ratios to derive the aggregate capital-output ratio:

$$\frac{w_t^*}{R_t^{K^*}} \frac{P_{c,t}^*}{P_{x,t}^*} \frac{\alpha^*}{1-\alpha^*} = \frac{K_{x,t-1}^*}{L_{x,t}^*} = \frac{K_{c,t-1}^*}{L_{c,t}^*} = \frac{K_{t-1}^*}{L_t^*} \tag{A.1}$$

In the steady state the labour does not grow so we can fix the L_t^*. To have a balanced growth path in the model the rate of return on investment has to be constant.

First, we will derive the trend of the relative price of investment by using the marginal product of labour from each sector:

$$w_t^* = (1-\alpha^*)\left(\frac{P_{F,t}^*}{P_{c,t}^*}\right)(A_{c,t}^*)^{1-\alpha^*}\left(\frac{K_{c,t-1}^*}{L_{c,t}^*}\right)^{\alpha^*} = (1-\alpha^*)\left(\frac{P_{x^F,t}^*}{P_{c,t}^*}\right)(Z_{x,t}^*)^{1-\alpha^*}\left(\frac{K_{x,t-1}^*}{L_{x,t}^*}\right)^{\alpha^*}$$

and then plugging in the capital-labour ratios yield:

$$\frac{P_{x^F,t}^*}{P_{H,t}^*} \frac{P_{F,t+1}^*}{P_{x^F,t+1}^*} = \left(\frac{Z_{x,t+1}^*}{Z_{x,t}^*}\right)^{1-\alpha^*} \tag{A.2}$$

Equivalently, in growth rates: $\dfrac{P_{x,t}^*}{P_{c,t}^*} \dfrac{P_{c,t+1}^*}{P_{x,t+1}^*} = \left(\dfrac{Z_{x,t+1}^*}{Z_{x,t}^*}\right)^{1-\alpha^*}$

From the marginal product of capital; $r_t^{K^*} = \alpha(Z_{x,t}^*)^{1-\alpha^*}(K_t^*)^{\alpha^*-1}\dfrac{P_{F,t}^*}{P_{x,t}^*}$ where $r_t^{K^*}$ is the rental rate of capital, we obtain:

$$\frac{Z_{x,t+1}^*}{Z_{x,t}^*} = \frac{K_t^*}{K_{t-1}^*} \tag{A.3}$$

If capital grows at the rate of $Z_{x,t}^*$ then this implies that investment also grows at the rate of $Z_{x,t}^*$ from the law of motion for capital.

[21] Here, we follow Herrendorf et al. (2014) which provides a detailed discussion on the derivation of trends in a two sector growth model.

Since the relative price of investment good grows, for the real rental rate of capital -measured in investment units-, $R_t^{K^*}$, to be stationary, one can show that the shadow price of investment -measured in consumption units-, Q_t^*, also needs to grow at the rate of the relative price of investment from household's first order condition with respect to capital: $\dfrac{Q_t^*}{Q_{t+1}^*} = \left(\dfrac{Z_{x,t+1}^*}{Z_{x,t}^*}\right)^{1-\alpha^*}$

To find the trend of consumption, we use the symmetric equilibrium condition:

$$\begin{aligned} Y_{c,t}^* = C_t^* &= (K_{c,t-1}^*)^{\alpha^*}(A_{c,t}^* L_{c,t}^*)^{1-\alpha^*} \\ &= \left(\frac{K_{t-1}^*}{L_t^*}\right)^{\alpha^*} (Z_{x,t}^*)^{1-\alpha^*} L_{c,t}^* \frac{P_{x,t}^*}{P_{c,t}^*} \end{aligned} \tag{A.4}$$

This implies that, C_t^* grows at gross rate $(Z_{x,t}^*)^{\alpha^*}(Z_{x,t}^*)^{1-\alpha^*}(1/Z_{x,t}^*)^{1-\alpha^*} = (Z_{x,t}^*)^{\alpha^*}$. The marginal rate of substitution implies that real wages will grow at the same constant rate for labour to be stationary.

As we have now found the trends, we need to transform the variables. We will denote the transformed variables with a tilde: $\tilde{K}_{t-1}^* = \dfrac{K_{t-1}^*}{Z_{x,t}^*}, \tilde{X}_t^* = \dfrac{X_t^*}{Z_{x,t}^*}, \tilde{Y}_{x,t}^* = \dfrac{Y_{x,t}^*}{Z_{x,t}^*}, \tilde{K}_{x,t}^* = \dfrac{K_{x,t-1}^*}{Z_{x,t}^*}, \tilde{K}_{c,t-1}^* = \dfrac{K_{c,t-1}^*}{Z_{x,t}^*}, \tilde{w}^*{}_t = \dfrac{w_t^*}{(Z_{x,t}^*)^{\alpha^*}}, \tilde{C}_t^* = \dfrac{C_t^*}{(Z_{x,t}^*)^{\alpha^*}}, \tilde{Y}_{c,t}^* = \dfrac{Y_{c,t}^*}{(Z_{x,t}^*)^{\alpha^*}}, \dfrac{\widetilde{P_{x,t}^*}}{P_{c,t}^*} = \dfrac{P_{x,t}^*}{P_{c,t}^*}(Z_{x,t}^*)^{1-\alpha^*}$,
$\tilde{Q}_t^* = Q_t^*(Z_{x,t}^*)^{1-\alpha^*}$.

The transformed equilibrium conditions results in:

$$\tilde{w}_t^* = (L_t^*)^\eta \left(\tilde{C}_t^* - h^*\tilde{C}_{t-1}^* \left(\frac{Z_{x,t-1}^*}{Z_{x,t}^*}\right)^{\alpha^*}\right) \tag{A.5}$$

$$1 = \beta(1+i_t^*)E_t\left[\left(\frac{\tilde{C}_t^* - h^*\tilde{C}_{t-1}^*\left(\frac{Z_{x,t-1}^*}{Z_{x,t}^*}\right)^{\alpha^*}}{\tilde{C}_{t+1}^*\left(\frac{Z_{x,t+1}^*}{Z_{x,t}^*}\right)^{\alpha^*} - h^*\tilde{C}_t^*}\right)\left(\frac{P_{c,t}^*}{P_{c,t+1}^*}\right)\right] \tag{A.6}$$

$$1 = \beta(1+i_t^*)\Theta(S_t B_{F,t}/P_{c,t})E_t\left[\left(\frac{\tilde{C}_t - h\tilde{C}_{t-1}\left(\frac{Z_{x,t-1}}{Z_{x,t}}\right)^{\alpha}}{\tilde{C}_{t+1}\left(\frac{Z_{x,t+1}}{Z_{x,t}}\right)^{\alpha} - h\tilde{C}_t}\right)\left(\frac{P_{c,t}}{P_{c,t+1}}\right)\left(\frac{S_{t+1}}{S_t}\right)\right] \tag{A.7}$$

$$\tilde{Q}_t^* = \beta E_t\Bigg[\Bigg(\frac{\tilde{C}_t^* - h^*\tilde{C}_{t-1}^*\left(\frac{Z_{x,t-1}^*}{Z_{x,t}^*}\right)^{\alpha^*}}{\tilde{C^*}_{t+1}\left(\frac{Z_{x,t+1}^*}{Z_{x,t}^*}\right)^{\alpha^*} - h^*\tilde{C}_t^*}\Bigg) \tag{A.8}$$

$$\left(\frac{\widetilde{P_{x,t+1}^*}}{P_{c,t+1}^*}\left(\frac{Z_{x,t}^*}{Z_{x,t+1}^*}\right)^{1-\alpha^*} R_{t+1}^{K^*} + (1-\delta^{K^*})\tilde{Q}_{t+1}^*\left(\frac{Z_{x,t}^*}{Z_{x,t+1}^*}\right)^{1-\alpha^*}\right)\Bigg]$$

$$\frac{\widetilde{P_{x,t}^*}}{P_{c,t}^*} - \tilde{Q}_t^*\left(1 - S\left(\frac{\tilde{X}_t^*}{\tilde{X}_{t-1}^*}\frac{Z_{x,t}^*}{Z_{x,t-1}^*}\right) - \left(\frac{\tilde{X}_t^*}{\tilde{X}_{t-1}^*}\frac{Z_{x,t}^*}{Z_{x,t-1}^*}\right)S'\left(\frac{\tilde{X}_t^*}{\tilde{X}_{t-1}^*}\frac{Z_{x,t}^*}{Z_{x,t-1}^*}\right)\right) =$$

$$\beta E_t\left[\left(\frac{\tilde{C}_t^* - h^*\tilde{C}_{t-1}^*\left(\frac{Z_{x,t-1}^*}{Z_{x,t}^*}\right)^{\alpha^*}}{\tilde{C}_{t+1}^*\left(\frac{Z_{x,t+1}^*}{Z_{x,t}^*}\right)^{\alpha^*} - h^*\tilde{C}_t^*}\right)\left(\frac{Z_{x,t}^*}{Z_{x,t+1}^*}\right)^{1-\alpha^*}\tilde{Q}_{t+1}^*\left(S'\left(\frac{\tilde{X}_{t+1}^*}{\tilde{X}_t^*}\frac{Z_{x,t+1}^*}{Z_{x,t}^*}\right)\left(\frac{\tilde{X}_{t+1}^*}{\tilde{X}_t^*}\frac{Z_{x,t+1}^*}{Z_{x,t}^*}\right)^2\right)\right] \tag{A.9}$$

with

$$\tilde{K}_t^* = (1-\delta^K)\tilde{K}_{t-1}^*\left(\frac{Z_{x,t-1}^*}{Z_{x,t}^*}\right) + \left[1 - S\left(\frac{\tilde{X}_t^*}{\tilde{X}_{t-1}^*}\frac{Z_{x,t}^*}{Z_{x,t-1}^*}\right)\right]\tilde{X}_t^* \tag{A.10}$$

The production functions are:

$$\tilde{Y^*}_{x,t} = \tilde{K^*}_{x,t-1}^{\alpha^*}(L_{x,t}^*)^{1-\alpha^*}\left(\frac{Z_{x,t-1}^*}{Z_{x,t}^*}\right)^{\alpha^*} \tag{A.11}$$

$$\tilde{Y^*}_{c,t} = \tilde{K^*}_{c,t-1}^{\alpha^*}(A_{c,t}^* L_{c,t}^*)^{1-\alpha^*}\left(\frac{Z_{x,t-1}^*}{Z_{x,t}^*}\right)^{\alpha^*} \tag{A.12}$$

Finally the capital-labour ratios:

$$\frac{\tilde{w}_t^*}{R_t^{K^*}} = \frac{1-\alpha^*}{\alpha^*}\frac{\widetilde{P_{x,t}^*}}{P_{c,t}^*}\frac{\tilde{K}_{x,t-1}^*}{L_{x,t}^*}\frac{Z_{x,t-1}^*}{Z_{x,t}^*} \tag{A.13}$$

$$\frac{\tilde{w}_t^*}{R_t^{K^*}} = \frac{1-\alpha^*}{\alpha^*}\frac{\widetilde{P_{x,t}^*}}{P_{c,t}^*}\frac{\tilde{K}_{c,t-1}^*}{L_{c,t}^*}\frac{Z_{x,t-1}^*}{Z_{x,t}^*} \tag{A.14}$$

The de-trending procedure for the home country variables is symmetric to the foreign country one, except for the investment sector production function. All home country variables will grow at the same rate as the foreign variables. But because the $Z_{x,t}$ component of the home investment production function is cointegrated with $Z^*_{x,t}$, the corresponding transformation will be:

$$Y_{x,t} = (K_{x,t-1})^{\alpha}(Z_{x,t}L_{x,t})^{1-\alpha}$$

$Y_{x,t}$ and $K_{x,t}$ grow at a gross rate of $Z^*_{x,t}$, we divide and multiply by $Z^*_{x,t}$ to remove the trend from these two variables:

$$\tilde{Y}_{x,t} = (\tilde{K}_{x,t-1})^{\alpha}(L_{x,t})^{1-\alpha}\left(\frac{Z_{x,t}}{Z^*_{x,t}}\right)^{(1-\alpha)}\left(\frac{Z^*_{x,t-1}}{Z^*_{x,t}}\right)^{(1-\alpha)} \tag{A.15}$$

Appendix B Steady State

Since we are using the de-trended variables for our analysis, we can compute the constant steady state which will be used to approximate the model. In the stationary steady state, we can normalise the technologies, thus the prices to 1. The equilibrium we present here, is symmetric across countries in which consumption, output, investment, capital and labour supply are constant: $\tilde{C} = \tilde{C}^*$; $\tilde{Y} = \tilde{Y}^*$; $\tilde{X} = \tilde{X}^*$; $\tilde{K} = \tilde{K}^*$; $\tilde{L} = \tilde{L}^*$.

The total world output is the population weighted average of the steady state output:

$$\tilde{Y}^w = n\,\tilde{Y} + (1-n)\,\tilde{Y}^* = n\,(\tilde{C}+\tilde{X}) + (1-n)\,(\tilde{C}^*+\tilde{X}^*) \tag{B.1}$$

The static demand functions in the steady state can be written as:

$$\tilde{C}^F = (1-\omega)\,\tilde{C}, = (1-n)\,\rho\,\tilde{C} \tag{B.2}$$

$$\tilde{C}^H = \omega\,\tilde{C} = (1-(1-n)\rho)\,\tilde{C} \tag{B.3}$$

$$\tilde{C}^{H^*} = (1-\omega^*)\,\tilde{C}^* = n\,\rho\,\tilde{C}^* \tag{B.4}$$

$$\tilde{C}^{F^*} = \omega^*\,\tilde{C}^* = (1-n\rho)\,\tilde{C}^* \tag{B.5}$$

$$\tilde{X}^F = (1-\nu)\,\tilde{X} = (1-n)\,\phi\,\tilde{X} \tag{B.6}$$

$$\tilde{X}^H = \nu\,\tilde{X} = (1-(1-n)\phi)\,\tilde{X} \tag{B.7}$$

$$\tilde{X}^{H^*} = (1-\nu^*)\,\tilde{X}^* = n\,\phi\,\tilde{X}^* \tag{B.8}$$

$$\tilde{X}^{F^*} = \nu^*\,\tilde{X}^* = (1-n\phi)\tilde{X}^* \tag{B.9}$$

We know that in steady state the nominal exchange rate is constant and equal to one, and also the steady state level of net foreign asset position is equal to zero. Consequently, the steady state level of net exports will be equal to zero as well; i.e. imports are equal to exports. Accordingly, the following expression can be obtained by applying the above steady state relationships to (36):

$$(1-n)\,(\tilde{C_H}^* + \tilde{X_H}^*) = n\,(\tilde{C_F} + \tilde{X_F})$$

Using $\tilde{C}^* = \tilde{C}$ and $\tilde{X}^* = \tilde{X}$,

$$\frac{n\,\rho\,\tilde{C} + n\,\phi\,\tilde{X}}{n} = \frac{(1-n)\,\rho\,\tilde{C} + (1-n)\,\phi\,\tilde{X}}{1-n} \tag{B.10}$$

The steady state market clearing conditions are characterised by:

$$\tilde{Y}_c = \tilde{C}_H + \frac{1-n}{n}\,\tilde{C}_H^*$$

equivalently, by using zero net exports assumption we can write this expression as:

$$\tilde{Y}_c = \tilde{C} \tag{B.11}$$

and, similarly:

$$\tilde{Y}_x = \tilde{X} \tag{B.12}$$

We can obtain the steady state interest rate by applying the above steady state conditions to Euler Equation (5) which is equal to the foreign country steady state interest rate:

$$\frac{1}{1+i} = \beta \tag{B.13}$$

This relationship implies $SB_FP = 0$ from the UIP condition, (6).

Because the capital is constant in the steady state, by the capital-Euler equation, (7), steady state level of the real rental rate of capital is:

$$R^K = \frac{1 - \beta(1 - \delta^K)}{\beta} \tag{B.14}$$

We will now derive the steady state value of wages [22]. To do so, we will use the marginal product of labour:

$$\tilde{w} = (1 - \alpha^c)\left(\frac{\tilde{K}_c}{L_c}\right)^{\alpha^c}$$

and plug in the capital-labour ratio:

$$\frac{\tilde{w}}{R^K} = \frac{1 - \alpha^c}{\alpha^c}\frac{\tilde{K}_c}{L_c}$$

After some algebra we obtain:

$$\tilde{w} = \left(R^{K^{\alpha^c}}(\alpha^c)^{-\alpha^c}(1 - \alpha^c)^{\alpha^c - 1}\right)^{1/(\alpha^c - 1)} \tag{B.15}$$

or equivalently:

$$\tilde{w} = \left(R^{K^{\alpha^x}}(\alpha^x)^{-\alpha^x}(1 - \alpha^x)^{\alpha^x - 1}\right)^{1/(\alpha^x - 1)} \tag{B.16}$$

As we have the steady state values of the wages and rental rate of capital we can also pin down the capital-labour ratios in each sector:

$$\frac{\tilde{K}_c}{L_c} = \frac{\tilde{w}}{R^K}\frac{\alpha^c}{1 - \alpha^c} \tag{B.17}$$

$$\frac{\tilde{K}_x}{L_x} = \frac{\tilde{w}}{R^K}\frac{\alpha^x}{1 - \alpha^x} \tag{B.18}$$

From the law of motion for capital; $\tilde{X} = \delta^K \tilde{K}$. By combining this and the market clearing condition, $\tilde{Y}_x = \tilde{X}$, we will now re-write the investment sector production function:

$$\delta^K \tilde{K} = \tilde{K}_x^{\alpha^x} L_x^{1-\alpha^x}$$

[22] For the rest of the derivations, we follow Liu et al. (2012) in which they present the steady state of a closed economy, two sector model.

We use the capital-labour ratio for investment sector and we obtain:

$$\frac{\tilde{K}_x}{\tilde{K}} = \left(\frac{\tilde{w}}{R^K} \frac{\alpha^x}{1-\alpha^x} \right)^{1-\alpha^x} \delta^K \tag{B.19}$$

From the capital market clearing condition:

$$\frac{\tilde{K}_c}{\tilde{K}} = 1 - \frac{\tilde{K}_x}{\tilde{K}} \tag{B.20}$$

We divide (B.18) to (B.17) and obtain:

$$\frac{L_c}{L_x} = \frac{\tilde{K}_c/\tilde{K}}{\tilde{K}_x/\tilde{K}} \frac{\alpha^x}{1-\alpha^x} \frac{1-\alpha^c}{\alpha^c} \tag{B.21}$$

We will call $\left(\frac{\tilde{K}_c/\tilde{K}}{\tilde{K}_x/\tilde{K}} \frac{\alpha^x}{1-\alpha^x} \frac{1-\alpha^c}{\alpha^c} \right)$ as κ for the rest of the derivations.

Combining the above expression with the labour market clearing condition, $L = L_x + L_c$, yields:

$$\frac{L_x}{L} = \frac{1}{1+\kappa} \tag{B.22}$$

$$\frac{L_c}{L} = 1 - \frac{1}{1+\kappa} \tag{B.23}$$

We will use the consumption sector production function combined with the corresponding market clearing and divide by L:

$$\frac{\tilde{C}}{L} = \left(\frac{\tilde{K}_c}{\tilde{K}} \right)^{\alpha^c} \frac{L_c}{L} \tag{B.24}$$

Finally, we will pin down the labour. We will use the marginal rate of substitution from the first order condition of the household, $\tilde{w} = L^\eta (1-h)\tilde{C}$ and divide it by L yields:

$$L = \left(\tilde{w} \frac{L}{(1-h)\tilde{C}} \right)^{1/\eta+1} \tag{B.25}$$

The rest of the derivations should be straight forward.

Appendix C Log-Linearised Model

Here, we list the log-linearised equilibrium conditions. We use the lower case variables to denote the percentage deviations of the stationary variable from its steady state value.

We express all prices relative to the consumer price index: $rx_t = p_{x,t} - p_{c,t}$, $rx_{H,t} = p_{x^H,t} - p_{c,t}$, $rc_{H,t} = p_{H,t} - p_{c,t}$, $rx_t^* = p_{x,t}^* - p_{c,t}^*$, $rx_{F,t}^* = p_{x^F,t}^* - p_{c,t}^*$, $rc_{F,t}^* = p_{F,t}^* - p_{c,t}^*$, $rx_{F,t} = p_{x^F,t}^* + s_t - p_{c,t} = rx_{F,t}^* + rer_t$, $rc_{F,t} = p_{F,t}^* + s_t - p_{c,t} = rc_{F,t}^* + rer_t$, $rx_{H,t}^* = p_{x^H,t}^* - s_t - p_{c,t}^* = rx_{H,t} - rer_t$, $rc_{H,t}^* = p_{H,t}^* - s_t - p_{c,t}^* = rc_{H,t} - rer_t$ where rer_t is the real exchange rate based on consumer prices.

Consumption Euler Equations:

$$c_t = \frac{1}{1+h}E_t c_{t+1} + \frac{h}{1+h}c_{t-1} - \frac{1-h}{1+h}r_t + \frac{\alpha^x}{1+h}(E_t z_{x,t+1} - z_{x,t}) - \frac{\alpha^x h}{1+h}(z_{x,t}^* - z_{x,t-1}^*) \quad \text{(C.1)}$$

$$c_t^* = \frac{1}{1+h^*}E_t c_{t+1}^* + \frac{h^*}{1+h^*}c_{t-1}^* - \frac{1-h^*}{1+h^*}r_t^* + \frac{\alpha^{x^*}}{1+h^*}(E_t z_{x,t+1} - z_{x,t}) - \frac{\alpha^{x^*} h^*}{1+h^*}(z_{x,t}^* - z_{x,t-1}^*) \quad \text{(C.2)}$$

where $r_t = i_t - E_t\pi_{c,t+1}$, $r_t^* = i_t^* - E_t\pi_{c,t+1}^*$ $\pi_{c,t+1} = p_{c,t+1} - p_{c,t}$ and $\pi_{c,t+1}^* = p_{c,t+1}^* - p_{c,t}^*$.

UIP condition:

$$E_t rer_{t+1} - rer_t = r_t - r_t^* + \delta b_t + \zeta_t \quad \text{(C.3)}$$

where ζ_t is a temporary UIP shock.

Labour supply equations:

$$w_t = \eta\, l_t + \frac{1}{1-h}(c_t - hc_{t-1}) + \frac{\alpha^x\, h}{1-h}\left(z_{x,t}^* - z_{x,t-1}^*\right) \quad \text{(C.4)}$$

$$w_t^* = \eta\, l_t^* + \frac{1}{1-h^*}\left(c_t^* - h^* c_{t-1}^*\right) + \frac{\alpha^{x^*}\, h^*}{1-h^*}\left(z_{x,t}^* - z_{x,t-1}^*\right) \quad \text{(C.5)}$$

Capital Euler equations:

$$q_t = \beta(1-\delta^K)E_t q_{t+1} + (1-\beta(1-\delta^K))(E_t r_{t+1}^K + rx_t) - i_t - (1-\alpha^x)(E_t z_{x,t+1}^* - z_{x,t}^*) \quad \text{(C.6)}$$

$$q_t^* = \beta(1-\delta^K)E_t q_{t+1}^* + (1-\beta(1-\delta^K))(E_t r_{t+1}^{K^*} + rx_t^*) - i_t^* - (1-\alpha^{x^*})(E_t z_{x,t+1}^* - z_{x,t}^*) \quad \text{(C.7)}$$

Investment equations:

$$x_t = \frac{1}{1+\beta}\left(\beta(E_t x_{t+1} + E_t z_{x,t+1}^* - z_{x,t}^*) + x_{t-1} - \left(z_{x,t}^* - z_{x,t-1}^*\right) + 1/\mu\,(q_t - rx_t)\right) \quad \text{(C.8)}$$

$$x_t^* = \frac{1}{1+\beta}\left(\beta(E_t x_{t+1}^* + E_t z_{x,t+1}^* - z_{x,t}^*) + x_{t-1}^* - \left(z_{x,t}^* - z_{x,t-1}^*\right) + 1/\mu^* \left(q_t^* - rx_t^*\right)\right) \tag{C.9}$$

where μ and μ^* are the parameters for the investment adjustment cost at home and foreign country, respectively.

Law of motion for capital:

$$k_t = \delta^K x_t + (1-\delta^K)\left(k_{t-1} - (z_{x,t}^* - z_{x,t-1}^*)\right) \tag{C.10}$$

$$k_t^* = \delta^K x_t^* + (1-\delta^K)\left(k_{t-1}^* - (z_{x,t}^* - z_{x,t-1}^*)\right) \tag{C.11}$$

Demand functions:

$$c_{H,t} = -\theta\, rc_{H,t} + c_t \tag{C.12}$$

$$c_{F,t} = -\theta\,(rc_{F,t}^* + rer_t) + c_t \tag{C.13}$$

$$c_{H,t}^* = -\theta\,(rc_{H,t} - rer_t) + c_t^* \tag{C.14}$$

$$c_{F,t}^* = -\theta\, rc_{F,t}^* + c_t^* \tag{C.15}$$

$$x_{H,t} = -\alpha\,(rx_{H,t} - rx_t) + x_t \tag{C.16}$$

$$x_{F,t} = -\alpha\,(rx_{F,t}^* - rx_t + rer_t) + x_t \tag{C.17}$$

$$x_{H,t}^* = -\alpha\,(rx_{H,t} - rer_t - rx_t) + x_t^* \tag{C.18}$$

$$x_{F,t}^* = -\alpha\,(rx_{F,t}^* - rx_t) + x_t^* \tag{C.19}$$

Price indices:

$$0 = \omega\, rc_{H,t} + (1-\omega)\,(rc_{F,t}^* + rer_t) \tag{C.20}$$

$$0 = \omega^*\, rc_{F,t}^* + (1-\omega^*)\,(rc_{H,t} - rer_t) \tag{C.21}$$

$$rx_t \;=\; \nu\, rx_{H,t} \;+\; (1\;-\;\nu)\,(rx^*_{F,t} + rer_t) \tag{C.22}$$

$$rx^*_t \;=\; \nu^*\, rx^*_{F,t} \;+\; (1\;-\;\nu^*)\,(rx_{H,t} - rer_t) \tag{C.23}$$

Production functions:

$$y_{c,t} = (1-\alpha^c)(a_{c,t} + l_{c,t}) + \alpha^c k_{c,t} - \alpha^x (z^*_{x,t} - z^*_{x,t-1}) \tag{C.24}$$

$$y^*_{c,t} = (1-\alpha^{c^*})(a^*_{c,t} + l^*_{c,t}) + \alpha^{c^*} k^*_{c,t} - \alpha^{x^*} (z^*_{x,t} - z^*_{x,t-1}) \tag{C.25}$$

$$y_{x,t} = (1-\alpha^x) l_{x,t} + \alpha^x k_{x,t} + (1-\alpha^x)(z_{x,t} - z^*_{x,t}) - \alpha^x (z^*_{x,t} - z^*_{x,t-1}) \tag{C.26}$$

$$y^*_{x,t} = (1-\alpha^{x^*}) l^*_{x,t} + \alpha^{x^*} k^*_{x,t} - \alpha^{x^*} (z^*_{x,t} - z^*_{x,t-1}) \tag{C.27}$$

Pricing Decisions:

$$rc_{H,t} = w_t + l_{c,t} - y_{c,t} \tag{C.28}$$

$$rc^*_{F,t} = w^*_t + l^*_{c,t} - y^*_{c,t} \tag{C.29}$$

$$rx_{H,t} = w_t + l_{x,t} - y_{x,t} \tag{C.30}$$

$$rx^*_{F,t} = w^*_t + l^*_{x,t} - y^*_{x,t} \tag{C.31}$$

Capital-labour ratios:

$$r^K_t = w_t - k_{c,t} + l_{c,t} + (z^*_{x,t} - z^*_{x,t-1}) - rx_t \tag{C.32}$$

$$r^{K^*}_t = w^*_t - k^*_{c,t} + l^*_{c,t} + (z^*_{x,t} - z^*_{x,t-1}) - rx^*_t \tag{C.33}$$

$$r^K_t = w_t - k_{x,t} + l_{x,t} + (z^*_{x,t} - z^*_{x,t-1}) - rx_t \tag{C.34}$$

$$r^{K^*}_t = w^*_t - k^*_{x,t} + l^*_{x,t} + (z^*_{x,t} - z^*_{x,t-1}) - rx^*_t \tag{C.35}$$

Market clearing conditions:

$$k_{t-1} = \frac{\tilde{K}_x}{\tilde{K}}\, k_{x,t} + \frac{\tilde{K}_c}{\tilde{K}}\, k_{c,t} \tag{C.36}$$

$$k^*_{t-1} = \frac{\tilde{K}^*_x}{\tilde{K}^*}\, k^*_{x,t} + \frac{\tilde{K}^*_c}{\tilde{K}^*}\, k^*_{c,t} \tag{C.37}$$

$$l_t = \frac{L_x}{L}\, l_{x,t} + \frac{L_c}{L}\, l_{c,t} \tag{C.38}$$

$$l^*_t = \frac{L^*_x}{L^*}\, l^*_{x,t} + \frac{L^*_c}{L^*}\, l^*_{c,t} \tag{C.39}$$

$$y_{c,t} = \frac{\tilde{C}_H}{\tilde{Y}_c} c_{H,t} + \frac{1-n}{n} \frac{\tilde{C}^*_H}{\tilde{Y}_c} c^*_{H,t} \tag{C.40}$$

$$y^*_{c,t} = \frac{\tilde{C}^*_F}{\tilde{Y}^*_c} c^*_{F,t} + \frac{n}{1-n} \frac{\tilde{C}_F}{\tilde{Y}^*_c} c_{F,t} \tag{C.41}$$

$$y_{x,t} = \frac{\tilde{X}_H}{\tilde{Y}_x} x_{H,t} + \frac{1-n}{n} \frac{\tilde{X}^*_H}{\tilde{Y}_x} x^*_{H,t} \tag{C.42}$$

$$y^*_{x,t} = \frac{\tilde{X}^*_F}{\tilde{Y}^*_x} x^*_{F,t} + \frac{n}{1-n} \frac{\tilde{X}_F}{\tilde{Y}^*_x} x_{F,t} \tag{C.43}$$

Current account and trade balance:

$$\begin{aligned}\beta b_t \; - \; b_{t-1} \; = \; & \frac{1-n}{n} \tilde{C}^*_H (c^*_{h,t} + rc_{H,t}) - \tilde{C}_F (c_{F,t} + rc^*_{F,t} + rer_t) \\ & + \frac{1-n}{n} \tilde{X}^*_H (x^*_{h,t} + rx_{H,t}) - \tilde{X}_F (x_{F,t} + rx^*_{F,t} + rer_t)\end{aligned} \tag{C.44}$$

$$tb_t = \frac{1-n}{n}\frac{\tilde{C}_H^*}{\tilde{Y}}(c_{h,t}^* + rc_{H,t}) - \frac{\tilde{C}_F}{\tilde{Y}}(c_{F,t} + rc_{F,t}^* + rer_t) + \frac{1-n}{n}\frac{\tilde{X}_H^*}{\tilde{Y}}(x_{h,t}^* + rx_{H,t}) - \frac{\tilde{X}_F}{\tilde{Y}}(x_{F,t} + rx_{F,t}^* + rer_t) \quad \text{(C.45)}$$

Stochastic processes:

$$\zeta_t \;=\; \rho_\zeta\, \zeta_{t-1} \;+\; \varepsilon_{\zeta,t} \quad \text{(C.46)}$$

$$a_{c,t} \;=\; \rho_{a^c}\, a_{c,t-1} + \varepsilon_{a^c,t} \quad \text{(C.47)}$$

$$a_{c,t}^* \;=\; \rho_{a^c}^*\, a_{c,t-1}^* + \varepsilon_{a^c,t}^* \quad \text{(C.48)}$$

$$z_{x,t}^* - z_{x,t-1}^* \;=\; \rho_{z^x}^*(z_{x,t-1}^* - z_{x,t-2}^*) \;+\; \varepsilon_{z^x,t}^* \quad \text{(C.49)}$$

$$z_{x,t} \;-\; z_{x,t}^* \;=\; \rho_{z^x}(z_{x,t-1} \;-\; z_{x,t-1}^*) \;+\; \varepsilon_{z^x,t} \quad \text{(C.50)}$$

Appendix D Data Sources

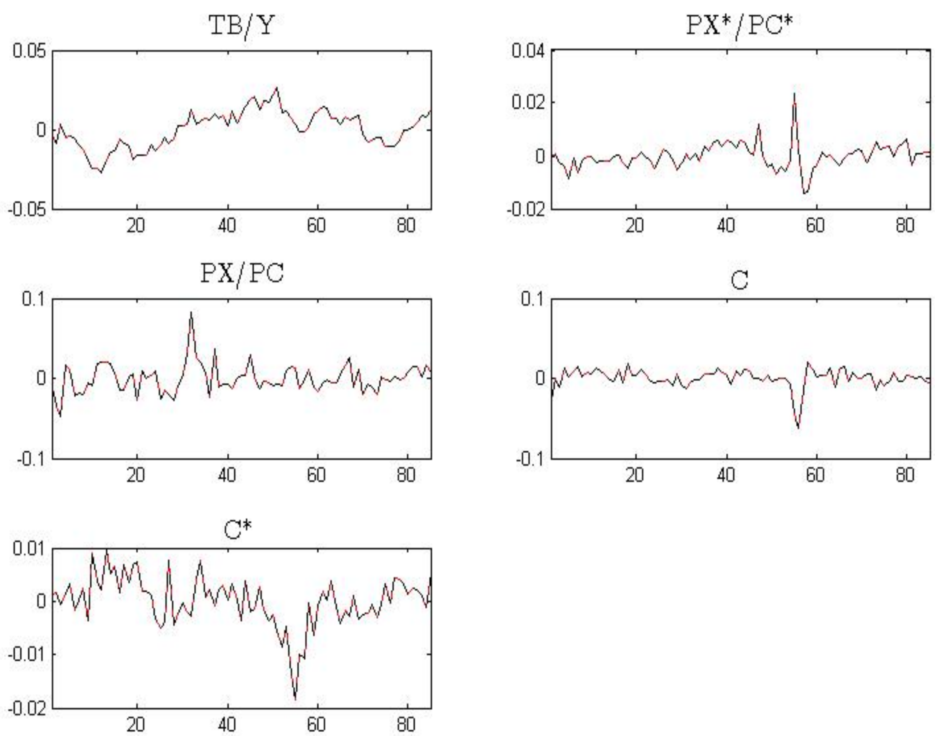
We first explain the data that is used for the Bayesian estimation of the model. We only use the seasonally adjusted series; if the raw data is seasonal, we seasonally adjust it by using the X13-ARIMA method. We take the real consumption data from the OECD, Quarterly National Accounts (QNA). We define the relative price of investment goods as the ratio of investment and consumption deflators. To calculate the deflators, we use the private final consumption expenditure and gross fixed capital formation at current and constant prices from the OECD, QNA. For the US, the real private final consumption expenditure and gross fixed capital formation are available as chained volume estimates. To calculate the bilateral trade balance, we take the monthly data for nominal exports and imports from the US Census Bureau. We aggregate the data by summing the corresponding months within a quarter. We obtain the nominal Mexican GDP from the OECD, QNA in order to express the trade balance as a ratio of GDP. The bilateral export and import data is available in the US dollars. Hence we transform the nominal GDP in national currency to the US dollars by dividing it to the bilateral nominal exchange rate. Finally, the data for population is coming from OECD Historical population data, for all persons. The population data is available at annual frequency; we transform it from annual to quarterly by using linear interpolation.

We use some further data to calculate the second order properties of the key macroeconomic variables.

We took the data for the real GDP from the OECD, QNA. To calculate the real exchange rate we used consumption deflator of each country and the bilateral nominal exchange rate. The data for the nominal exchange rate (national currency per USD) is taken from the IMF, IFS dataset.

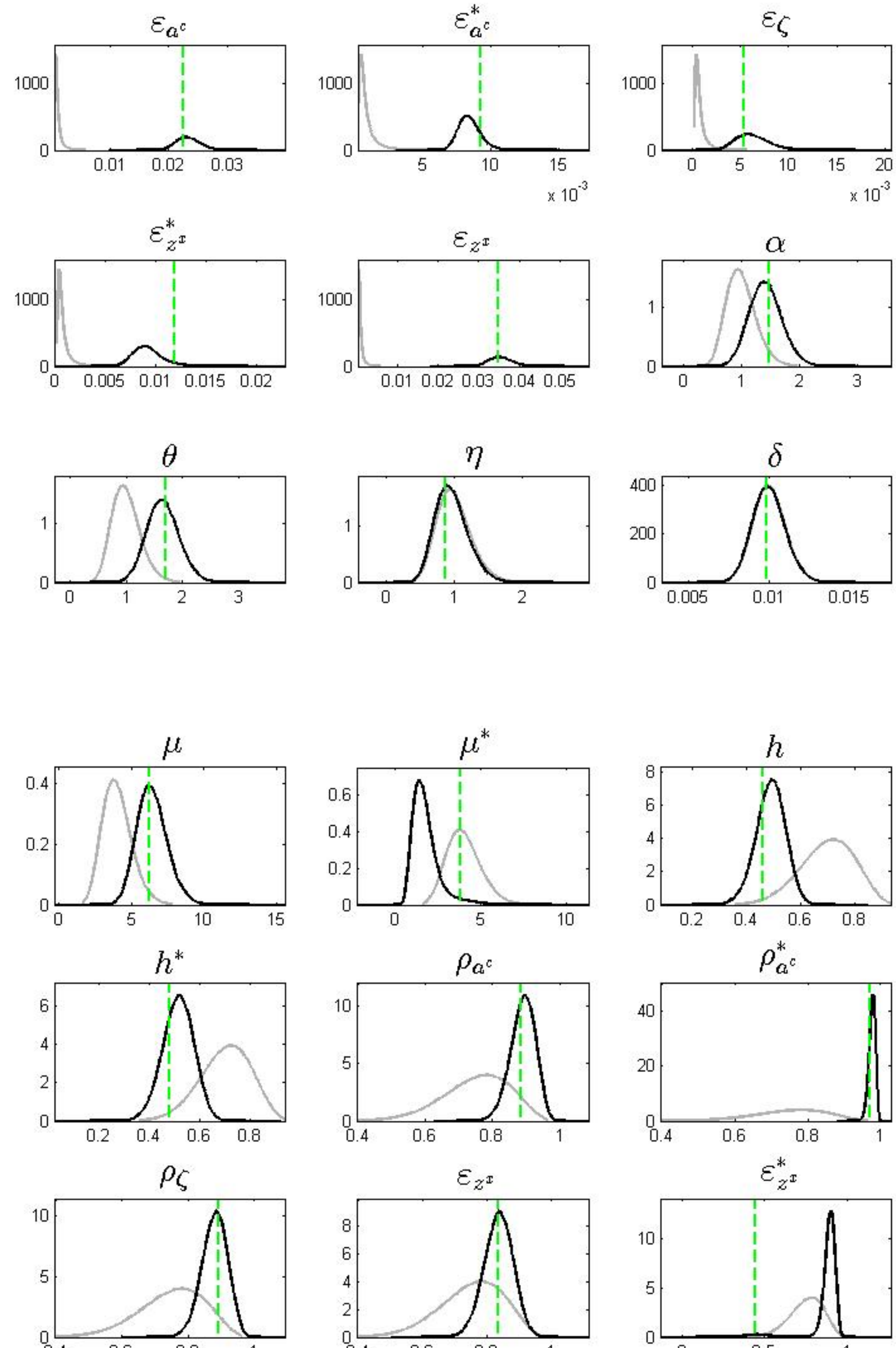
Appendix E   Additional Tables and Figures

Figure 3: Data Series



Note: All series are in natural logarithms except for the ratio of the trade balance to GDP. We divided the bilateral trade balance to the nominal GDP of Mexico. PX/PC refers to the log difference between the price of investment goods and the price of consumption goods. Consumption and the relative price of investment goods are in first differences. All series are demeaned.

Figure 4: Prior and Posterior Distributions



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