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Abstract

This paper incorporates home production into a real business cycle (RBC) model of a small open economy to explain the empirical pattern of international business cycles in developed economies and emerging markets. It is well known in the literature that in order for the RBC model to replicate quantitatively plausible empirical moments of small open economies, the model needs to feature counterfactually a small income effect on labor supply. This paper provides a solution to this puzzle by considering home production that introduces substitutability between market consumption and home consumption, which in turn generates a high volatility in market consumption in accordance with the data, even in the presence of a sizable income effect on labor supply. Furthermore, the model with estimated parameter values based on the simulated method of moments is able to match other empirical moments, such as the standard deviations of output, investment and the trade balance and the correlations between output and other macroeconomic variables. Given that home production is more prevalent in emerging markets than in developed economies, the model is also able to replicate empirical differences between emerging markets and developed economies in the volatility of market consumption and the volatility/countercyclicality of the trade balance.

JEL classification: D13, E32, F41, O16
Keywords: small open economy; home production; emerging markets; business cycles.

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1 Introduction

Developed small open economies are characterized by the following stylized facts. First, consumption is less volatile than output. Second, investment is more volatile than output. Third, the trade balance to GDP ratio is weakly countercyclical. In their pioneering works, Mendoza (1991), Correia *et al.* (1995) and Schmitt-Grohé and Uribe (2003) develop a workhorse real business cycle (RBC) model of a small open economy to explain these stylized facts.[1] In order for the RBC model to replicate quantitatively plausible empirical moments of small open economies, the model needs to feature counterfactually a small income effect on labor supply, which is accomplished by specifying the representative household's utility function in the form proposed by Greenwood *et al.* (1988) (hereafter the GHH preference). However, Correia *et al.* (1995) find that when the income effect on labor supply is present as in the utility function proposed by King *et al.* (1988) (hereafter the KPR preference), volatilities of consumption and the trade balance to GDP ratio decrease significantly and the trade balance to GDP ratio becomes procyclical. With this understanding, we can conclude that under the KPR preference with a sizable income effect on labor supply, it is difficult for the RBC model to replicate quantitatively plausible empirical moments of developed small open economies.

The intuition behind the above result can be explained as follows. Given that the world interest rate faced by a small open economy is exogenous, the variation in the marginal utility of consumption tends to be small in response to a domestic technology shock. In the case of the KPR preference that features a sizable income effect on labor supply, consumption and leisure are complements in utility. Thus, an increase in equilibrium labor led by a positive technology shock reduces leisure and restrains the increase in consumption. As a result, consumption is not as volatile as in the data. By contrast, under the GHH preference that does not feature any income effect on labor supply, consumption and leisure are substitutes in utility. In this case, a positive technology shock reduces leisure and increases consumption significantly. As a result, consumption can be as volatile as in the data. However, empirical studies, such as Imbens *et al.* (2001), Kimball and Shapiro (2010) and Khan and Tsoukalas (2011, 2012), often find a sizable income effect on labor supply, implying that the KPR preference is the more plausible specification for the utility function.

In this study, we provide a solution to this puzzle by considering home production. Specifically, we consider two distinctive products: a home-produced product and a market-produced product. The home-produced product is not traded in the market; instead, it is consumed by the representative household for its own satisfaction. An advantage of the introduction of home production is that it allows the household to substitute between home consumption and market consumption, which in turn generates a high volatility in market consumption in accordance with the data, even in the presence of a sizable income effect on labor supply. The presence of substitutability between market consumption and home consumption is supported by Blankenau and Kose (2007).[2] Baxter and Jermann (1999) also

[1] For seminal studies on the two-country RBC model; see, for example, Backus *et al.* (1992) and Stockman and Tesar (1995).

[2] Based on data for market variables in industrialized countries, Blankenau and Kose (2007) use the small open economy RBC model to generate simulated data of home variables. They find that market consumption is negatively correlated with home consumption, and market hours worked are negatively correlated with

employ the substitutability between market consumption and home consumption to explain the excess sensitivity of consumption to income.

Intuitively, in the presence of home production, when the domestic economy experiences a positive technology shock in the production of market goods, it leads to a lower price of market consumption. Then the representative household increases its market consumption and substitutes away from home consumption. This substitution between market consumption and home consumption introduces a channel for an increase in the volatility of market consumption. In addition, a positive market technology shock raises the marginal product of capital. Consequently, households increase the accumulation of domestic capital and the borrowing from the world capital market. This capital inflow causes a trade deficit and reduces the trade balance to GDP ratio. This result implies that the trade balance to GDP ratio is countercyclical and more volatile in the presence of home production. Accordingly, home production is a plausible channel to explain business cycles in small open economies.

Moreover, some studies highlight the different features of business cycles between emerging markets and developed economies. In their influential articles, Neumeyer and Perri (2005) and Aguiar and Gopinath (2007) point out three important differences between these two types of economies. First, the volatility of output in emerging markets is higher than that in developed economies. Second, the volatility of output exceeds the volatility of consumption in developed economies, whereas output is less volatile than consumption in emerging markets. Third, the trade balance to GDP ratio is more volatile and more countercyclical in emerging markets than in developed economies. Some studies are devoted to explaining these empirical differences between emerging markets and developed economies. Neumeyer and Perri (2005) introduce a country risk shock to amplify the intertemporal substitution between current and future consumption. Aguiar and Gopinath (2007) and Boz *et al.* (2011) emphasize the importance of trend shocks to technology. In this study, we explore home production as a plausible explanation of the empirical pattern of international business cycles in developed economies and emerging markets.

Parente *et al.* (2000) point out that developing economies spend more hours working in the home sector than developed economies do. For example, based on time-use survey data for Canada and Mexico, we find that home hours worked per day are 3.10 in Canada and 5.16 in Mexico, whereas market hours worked per day are 3.50 in Canada and 3.62 in Mexico. Therefore, we consider as a stylized fact that people spend more time on home production in emerging markets than in developed economies. More hours worked on home production can be captured by a higher utility share of home consumption in our model. When home production becomes more prevalent, market consumption becomes less important in smoothing the marginal utility of aggregate consumption (aggregated over market and home consumption). The substitutability between market and home consumption can then play an important role in explaining the volatility of market consumption. To sum up, the presence of home production leads to an increase in the volatility of market consumption. Moreover, given that home production is more important in emerging markets than in developed economies, our model is able to replicate empirical differences between these two types of economies in the volatility of market consumption and the volatility/countercyclicality of the trade balance.

home hours worked.

The remainder of this paper proceeds as follows. Section 2 documents stylized facts of developed economies and emerging markets. Section 3 develops a small open economy RBC model with home production and characterizes the domestic economy's competitive equilibrium. Section 4 analyzes the quantitative results. Section 5 discusses the concluding remarks.

2 Stylized facts

In this section, we first document stylized facts of business cycles in small open economies and update business cycle moments from previous studies. We begin by describing a data set in which the sample includes 27 small open economies. According to the classification of Morgan Stanley Capital International (MSCI), the sample countries are divided into developed economies and emerging markets. In our sample, developed economies consist of 13 countries: Australia, Austria, Belgium, Canada, Denmark, Finland, Luxembourg, the Netherlands, New Zealand, Portugal, Spain, Sweden, and Switzerland. Emerging markets consist of 14 countries: Argentina, Brazil, the Czech Republic, Estonia, Hungary, Korea, Malaysia, Mexico, Poland, the Slovak Republic, Slovenia, South Africa, Thailand, and Turkey.

The data that we use come from the database of the Organisation for Economic Cooperation and Development (OECD) for the available period 1978:I-2008:III.[3] For each country, there are six time series of data used in the computation of empirical moments: GDP $\hat{y}_t$, private final consumption $\hat{c}_{m,t}$, gross fixed capital formation $\hat{I}_t$, the trade balance to GDP ratio $\hat{b}_t$, population (defined as persons 16 years of age and older), and the GDP deflator.[4] The time series data we use are seasonally adjusted.[5] All variables except the trade balance to GDP ratio $\hat{b}_t$ are expressed in natural logarithms, and all variables (including $\hat{b}_t$) are de-trended by the HP-filter with the smoothing parameter set to 1,600.

Given the data, we compute the business cycle moments for each country including the standard deviation of output $std(\hat{y}_t)$, the standard deviation of market consumption $std(\hat{c}_{m,t})$, the standard deviation of investment $std(\hat{I}_t)$, the standard deviation of the trade balance to GDP ratio $std(\hat{b}_t)$, the correlation coefficient between consumption and output $corr(\hat{c}_{m,t}, \hat{y}_t)$, the correlation coefficient between investment and output $corr(\hat{I}_t, \hat{y}_t)$, and the correlation coefficient between the trade balance to GDP ratio and output $corr(\hat{b}_t, \hat{y}_t)$. The business cycle moments in developed economies and emerging markets are summarized in Table 1 and Table 2, respectively. Moreover, it should be noted that in Table 1 and Table 2, the average moments in the last row are weighted by each country's share of the group's aggregate GDP.

Table 1 shows that in developed economies the average standard deviation of output $std(\hat{y}_t)$ is 1.32, the average standard deviation of market consumption $std(\hat{c}_{m,t})$ is 1.24, the

[3]The only exceptions are that the data on Malaysia and Thailand come from the CEIC-Asia database and the data on population in Argentina come from the International Labor Organization (ILO) database.

[4]The series of the trade balance to GDP ratio $\hat{b}_t$ is derived from the trade balance divided by GDP, and the trade balance is derived by subtracting imports of goods and services from exports of goods and services. In addition, given the fact that the series of the GDP deflator is derived from nominal gross domestic product divided by real gross domestic product, we can then use the GDP deflator to deflate nominal values of the relevant variables.

[5]We employ the X-12 ARIMA program provided by the U.S. Census Bureau to produce the seasonally-adjusted data.

standard deviation of investment $std(\hat{I}_t)$ is 4.58, and the correlation coefficient between the trade balance to GDP ratio and output $corr(\hat{b}_t, \hat{y}_t)$ is -0.25. Accordingly, we can find that developed small open economies feature three stylized facts of business cycles, which have been explored by previous studies, such as Mendoza (1991), Correia *et al.* (1995) and Schmitt-Grohé and Uribe (2003). First, market consumption is less volatile than output. Second, investment is more volatile than output. Third, the trade balance to GDP ratio is weakly countercyclical.

Table 1: Business cycle moments in developed economies

Country	sample	$std(\hat{y}_t)$	$\frac{std(\hat{c}_{m,t})}{std(\hat{y}_t)}$	$\frac{std(\hat{I}_t)}{std(\hat{y}_t)}$	$std(\hat{b}_t)$	$corr(\hat{c}_{m,t}, \hat{y}_t)$	$corr(\hat{I}_t, \hat{y}_t)$	$corr(\hat{b}_t, \hat{y}_t)$
Australia	78:I-08:III	1.38	0.80	3.51	0.95	0.35	0.81	−0.34
Austria	78:I-08:III	1.03	0.94	2.28	0.77	0.68	0.58	−0.05
Belgium	78:I-08:III	0.99	1.02	4.15	1.05	0.70	0.75	−0.31
Canada	78:I-08:III	1.47	0.78	2.91	0.91	0.61	0.73	−0.10
Denmark	78:I-08:III	1.37	1.28	4.16	1.06	0.74	0.69	−0.41
Finland	78:I-08:III	1.94	0.64	3.56	1.36	0.56	0.87	−0.26
Luxembourg	78:I-08:III	1.79	1.29	4.41	2.57	0.41	0.33	0.23
Netherlands	78:I-08:III	1.28	0.93	3.47	0.94	0.69	0.72	−0.10
New Zealand	78:I-08:III	1.80	1.04	3.42	1.41	0.52	0.59	0.02
Portugal	78:I-08:III	1.65	1.12	3.86	1.81	0.66	0.81	−0.48
Spain	78:I-08:III	1.09	1.18	4.00	1.02	0.78	0.76	−0.47
Sweden	78:I-08:III	1.35	0.99	3.79	0.99	0.46	0.78	−0.09
Switzerland	78:I-08:III	1.25	0.76	2.99	0.96	0.68	0.83	−0.44
Average		1.32	0.94	3.47	1.02	0.63	0.75	−0.25

Notes: For each country, the business cycle moments include the standard deviations of output $std(\hat{y}_t)$, market consumption $std(\hat{c}_{m,t})$, investment $std(\hat{I}_t)$ and the trade balance to GDP ratio $std(\hat{b}_t)$ and the correlation coefficients between consumption and output $corr(\hat{c}_{m,t}, \hat{y}_t)$, investment and output $corr(\hat{I}_t, \hat{y}_t)$, and the trade balance to GDP ratio and output $corr(\hat{b}_t, \hat{y}_t)$. All variables apart from the trade balance to GDP ratio $\hat{b}_t$ are in natural logarithms, and all variables (including $\hat{b}_t$) are de-trended by the HP-filter with the smoothing parameter set to 1,600. The standard deviations of output, market consumption, investment, and the trade balance to GDP ratios are reported in percentage terms. In addition, the average moments are weighted by each country's share of each group's GDP (in US dollars in 2000).

Moreover, in view of the business cycle moments exhibited in Table 1 and Table 2, we can find three stylized facts of business cycles in developed economies and emerging markets, which are consistent with the findings in Neumeyer and Perri (2005), Aguiar and Gopinath (2007) and Ávarez-Parra *et al.* (2013). First, output is more volatile in emerging markets than in developed economies. Specifically, the average standard deviations of output $std(\hat{y}_t)$ are respectively 1.32 and 2.34 in developed economies and emerging markets. Second, market consumption is less volatile than output in developed economies, whereas it is more volatile than output in emerging markets. Specifically, the average ratios between the standard deviations of market consumption and output $std(\hat{c}_{m,t})/std(\hat{y}_t)$ are respectively 0.94 for developed economies and 1.36 for emerging markets. Third, the trade balance to GDP ratio is more volatile and more countercyclical in emerging markets than in developed economies. Specifically, the average standard deviations of the trade balance to GDP ratio $std(\hat{b}_t)$ are respectively 1.02 for developed economies and 2.07 for emerging markets. Furthermore, the average correlation coefficients between the trade balance to GDP ratio and output $corr(\hat{b}_t, \hat{y}_t)$ are respectively –0.25 for developed economies and –0.50 for emerging markets. With these stylized facts, we will develop a small open economy model in the next section and test the model by replicating the business-cycle features exhibited above.

Table 2: Business cycle moments in emerging market economies

Country	sample	$std(\hat{y}_t)$	$\frac{std(\hat{c}_{m,t})}{std(\hat{y}_t)}$	$\frac{std(\hat{I}_t)}{std(\hat{y}_t)}$	$std(\hat{b}_t)$	$corr(\hat{c}_{m,t}, \hat{y}_t)$	$corr(\hat{I}_t, \hat{y}_t)$	$corr(\hat{b}_t, \hat{y}_t)$
Argentina	93:I-08:III	4.12	1.36	3.17	2.81	0.93	0.92	−0.82
Brazil	96:I-08:III	1.37	1.44	3.35	0.96	0.71	0.76	−0.32
Czech Republic	95:I-08:III	1.24	1.11	3.20	1.31	0.59	0.62	−0.35
Estonia	95:I-08:III	2.36	1.22	3.65	2.51	0.80	0.88	−0.58
Hungary	95:I-08:III	0.98	2.22	2.34	1.61	0.43	0.30	−0.26
Korea	78:I-08:III	2.42	1.35	2.41	2.55	0.76	0.76	−0.43
Malaysia	91:I-08:III	2.76	1.62	4.53	4.59	0.73	0.81	−0.62
Mexico	78:I-08:III	2.53	1.26	3.39	2.07	0.77	0.82	−0.60
Poland	95:I-08:III	1.35	1.33	4.58	1.08	0.54	0.77	−0.56
Slovak Republic	93:I-08:III	1.58	1.53	6.10	4.10	0.46	0.57	−0.26
Slovenia	96:I-08:III	0.86	1.30	5.03	1.68	0.26	0.51	−0.08
South Africa	78:I-08:III	1.79	1.46	3.27	2.44	0.62	0.69	−0.41
Thailand	94:I-08:III	3.60	1.08	3.43	4.17	0.93	0.91	−0.68
Turkey	78:I-08:III	3.01	1.35	3.38	1.67	0.66	0.79	−0.50
Average		2.34	1.36	3.30	2.07	0.73	0.78	−0.50

Notes: For each country, the business cycle moments include the standard deviations of output $std(\hat{y}_t)$, market consumption $std(\hat{c}_{m,t})$, investment $std(\hat{I}_t)$ and the trade balance to GDP ratio $std(\hat{b}_t)$ and the correlation coefficients between consumption and output $corr(\hat{c}_{m,t}, \hat{y}_t)$, investment and output $corr(\hat{I}_t, \hat{y}_t)$, and the trade balance to GDP ratio and output $corr(\hat{b}_t, \hat{y}_t)$. All variables except for the trade balance to GDP ratio $\hat{b}_t$ are in natural logarithms, and all variables (including $\hat{b}_t$) are de-trended by the HP-filter with the smoothing parameter set to 1,600. The trade balance to GDP ratios are reported in percentage terms. In addition, the average moments are weighted by each country's share of each group's GDP (in US dollars in 2000).

In the rest of this section, we document some stylized facts of market and home production in Canada and Mexico, given that we consider Canada and Mexico respectively as a representative developed economy and a representative emerging market. The time-use survey data for Canada are obtained from Statistics Canada, General Social Survey in 2005, and the time-use survey data for Mexico are from the Instituto Nacional de Estadística y Geografía (INEGI), Encuesta Nacional sobre Uso del Tiempo in 2009. Based on these time-use survey data for Canada and Mexico, both home hours worked and market hours worked are depicted in Table 3. As shown in Table 3, the number of market hours worked is 3.50 in Canada, which is slightly lower than the 3.62 in Mexico. In addition, the number of home hours worked is 3.10 in Canada, which is significantly lower than the 5.16 in Mexico, showing that people spend more time on home production in Mexico than in Canada. After estimating the model using other empirical moments, we will also compare the simulation results with the data in Table 3 as a robustness check.

Table 3: Time-use in Canada and Mexico

	Canada	*Mexico*
Home hours worked per day	3.10	5.16
Market hours worked per day	3.50	3.62

Notes: Based on the time-use data, market hours worked are measured by time spent on paid market work, and home market hours worked are measured by time spent on the activities of unpaid household work. Following Ramey and Francis (2009), we define home production activities as: planning, purchasing goods and services, care of children and adults, general cleaning, care and repair of the house and grounds, preparing and clearing food, making, mending, and laundering of clothing and other household textiles.

3 A small open economy RBC model with home production

The domestic economy is inhabited by a representative household. In what follows, we describe the behavior of the representative household and characterize the competitive equilibrium of the economy.

3.1 The representative household-producer

We follow Benhabib *et al.* (1991) and Baxter and Jermann (1999) to model home production in the RBC model. The representative household-producer derives utility from aggregate consumption C_t, which is composed of market consumption $c_{m,t}$ and home consumption $c_{h,t}$, and incurs disutility from total hours worked N_t, which is the sum of market hours worked $n_{m,t}$ and home hours worked $n_{h,t}$. In line with Jaimovich and Rebelo (2009), we propose the following utility function that nests the GHH preference and the KPR preference as special cases:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left(C_t - \omega N_t^{\xi} X_t\right)^{1-\sigma} - 1}{1-\sigma}, \tag{1}$$

where aggregate consumption C_t, total hours worked N_t and the geometric average of current and past consumption levels X_t are defined as follows:

$$X_t = C_t^{\gamma} X_{t-1}^{1-\gamma}, \tag{2a}$$

$$C_t = \left[\theta c_{m,t}^{\phi} + (1-\theta)\, c_{h,t}^{\phi}\right]^{\frac{1}{\phi}}, \tag{2b}$$

$$N_t = n_{m,t} + n_{ht}, \tag{2c}$$

where $\theta \in (0,1)$ denotes the utility share of market consumption, $\phi < 1$ governs the elasticity of substitution between market and home consumption (i.e., $e \equiv \frac{1}{1-\phi}$), $\sigma > 0$ denotes the inverse of the intertemporal elasticity of substitution in consumption, $\xi > 0$ denotes the inverse of the Frisch labor supply elasticity, $\beta \in (0,1)$ represents the household's subjective discount factor, and $\omega > 0$ denotes the scaling disutility of labor supply. A salient feature of the Jaimovich-Rebelo preference reported in equations (1) and (2a) is that $\gamma \in [0,1]$ parameterizes the short-run income effect of labor supply. When $\gamma = 1$, the sizable income effect leads to a reduction in labor supply upon experiencing a productivity improvement, and this is associated with the KPR preference.[6] When $\gamma = 0$, the absence of the income effect leads to an increase in labor supply upon the arrival of a productivity improvement, and this is associated with the GHH preference.

Each representative household produces market output and home consumption goods according to the following Cobb-Douglas form:

$$y_t = A_{m,t} k_{m,t}^{\alpha_m} n_{m,t}^{1-\alpha_m}, \tag{3a}$$

$$c_{h,t} = A_{h,t} k_{h,t}^{\alpha_h} n_{h,t}^{1-\alpha_h}, \tag{3b}$$

where $k_{m,t}$ and $k_{h,t}$ respectively denote market capital and home capital, $\alpha_m \in (0,1)$ and $\alpha_h \in (0,1)$ respectively denote the production share of market capital and home capital, and $A_{m,t}$ and $A_{h,t}$ respectively denote the level of total factor productivity in each production sector. We assume that the natural logarithms of both total factor productivity processes are persistent, following a first-order autoregressive process:

$$\log A_{m,t} = \rho_m \log A_{m,t-1} + \varepsilon_{m,t}, \tag{4a}$$

$$\log A_{h,t} = \rho_h \log A_{h,t-1} + \varepsilon_{h,t}, \tag{4b}$$

where $\rho_m \in (0,1)$ and $\rho_h \in (0,1)$ denote persistence parameters and $\varepsilon_{m,t}$ and $\varepsilon_{h,t}$ denote exogenous innovations in the market and home production sectors, respectively. Both $\varepsilon_{m,t}$ and $\varepsilon_{h,t}$ are normally distributed with zero mean and finite variance σ_m^2 and σ_h^2.

In each period, the representative household can finance its budget deficit by borrowing from the world market, and a flow of foreign debt is linked to any difference between its expenditure and its income. Let d_t denote foreign debt measured in terms of domestic output and r_t represent the world real interest rate on foreign debt. The household's flow budget constraint can then be expressed as:

$$d_{t+1} = (1+r_t)d_t + c_{m,t} + I_{m,t}\left[1 + \Psi_m\left(\frac{I_{m,t}}{k_{m,t}}\right)\right] + I_{h,t}\left[1 + \Psi_h\left(\frac{I_{h,t}}{k_{h,t}}\right)\right] - y_t, \tag{5}$$

where $I_{m,t}$ and $I_{h,t}$ denote investment in market capital and home capital. The representative household installs market and home capital involving extra adjustment costs (installation costs). In line with Hayashi (1982) and Abel and Blanchard (1983), the adjustment cost functions in the two sectors are specified as follows:

$$\Psi_m\left(\frac{I_{m,t}}{k_{m,t}}\right) = \frac{\psi_m}{2}\frac{I_{m,t}}{k_{m,t}}, \tag{6a}$$

$$\Psi_h\left(\frac{I_{h,t}}{k_{h,t}}\right) = \frac{\psi_h}{2}\frac{I_{h,t}}{k_{h,t}}, \tag{6b}$$

[6] In the case of a productivity improvement, the decrease in labor supply is offset by an increase in labor demand such that the labor input increases in equilibrium.

where $\Psi_m\left(\frac{I_{m,t}}{k_{m,t}}\right)$ and $\Psi_h\left(\frac{I_{h,t}}{k_{h,t}}\right)$ reflect the adjustment costs incurred by each unit of market capital investment and home capital investment.[7] $\psi_m > 0$ and $\psi_h > 0$ denote the intensity parameters of the investment adjustment costs in the market and home sectors. As is evident in equations (6a) and (6b), the investment adjustment cost functions satisfy the following properties: $\Psi'_m(\cdot) > 0$ and $\Psi'_h(\cdot) > 0$.

Aggregate investment and the law of motion of the capital stock in each sector can be specified as follows:

$$k_{m,t+1} = (1-\delta_m)\, k_{m,t} + I_{m,t}, \tag{7a}$$

$$k_{h,t+1} = (1-\delta_h)\, k_{h,t} + I_{h,t}, \tag{7b}$$

$$I_t = I_{m,t} + I_{h,t}, \tag{7c}$$

where $\delta_m \in (0,1)$ and $\delta_h \in (0,1)$ respectively stand for the depreciation rates of market capital and home capital and I_t denotes aggregate investment.

The sequence of $\{c_{m,t}, c_{h,t}, X_t, n_{m,t}, n_{h,t}, I_{m,t}, I_{h,t}, k_{m,t+1}, k_{h,t+1}, d_{t+1}\}$ is chosen by the household to maximize lifetime utility in equation (1) subject to equations (2a)-(7c). Let g_t, μ_t, λ_t, $q'_{m,t}$ and $q'_{h,t}$ be the Lagrange multipliers associated with (2a), (3b), (5), (7a) and (7b), respectively. We define $q_{m,t} \equiv \frac{q'_{m,t}}{\lambda_t}$ and $q_{h,t} \equiv \frac{q'_{h,t}}{\lambda_t}$ such that $q_{m,t}$ and $q_{h,t}$ represent the relative prices of additional installed market and home capital in terms of the marginal utility of consumption. The optimality conditions necessary for the representative household with respect to the indicated variables are:

$$c_{m,t}: \quad \left[\left(C_t - \omega N_t^{\xi} X_t\right)^{-\sigma} + g_t\gamma\left(\frac{C_t}{X_{t-1}}\right)^{\gamma-1}\right]\theta\left(\frac{c_{m,t}}{C_t}\right)^{\phi-1} = \lambda_t, \tag{8a}$$

$$c_{h,t}: \quad \frac{\theta}{1-\theta}\left(\frac{c_{m,t}}{c_{h,t}}\right)^{\phi-1} = \frac{\lambda_t}{\mu_t}, \tag{8b}$$

$$X_t: \quad \left(C_t - \omega N_t^{\xi} X_t\right)^{-\sigma}\omega N_t^{\xi} + g_t = \beta g_{t+1}(1-\gamma)\left(\frac{C_{t+1}}{X_t}\right)^{\gamma}, \tag{8c}$$

$$n_{m,t}: \quad \frac{\left(C_t - \omega N_t^{\xi} X_t\right)^{-\sigma}\omega\xi N_t^{\xi-1}}{\left(C_t - \omega N_t^{\xi} X_t\right)^{-\sigma} + g_t\gamma\left(\frac{C_t}{X_{t-1}}\right)^{\gamma-1}}\frac{X_t}{\theta}\left(\frac{c_{m,t}}{C_t}\right)^{1-\phi} = (1-\alpha_m)\frac{y_t}{n_{m,t}}, \tag{8d}$$

$$n_{h,t}: \frac{\mu_t}{\lambda_t} = \frac{1-\alpha_m}{1-\alpha_h}\frac{y_t/n_{m,t}}{c_{h,t}/n_{h,t}}, \tag{8e}$$

$$I_{m,t}: \quad \frac{I_{m,t}}{k_{m,t}} = \frac{q_{m,t}-1}{\psi_m}, \tag{8f}$$

$$I_{h,t}: \quad \frac{I_{h,t}}{k_{h,t}} = \frac{q_{h,t}-1}{\psi_h}, \tag{8g}$$

$$k_{m,t+1}: \quad q_{m,t} = \beta\frac{\lambda_{t+1}}{\lambda_t}\left[\alpha_m\frac{y_{t+1}}{k_{m,t+1}} + \frac{(q_{m,t+1}-1)^2}{2\psi_m} + (1-\delta_m)q_{m,t+1}\right], \tag{8h}$$

[7] The unit adjustment costs being a function of investment relative to the capital stock can be justified by learning-by-doing in the installation process.

$$k_{h,t+1}:\ q_{h,t} = \beta \frac{\lambda_{t+1}}{\lambda_t} \left[\alpha_h \frac{\mu_{t+1}}{\lambda_{t+1}} \frac{c_{h,t+1}}{k_{h,t+1}} + \frac{(q_{h,t+1}-1)^2}{2\psi_h} + (1-\delta_h) q_{h,t+1} \right], \tag{8i}$$

$$d_{t+1}:\ 1 = \beta \frac{\lambda_{t+1}}{\lambda_t} (1 + r_{t+1}). \tag{8j}$$

Before ending this subsection, an important point should be mentioned here. The presence of home consumption allows for substitutability between home consumption and market consumption. The engine driving this substitutability is the change in the relative price between home consumption and market consumption. To shed light on the importance of home production, it is helpful to discuss how the relative price between market and home consumption $p_t (= \frac{\lambda_t}{\mu_t})$ reacts in response to technology shocks.

From equations (3a), (3b), (8b), and (8e), the relative price between market and home consumption can be expressed as:

$$p_t = \frac{\theta}{1-\theta} \left(\frac{c_{m,t}}{c_{h,t}} \right)^{\phi - 1} = \frac{1-\alpha_h}{1-\alpha_m} \frac{A_{h,t} k_{h,t}^{\alpha_h} n_{h,t}^{-\alpha_h}}{A_{m,t} k_{m,t}^{\alpha_m} n_{m,t}^{-\alpha_m}}. \tag{9}$$

Equation (9) denotes the optimal allocation between market and home consumption. It states that the relative price of market consumption equals the marginal rate of substitution between market and home consumption. It also equals the ratio between the marginal product of home hours worked and the marginal product of market hours worked.[8] As is clear in equation (9), a rise in the marginal product of market hours worked leads to a lower relative price p_t, which in turn causes the household to raise market consumption and reduce home consumption.

3.2 Competitive equilibrium

The representative household has access to the world capital market and is able to borrow from the international market. In line with Edwards (1984), Chung and Turnovsky (2010), Li (2011) and Heer and Schubert (2012), the household faces an upward-sloping curve for debt when borrowing from abroad. More specifically, to reflect the extent of default risk in association with foreign debt, the borrowing rate charged by the foreign country on debt is specified to be positively related to the debt to GDP ratio:

$$r_{t+1} = R + \eta \left[\exp\left(\frac{d_{t+1}}{y_t} - \upsilon \right) - 1 \right]. \tag{10}$$

[8] Based on equations (3a), (3b), and (8e), the household's optimal allocation between market and home hours worked can be inferred as:

$$1 = \frac{\lambda_t}{\mu_t} \frac{(1-\alpha_m) A_{m,t} k_{m,t}^{\alpha_m} n_{m,t}^{-\alpha_m}}{(1-\alpha_h) A_{h,t} k_{h,t}^{\alpha_h} n_{h,t}^{-\alpha_h}}.$$

This equation indicates that the marginal rate of substitution between market and home hours worked (on the left-hand side) is equal to the marginal rate of transformation between market and home hours worked (on the right-hand side). Since $p_t = \frac{\lambda_t}{\mu_t}$ denotes the relative price of market consumption, i.e., the ratio between the marginal utilities of market and home consumption, from equations (8a) and (8b) the relative price of market consumption p_t can then be derived as the expression in equation (12).

In equation (10), the parameter R denotes the exogenous component of the world interest rate and the parameter υ reflects the stationary foreign debt to output ratio. The parameter η reflects the borrowing premium associated with default risk and can be interpreted as the extent of the country default risk. It is important to note that in this small open economy we follow the standard treatment in the literature to assume that the representative household-producer is a price-taker in the world capital market, and he/she is unable to affect the level of the world interest rate r_{t+1}. Therefore, the representative household-producer takes r_{t+1} as given when he/she is making optimality decisions.

For ease of exposition, we use b_t to denote the trade balance to GDP ratio; i.e., $b_t \equiv \frac{1}{y_t}[y_t - c_{m,t} - I_{m,t}(1 + \frac{\psi_m}{2}\frac{I_{m,t}}{k_{m,t}}) - I_{h,t}(1 + \frac{\psi_h}{2}\frac{I_{h,t}}{k_{h,t}})]$. Equation (5) can be reexpressed as:

$$d_{t+1} - d_t = -\left(b_t y_t - r_t d_t\right). \qquad (11)$$

Equation (11) states that the economy's net accumulation of foreign debt is equal to the negative value of the current account (the trade balance minus the net interest payment on foreign debt). The competitive equilibrium of the economy is composed of 22 equations: (2a)-(3b), (5) and (7a)-(11). The endogenous variables are the sequences of quantities $\{y_t, c_{m,t}, c_{h,t}, C_t, X_t, N_t, n_{m,t}, n_{h,t}, I_{m,t}, I_{h,t}, I_t, k_{m,t}, k_{h,t}, d_t, b_t\}$ and prices $\{r_t, g_t, \mu_t, \lambda_t, p_t, q_{m,t}, q_{h,t}\}$.

4 Results

We consider Canada and Mexico respectively as a representative developed economy and a representative emerging market. We begin by characterizing a benchmark economy, in which structural parameters are divided into two groups. Each parameter in the first group is either set to a commonly used value or calibrated to match empirical evidence in Canada and Mexico. Each parameter in the second group is estimated by the simulated method of moments (hereafter SMM).

This section is arranged as follows. We first deal with the calibration of parameters in the first group. Next, we estimate parameters in the second group using SMM and report quantitative results to show that our theoretical model embodying home production is able to replicate standard business cycle moments in the two small open economies. In addition, we explore impulse responses in response to market-technology and home-technology shocks and explain why home production enables the model to produce empirically plausible business cycle moments in the two types of economies. Finally, we report sensitivity analysis.

4.1 Calibration

In the first group of parameters, we consider the following commonly used values in the literature: the discount factor $\beta = 0.98$, the inverse of the Frisch labor supply elasticity $\xi = 1.6$, and the inverse of the intertemporal elasticity of substitution in consumption $\sigma = 2$. Following Greenwood and Hercowitz (1991), Parente *et al.* (2000) and Karabarbounis (2013), we assume that the depreciation rates of market capital and home capital are identical; i.e., $\delta_m = \delta_h = \delta$, and δ is set to 0.025. Given an overall non-sleeping time of 16 hours in both countries, the scaling disutility of labor supply ω is set to 1.56 for Canada and 0.83 for

Mexico to match a steady-state value of market hours worked of $n_m = 0.22$ for Canada and 0.23 for Mexico.

In line with Rupert *et al.* (1995), Schmitt-Grohé (1998) and Karabarbounis (2013), we set $\phi = 0.75$ and this implies an elasticity of substitution between market and home consumption of 4.[9] According to Greenwood *et al.* (1995), the production shares of market capital and home capital are set to $\alpha_m = 0.29$ and $\alpha_h = 0.32$, respectively. In addition, we set the parameter governing the short-run income effect on labor supply as $\gamma = 1$, and hence the utility function is associated with the KPR preference.[10] The data show that the foreign debt to output ratio is 25% in Canada and 44% in Mexico. Hence, we set $\upsilon = 0.25$ in the developed economy and $\upsilon = 0.44$ in the emerging market. In line with Neumeyer and Perri (2005), Otsu (2008) and Jaimovich and Rebelo (2009), the parameter η reflecting the borrowing premium associated with default risk is set to 0.00001.[11] Finally, following McGrattan *et al.* (1997), we assume that the innovations in the market and home sectors are uncorrelated in our benchmark estimation.[12] A summary of the calibrated parameter values is reported in Table 4.

Table 4: Parameter calibration

	β	ξ	σ	δ	ω	ϕ	γ	α_m	α_h	υ	η
Canada	0.98	1.6	2	0.025	1.56	0.75	1	0.29	0.32	0.25	0.00001
Mexico	0.98	1.6	2	0.025	0.83	0.75	1	0.29	0.32	0.44	0.00001

4.2 SMM estimation and quantitative results

We now consider the second group of parameters. Due to the model's complexity, we resort to numerical methods to solve the model by linearizing the dynamic equations around the steady state.[13] We assume that the intensity parameters of investment adjustment costs

[9] In their pioneering studies, Benhabib *et al.* (1991) and Greenwood and Hercowitz (1991) set the elasticity of substitution between market and home consumption e equal to 5 and 3, respectively. In addition, Rupert *et al.* (1995) estimate the plausible value of e to be in the range of 0 to 5 (see Baxter and Jermann (1999, p.909)). Accordingly, the value of $e = 4$ lies within the values reported in the previous studies.

[10] This strong income effect will make it difficult for our model to match the business cycle properties of small open economies. We consider this case in order to see how robust our model with home production could be.

[11] Based on Schmitt-Grohé and Uribe (2003), the presence of the parameter η reflecting the borrowing premium in association with the default risk ensures that the model is stationary. In addition, a small value of η implies that the borrowing premium in association with the default risk cannot affect the short-run dynamics of the model. Therefore, we set $\eta = 0.00001$ in the two economies to satisfy these two purposes. Moreover, we will show that the model is able to characterize business cycles in small open economies even with the strict restriction of an identical η in the two economies. Our model will have better performance to capture business cycles in small open economies when this restriction is relaxed.

[12] In the literature on home production, a positive correlation between market technology shocks and home technology shocks plays a role in explaining the synchronized relationship between market investment and home investment in the United States (see the more detailed discussion in Greenwood *et al.* (1995)). Therefore, as a robustness check in the next subsection, we show that allowing market and home technology shocks to be positively correlated does not affect our main results.

[13] The stationary expressions of variables and derivations are relegated to Appendix A.

in both the market and home sectors are identical (i.e., $\psi_m = \psi_h = \psi$), the persistent parameters are identical (i.e., $\rho_m = \rho_h = \rho$) and the variances of technology shocks in the market and home sectors are identical (i.e., $\sigma_m^2 = \sigma_h^2 = \sigma^2$).[14] Then, as our benchmark estimation, we employ SMM to estimate the following vector of parameters $\zeta = \{\theta, \psi, \rho, \sigma^2\}$ by minimizing the difference between the empirical and simulated moments from the model. The data that we use for Canada and Mexico come from the OECD database for the period 1978:I-2008:III. We thus have a sample size of $T = 123$. Let m denote the vector of moments computed from actual data and m^s denote the vector of average simulated moments over N simulations from our model with the same sample size. In addition, in line with Beaudry and Portier (2004) and Karnizova (2010), we set $N = 20$. Formally, the estimator of ζ can be described as:

$$\tilde{\zeta} = \arg\min J(\zeta) = \frac{TN}{1+N}[m - m^s(\zeta)]W[m - m^s(\zeta)]', \tag{12}$$

where W denotes a positive-definite of the weighting matrix.[15]

The five target moments we select are informative for estimating SMM parameters. The reasons for choosing these target moments to estimate the vector of parameters ζ can be explained as follows. First, it is reasonable to expect that the standard deviation of output $std(\hat{y}_t)$ can provide information on the variance of technology shocks σ^2. Second, as we will show later, the standard deviation of market consumption $std(\hat{c}_{m,t})$ and the correlation coefficient between the trade balance to GDP ratio and output $corr(\hat{b}_t, \hat{y}_t)$ are crucially related to the utility share of market consumption θ, and hence it can provide information for estimating θ. Third, the standard deviation of investment $std(\hat{I}_t)$ is informative for estimating the persistence parameter of the total factor productivity process ρ. Finally, the correlation coefficient between investment and output $corr(\hat{I}_t, \hat{y}_t)$ can provide information on the intensity parameter of investment adjustment costs ψ.

Moreover, given our basic premise that the channel of home production is crucial for understanding business cycles in developed economies and emerging markets, we further explore the importance of this channel. To this end, we also use SMM in three other estimations for robustness checks. First, we estimate the model without home production by setting $\theta = 1$. In the model without home production, we include the parameter that governs the short-run income effect of labor supply γ in SMM. In other words, the vector of SMM parameters in the benchmark estimation $\{\theta, \psi, \rho, \sigma^2\}$ is replaced by $\{\gamma, \psi, \rho, \sigma^2\}$. Second, in order to show that the different values of θ are mainly driving the differences in the business cycle moments across developed economies and emerging markets, we estimate the model by restricting the value of ψ to be identical in Canada and Mexico. Specifically, we set ψ to one in both Canada and Mexico. Then, given $\psi = 1$, the vector of SMM parameters is $\{\theta, \rho, \sigma^2\}$. Third, we estimate the model in the presence of a positive correlation between market technology shocks and home technology shocks (i.e., $corr(\varepsilon_{m,t}, \varepsilon_{h,t}) > 0$). Let $\mu \equiv corr(\varepsilon_{m,t}, \varepsilon_{h,t})$, and we set $\mu = 0.38$ under which the model generates a synchronized relationship between market investment and home investment.

A summary of the estimated parameters in the benchmark model with home production

[14] Allowing the parameters to be different would enable the model to fit the data more easily.

[15] W is computed by the Newey-West estimator.

for Canada and Mexico is reported in column (1) in Part A and Part B of Table 5, respectively. A summary of the estimated parameters in the model without home production (i.e., $\theta = 1$) for Canada and Mexico is reported in column (2) in Part A and Part B of Table 5, respectively. A summary of the estimated parameters in the model with an identical value of $\psi = 1$ in Canada and Mexico is reported in column (3) in Part A and Part B of Table 5, respectively. A summary of the estimated parameters in the model with a positive correlation between shocks (i.e., $\mu > 0$) is reported in column (4) in Part A and Part B of Table 5. Finally, a summary of the targeted, selected and simulated moments for Canada and Mexico is reported in Part A and Part B of Table 6, respectively.

Table 5: SMM parameters

	Part A: *Canada*				Part B: *Mexico*			
	(1) benchmark	(2) $\theta = 1$	(3) $\psi = 1$	(4) $\mu > 0$	(1) benchmark	(2) $\theta = 1$	(3) $\psi = 1$	(4) $\mu > 0$
θ	0.504	–	0.514	0.486	0.448	–	0.453	0.425
	(0.005)		(0.004)	(0.005)	(0.004)		(0.004)	(0.005)
ψ	0.371	4.760	–	0.676	0.889	3.280	–	1.254
	(0.077)	(0.165)		(0.189)	(0.064)	(0.200)		(0.096)
ρ	0.733	0.939	0.899	0.838	0.973	0.937	0.976	0.980
	(0.042)	(0.003)	0.004	(0.045)	(0.004)	(0.005)	(0.005)	(0.002)
σ^2	0.465	0.545	0.455	0.431	0.830	1.313	0.904	1.076
	(0.027)	(0.030)	(0.029)	(0.017)	(0.043)	(0.071)	(0.060)	(0.080)
γ	–	0.000	–	–	–	0.000	–	–
		(0.000)				(0.000)		
J	0.32	5.60	1.28	0.77	0.23	35.89	0.56	0.12

Notes: Part A reports estimates for Canada, whereas Part B reports estimates for Mexico. Column (1) reports the benchmark estimation, column (2) reports the estimation of the model without home production (i.e., $\theta = 1$), column (3) reports the estimation of the model with an identical value of ψ across countries, and column (4) reports the estimation of the model with a positive correlation between shocks (i.e., $\mu > 0$). Based on the statistics of targeted moments in Table 6, the reported values of SMM parameters with the standard deviations in the parentheses are computed by using 500 replications of the estimation procedure. The variances of the aggregate factor productivity shock are reported in percentage terms.

We first discuss the quantitative results generated from the benchmark estimation for Canada, which represents developed economies. As shown in column (1) in Part A of Table 5, the utility share of market consumption θ is estimated to be equal to 0.504. The intensive parameter of investment adjustment costs ψ is estimated to be 0.371. The persistence of the total factor productivity process and the variance of technology shocks are estimated to be $\rho = 0.733$ and $\sigma^2 = 0.465$, respectively. It should be noted that the J statistic described in equation (12) is asymptotically chi-square with 1 degree of freedom (i.e., the number of over-identification restrictions). The chi-square statistic at the 95% level is $\chi^2_{0.95}(1) = 3.84$, and the test statistic $J = 0.32$ implies that the model cannot be rejected by the data. Column (1) in Part A of Table 6 shows that simulated moments from the benchmark model are close to empirical moments from the Canadian economy. Specifically, the benchmark model features that market consumption is less volatile than GDP (i.e., $std(\hat{c}_{m,t})/std(\hat{y}_t) = 0.79$), investment is more volatile than GDP (i.e., $std(\hat{I}_t)/std(\hat{y}_t) = 2.81$) and the trade balance to GDP ratio is weakly countercyclical (i.e., $corr(\hat{b}_t, \hat{y}_t) = -0.16$). Furthermore, the following simulated moments $std(\hat{b}_t) = 0.72$, $corr(\hat{c}_{m,t}, \hat{y}_t) = 0.69$ and $corr(\hat{I}_t, \hat{y}_t) = 0.79$ are close to the data.

Table 6: Targeted, selected, and simulated moments

Moments	Part A: *Canada* data	(1)	(2)	(3)	(4)	Part B: *Mexico* data	(1)	(2)	(3)	(4)
$std(\hat{y}_t)$	1.47	1.52	1.71	1.60	1.55	2.53	2.43	2.67	2.45	2.49
$std(\hat{c}_{m,t})$	1.15 (0.78)	1.20 (0.79)	1.17 (0.68)	1.24 (0.77)	1.17 (0.75)	3.19 (1.26)	3.06 (1.26)	1.83 (0.69)	3.12 (1.27)	3.11 (1.25)
$std(\hat{I}_t)$	4.28 (2.91)	4.27 (2.81)	4.47 (2.61)	4.30 (2.69)	4.24 (2.74)	8.57 (3.39)	8.08 (3.33)	8.77 (3.28)	8.04 (3.28)	8.35 (3.35)
$std(\hat{b}_t)$	0.91	0.72	0.15	0.63	0.76	2.07	2.97	0.49	2.88	3.37
$corr(\hat{c}_{m,t}, \hat{y}_t)$	0.61	0.69	1.00	0.77	0.46	0.77	0.78	1.00	0.81	0.63
$corr(\hat{I}_t, \hat{y}_t)$	0.73	0.79	0.97	0.82	0.82	0.82	0.73	0.96	0.74	0.77
$corr(\hat{b}_t, \hat{y}_t)$	−0.10	−0.16	−0.07	−0.20	−0.04	−0.60	−0.53	−0.56	−0.55	−0.56

Notes: The SMM targeted moments are: $std(\hat{y}_t)$, $std(\hat{c}_t)$, $std(\hat{I}_t)$, $corr(\hat{I}_t, \hat{y}_t)$, and $corr(\hat{b}_t, \hat{y}_t)$. The selected moments are $std(\hat{b}_t)$ and $corr(\hat{c}_t, \hat{y}_t)$. Part A reports estimates for Canada, whereas Part B reports estimates for Mexico. Column (1) reports the simulated moments generated from the benchmark model, column (2) reports the simulated moments generated from the model without home production (i.e., $\theta = 1$), column (3) reports the simulated moments generated from the model with an identical value of ψ across countries, and column (4) reports the simulated moments generated from the model with a positive correlation between shocks (i.e., $\mu > 0$). All variables are de-trended by the HP-filter with the smoothing parameter set to 1,600. The standard deviations of output and consumption are reported in percentage terms, and the ratios of each standard deviation to the standard deviation of output are stated in the parentheses. While the sampling period is 1978:I-2008:III, the simulated moments are the averages across 1,000 replications of 123 periods.

We next focus on the quantitative results generated from the benchmark model estimated for Mexico, which represents an emerging market. As shown in column (1) in Part B of Table 5, the utility share of market consumption θ is estimated to be 0.448. The intensity parameter of the investment adjustment cost ψ is estimated to be 0.889. The persistence of the total factor productivity process and the variance of technology shocks are estimated to be $\rho = 0.973$ and $\sigma^2 = 0.830$, respectively. It is useful to note that the chi-square statistic at the 95% level is $\chi^2_{0.95}(1) = 3.84$, and thus the test statistic $J = 0.23$ implies that the model cannot be rejected by the data. As reported in column (1) in Part B of Table 6, simulated moments from the benchmark model are close to the empirical moments from Mexico. More importantly, given the estimated values of the parameters, we find that market consumption is more volatile than GDP (i.e., $std(\hat{c}_{m,t})/std(\hat{y}_t) = 1.26$) and the trade balance to GDP ratio is more volatile and more countercyclical (i.e., $std(\hat{b}_t) = 2.97$ and $corr(\hat{b}_t, \hat{y}_t) = -0.53$) in the emerging market. Furthermore, the following simulated $std(\hat{I}_t)/std(\hat{y}_t) = 3.33$, $corr(\hat{c}_{m,t}, \hat{y}_t) = 0.78$, and $corr(\hat{I}_t, \hat{y}_t) = 0.73$ are close to the data.

The quantitative results imply that even in the presence of a sizable income effect on labor supply, our benchmark model with home production can capture main business cycle moments well for both developed economies and emerging markets. More importantly, it reveals that the different estimated values of parameters (i.e., $\{\theta, \psi, \rho, \sigma^2\}$) between developed economies and emerging markets can characterize the main differences in business cycles across the two countries. We now analyze the differences in the four estimated parameters across the countries as follows.

First, the utility share of market consumption θ is higher in Canada (0.504) than in Mexico (0.448). It is worth noting that θ is related to the average value of home hours worked n_h. The data reported in Table 3 confirm that the estimated values of θ in Canada and Mexico are plausible. Given that the overall non-sleeping time is assumed to be 16 hours per day in both countries, Table 7 summarizes the data and simulated home hours worked. As shown in Table 7, the benchmark model generates $n_h = 0.17$ in Canada and 0.34 in Mexico. These simulated values are close to the empirical values of 0.19 in Canada and 0.32 in Mexico. Therefore, the difference in the estimated values of θ across the two countries reasonably reflects the fact that people spend more time on home production in an emerging market than in a developed economy.[16] Second, we estimate that the intensity parameter of investment adjustment costs ψ is lower in Canada (0.371) than in Mexico (0.889). This result implies that the efficiency of capital allocation is higher in developed economies than in emerging markets in accordance with the empirical study of Wurgler (2000).

Third, the persistence of the total factor productivity process ρ is lower in Canada (0.733) than in Mexico (0.973). This result is consistent with the finding of Aguiar and Gopinath (2007), who show that permanent shocks to the total factor productivity are more important for Mexico than for Canada. Fourth, the estimate for the variance of technology shocks σ^2 is lower in Canada (0.465) than in Mexico (0.830). In the real business cycle model, the variance of technology shocks is commonly used to measure the volatility of output. Therefore, it is hardly surprising that a higher variance of technology shocks will generate the higher volatility of output in Mexico.

Table 7: Home hours worked (n_h) in Canada and Mexico

	Canada	*Mexico*
data	0.19	0.32
(1) benchmark	0.17	0.34
(2) $\psi = 1$	0.15	0.33
(3) $\mu > 0$	0.22	0.43

Notes: Rows (1), (2), and (3) report the average values of home hours for Canada and Mexico, which are derived from the benchmark model, the model with an identical value of ψ in the two countries (i.e., $\psi = 1$), and the model with a positive correlation between shocks (i.e., $\mu > 0$), respectively.

Moreover, the estimations of the following three alternative models are helpful for us to further demonstrate that home production is mainly responsible for explaining business

[16] In this paper, we focus on the share of market consumption θ that reflects the scale of the market sector in explaining the major differences in business cycles between developed economies and emerging markets. A related study by Gomme and Zhao (2011) instead focuses on the long-run technology levels in the market and home sectors and the transmission of technology shocks across the market and home sectors. Specifically, they offer an explanation of the high volatility of market consumption in Mexico by proposing that the long-run technology level is lower in the market sector than in the home sector and that market technology shocks can be transmitted to the home sector. Moreover, in the present study, we use a general preference that nests the KPR and GHH preferences to discuss the major features of business cycles involving the volatility and countercyclicality of the trade balance to GDP ratio in emerging markets in addition to the volatility of market consumption.

cycles in small open economies. First, in the estimation of the model *without home production* (i.e., $\theta = 1$) for Canada and Mexico, as depicted in column (2) in Part A and Part B of Table 5, we find that the parameter γ governing the income effect on labor supply is estimated to be close to zero. An implication is that the income effect on labor supply needs to be absent such that the utility function approximates the GHH preference. This result is consistent with previous findings in Mendoza (1991), Correia *et al.* (1995) and Schmitt-Grohé and Uribe (2003), who show that the volatility of market consumption in a small open economy under the KPR preference is too low compared to its empirical value. Hence one needs to resort to the GHH preference ($\gamma = 0$) in order to raise the volatility of market consumption to match the data.

Can the moments generated from the model *without home production* (i.e., $\theta = 1$) fit the data well? In the case of Canada, given that the chi-square statistic of $\chi^2_{0.99}(1) = 6.64$ at the 99% level, the test statistic of $J = 5.60$ implies that the moments generated from this model barely match the data. On the other hand, in the case of Mexico, when the channel of home production is absent, the ratio of the standard deviations between market consumption and GDP is estimated to be $std(\hat{c}_{m,t})/std(\hat{y}_t) = 0.69$. In other words, the model has difficulty matching an important stylized fact that the volatility of market consumption exceeds the volatility of GDP. Accordingly, these significant differences between the simulated and empirical values of $std(\hat{c}_{m,t})$ give rise to a test statistic of $J = 35.89$, implying that the model without home production is rejected by the data. By comparing this result with the estimates of the benchmark model, we can see that in the presence of an income effect on labor supply the channel of home production plays a very important role in explaining business cycles in small open economies. More importantly, home production can be viewed as a key vehicle for characterizing the main differences in business cycles in developed economies and emerging markets.

Second, in the quantitative results of the model with an identical value of ψ in Canada and Mexico (i.e., $\psi = 1$), as depicted in column (3) in Part A and Part B of Table 5, the estimates are similar to the estimates of the benchmark model. It should be noted that the J statistic described in equation (12) is asymptotically chi-square with 2 degrees of freedom (i.e., the number of over-identification restrictions). The chi-square statistic at the 95% level is $\chi^2_{0.95}(2) = 5.99$, and thus the test statistics of $J = 1.28$ in Canada and 0.56 in Mexico imply that the model cannot be rejected by the data from the two countries. As reported in column (3) in Part A and Part B of Table 6, the simulated moments from this model are close to the empirical moments from Canada and Mexico. In addition, Table 7 shows that this model generates $n_h = 0.15$ in Canada and 0.33 in Mexico, which are close to their empirical values. Accordingly, the results of this model reveal that except for the persistent parameter ρ and the variance of technology shocks σ^2, this study only relies on the differences in the utility share of market consumption θ to capture the main differences in the features of business cycles across developed economies and emerging markets (i.e., $\theta = 0.514$ in Canada and 0.453 in Mexico).

Finally, we discuss the quantitative results of the model with a positive correlation between shocks (i.e., $\mu = corr(\varepsilon_{m,t}, \varepsilon_{h,t}) > 0$). In columns (4) in Part A and Part B of Table 5, we can see that the estimates are consistent with the estimates of the benchmark model. The chi-square statistic at the 95% level is $\chi^2_{0.95}(1) = 3.84$, and thus the test statistics of $J = 0.77$ in Canada and 0.12 in Mexico imply that the model cannot be rejected by the data from the two countries. As reported in column (4) in Part A and Part B of Table 6, the simulated moments from this model are close to the empirical moments from Canada and Mexico. In addition, Table 7 shows that this model generates $n_h = 0.22$ in Canada and 0.43 in Mexico, which are close to their empirical values. Therefore, even in the presence of a positive correlation between technology shocks, our results are robust.

4.3 Impulse responses

We are now in a position to analyze impulse responses in association with technology shocks in the market and home sectors and provide some economic intuition to explain the fluctuation under these shocks. Based on the benchmark estimation in the previous section, the impulse responses to technology shocks in Canada and Mexico are depicted in Figures 1 and 2, respectively. It should be noted that the solid line and the dashed line represent the impulse responses to a 1% increase in market technology and home technology, respectively.

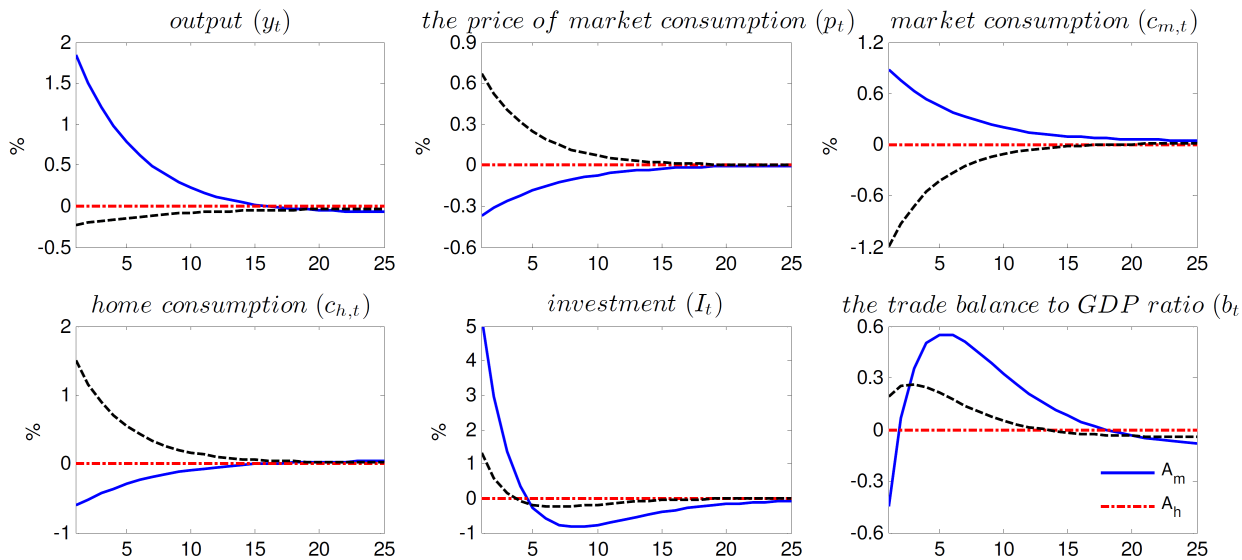

Figure 1: Impulse responses: Canada

Notes: The solid line and dashed line represent the impulse responses to a 1% increase in market technology and home technology, respectively. The values of the parameters are based on the calibration and estimation in the benchmark model.

In Canada, as exhibited in Figure 1, a positive market technology shock raises market output y_t and market consumption $c_{m,t}$. It also reduces the price of market consumption p_t, home consumption $c_{h,t}$ and the trade balance to GDP ratio b_t. By contrast, a positive home technology shock decreases market output y_t and market consumption $c_{m,t}$. It also increases the price of market consumption p_t, home consumption $c_{h,t}$ and the trade balance to GDP ratio b_t.

These fluctuations driven by market and home technology shocks can be understood by analyzing the following equations. Based on equations (9) and (11), the prices of market consumption and the social resource constraint linearized around the steady state are respectively given by:

$$\hat{p}_t = (1-\phi)(\hat{c}_{h,t} - \hat{c}_{m,t}) = (\hat{c}_{h,t} - \hat{n}_{n,t}) - (\hat{y}_t - \hat{n}_{m,t}), \tag{13a}$$

$$\hat{b}_t = \frac{(1+r)\,\hat{d}_t - \hat{d}_{t+1} + rd\hat{r}_t}{y} - \frac{rd}{y}\hat{y}_t. \tag{13b}$$

Given $\gamma = 1$ in the benchmark estimation and equations (8a), (8c), (8d), (8i) and (9), the optimal decision regarding market consumption and the non-arbitrage condition between foreign debt and domestic capital linearized around the steady state are respectively given by:

$$\hat{c}_{m,t} = \frac{1}{\sigma + (\sigma-1)\Omega}\left[(\sigma-1)\Omega(\hat{y}_t - \hat{n}_{m,t}) - \hat{\lambda}_t - \frac{1}{1-\phi}\frac{(\sigma-1)(1+\phi\Omega)+\phi}{\frac{\theta}{1-\theta}\left(\frac{c_m}{c_h}\right)^{\phi}+1}\hat{p}_t\right],$$

$$where\ \Omega \equiv \frac{\xi\omega N^{\xi}}{(\xi-1)(1-\omega N^{\xi}) + \xi\omega N^{\xi}} \in (0,1), \tag{14a}$$

$$\eta\upsilon\left(\frac{\hat{d}_{t+1}}{d} - \hat{y}_t\right) = \left[\frac{\alpha_h c_h}{pq_h k_h}\left(\hat{c}_{h,t+1} - \hat{k}_{h,t+1} - \hat{p}_{t+1}\right) + \hat{q}_{h,t+1}\right] - \frac{1}{\beta}\hat{q}_{h,t}. \tag{14b}$$

From equation (14a), we find that market consumption $\hat{c}_{m,t}$ is associated with three terms. To be more precise, given that the intertemporal elasticity of substitution in consumption is in general less than unity (i.e., $\sigma > 1$), market consumption is positively related to the marginal production of labor $\hat{y}_t - \hat{n}_{m,t}$ and negatively related to the shadow price of foreign debt $\hat{\lambda}_t$ and the price of market consumption $\hat{p}_t$.[17,18] In addition, equation (14b) indicates that the world interest rate (on the left-hand-side) equals the capital gains from holding domestic capital (on the right-hand-side).

When the economy experiences a positive market (home) technology shock, it leads to a productivity improvement in the market (home) sector. As a consequence, based on equation (13a), we find that market goods become cheaper (more expensive) than home goods, and hence, it reduces (raises) the price of market consumption $\hat{p}_t$. Then from equation (14a), the household increases (decreases) its market output $\hat{y}_t$ and market consumption $\hat{c}_{m,t}$ and decreases (increases) its home consumption $\hat{c}_{h,t}$. On the other hand, based on equation (14b), a lower (higher) $\hat{p}_t$ leads to a rise (reduction) in capital gains from holding domestic

[17] Given that most of the empirical studies support the view that the intertemporal elasticity of substitution in consumption is in general less than unity (i.e., $\sigma > 1$), based on equation (14), we can have: $\frac{\partial \hat{c}_{m,t}}{\partial(\hat{y}_t - \hat{n}_{m,t})} = \frac{\sigma-1}{\sigma+(\sigma-1)\Omega} > 0$, $\frac{\partial \hat{c}_{m,t}}{\partial(\hat{y}_t - \hat{n}_{m,t})} = \frac{-1}{\sigma+(\sigma-1)\Omega} < 0$, and $\frac{\partial \hat{c}_{m,t}}{\partial(\hat{p}_t)} = \frac{-1}{\sigma+(\sigma-1)\Omega}\frac{(\sigma-1)(1+\phi\Omega)+\phi}{\frac{\theta}{1-\theta}\left(\frac{c_m}{c_h}\right)^{\phi}+1} < 0$. Moreover, a detailed derivation of equation (14a) is provided in Appendix B.

[18] We set the parameter governing the short-run income effect on labor supply as $\gamma = 1$ in the benchmark model, and hence the utility function is associated with the KPR preference. With the income effect on labor supply, it implies that market consumption is positively related to the equilibrium real wage rate. Accordingly, as shown in equation (14a), given that the real wage rate equals the marginal product of labor in equilibrium, the marginal product of labor has a positive effect on market consumption.

capital, and thereby the household borrows more (less) foreign debt $\hat{d}_{t+1}$ from the world capital market. Accordingly, equation (13b) shows that capital inflows (outflows) lead to an increase (a decrease) in the trade deficit. As a result, the trade balance to GDP ratio displays countercyclicality.

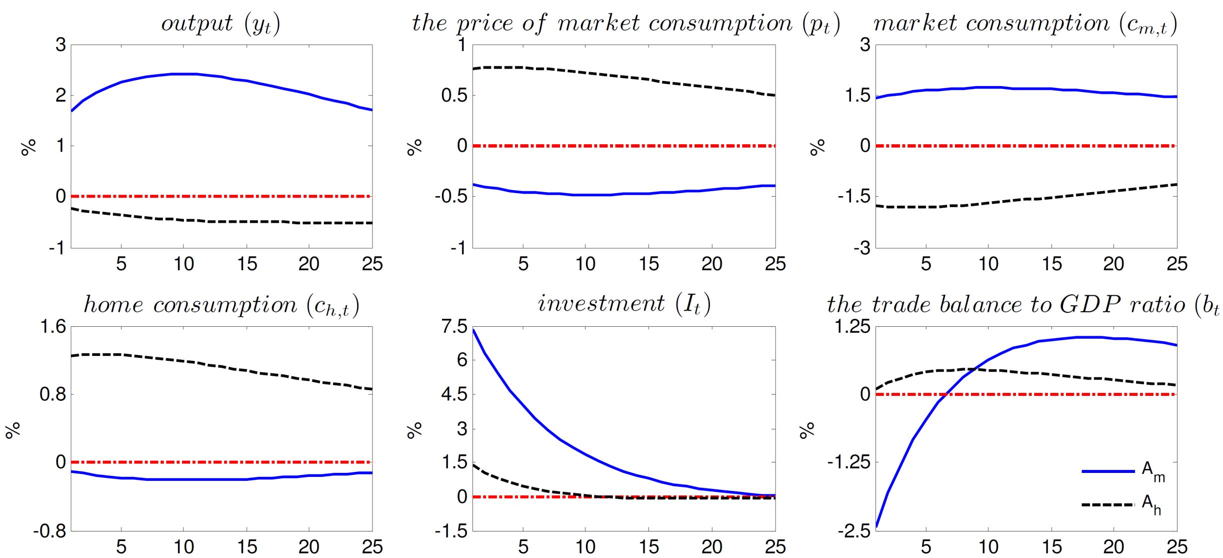

Figure 2: Impulse responses: Mexico

Notes: The solid line and dashed line represent the impulse responses to a 1% increase in market technology and home technology, respectively. The values of the parameters are based on the calibration and estimation in the benchmark model.

Figure 2 depicts impulse responses to a 1% increase in technology in Mexico. By comparing the impulse responses depicted in Figure 2 with those in Figure 1, we find that the patterns of movement in y_t, p_t, $c_{m,t}$, $c_{h,t}$, I_t, and b_t are similar to the ones in Canada. However, the adjustments of these variables are more persistent (recall that the estimated value of $\rho = 0.973$ in Mexico is higher than the corresponding $\rho = 0.733$ in Canada). As a result, the volatilities of these variables increase in response.

In addition, Figure 2 shows that the volatility of market consumption exceeds the volatility of output. A lower market consumption share θ in Mexico is a plausible explanation to demonstrate this result. Based on equation (14a), we can infer that $\frac{\partial \hat{c}_{m,t}}{\partial \hat{p}_t} < 0$ and $\partial(\frac{\partial \hat{c}_{m,t}}{\partial \hat{p}_t})/\partial\theta > 0$.[19] The former equation reflects the fact that due to the substitution effect between market and home consumption, the increases in the price of market consumption may reduce market consumption. The latter equation illustrates that the decreases in the market consumption share θ may reinforce this substitution effect on market consumption. Therefore, when home production is more prevalent in Mexico (i.e., a lower value of θ), market consumption becomes less important in smoothing the marginal utility of aggregate consumption. An increase in the substitutability between market and home consumption helps to increase the volatility of market consumption to match the data.

[19] A detailed derivation of equation (14a) is provided in Appendix B.

A lower value of θ can also explain the reason why the trade balance to GDP ratio $\hat{b}_t$ is more volatile and more countercyclical in Mexico. Given that a lower value of θ can raise the volatility of market consumption, equation (13a) shows that a lower value of θ can further raise the volatility of the price of market consumption. According to the previous analysis of the impulse responses of Canada, when a positive market (home) technology shock is present, a more volatile price of market consumption can amplify the decrease (increase) in the trade balance to GDP ratio in response. Therefore, a lower value of θ may lead to a more volatile and more countercyclical trade balance to GDP ratio $\hat{b}_t$ in Mexico.

4.4 Sensitivity analysis

In the previous subsection, we have provided some economic intuition to explain that a smaller market consumption share θ strengthens the substitution effect between market and home consumption. As a result, it will raise the volatilities of market consumption $\hat{c}_t$, the price of market consumption $\hat{p}_t$, and the trade balance to GDP ratio $\hat{b}_t$ and reinforce the countercyclicality of the trade balance to GDP ratio $\hat{b}_t$. In order to clarify further the relationship between the market consumption share θ and the business cycle moments, we provide a sensitivity analysis in this subsection.

Figure 3 depicts the sensitivity analysis of simulated moments $std(\hat{c}_{m,t})/std(\hat{y}_t)$, $std(\hat{b}_t)$, and $corr(\hat{b}_t, \hat{y}_t)$ in Canada and Mexico. The effects of the market consumption share θ on $std(\hat{c}_{m,t})/std(\hat{y}_t)$, $std(\hat{b}_t)$, and $corr(\hat{b}_t, \hat{y}_t)$ are respectively presented in Parts A, B and C. In Figure 3, the solid line and the dashed line denote the simulated moments of $std(\hat{c}_{m,t})/std(\hat{y}_t)$, $std(\hat{b}_t)$, and $corr(\hat{b}_t, \hat{y}_t)$ in Canada and Mexico, respectively. Each point is computed from the average across 1,000 replications under a value of θ. We take the estimated value of θ as our benchmark and vary its value while holding other parameter values constant.

In Part A of Figure 3, it can be seen that $std(\hat{c}_{m,t})/std(\hat{y}_t)$ in both countries is decreasing in the value of θ. When home production is absent (i.e., $\theta = 1$), $std(\hat{c}_{m,t})/std(\hat{y}_t)$ equals 0.20 in Canada and 0.49 in Mexico, respectively. These simulated values are significantly lower than the empirical values of 0.78 in Canada and 1.26 in Mexico. In addition, because the relative volatility between market consumption and output $std(\hat{c}_{m,t})/std(\hat{y}_t)$ is decreasing in θ, $std(\hat{c}_{m,t})/std(\hat{y}_t)$ converges to its empirical values when θ decreases toward the estimated values of 0.504 in Canada and 0.448 in Mexico. Moreover, given that the value of the income effect parameter $\gamma = 1$ in the benchmark model, we conclude that even in the presence of a significant income effect on labor supply, home production is still a useful channel for explaining business cycles in small open economies. In particular, market consumption is more volatile than output in the emerging market.

Part B of Figure 3 shows that when home production is absent (i.e., $\theta = 1$), the volatility of the trade balance to GDP ratio equals 0.49 in Canada and 0.90 in Mexico. These simulated values are substantially smaller than the empirical values of 0.91 in Canada and 2.07 in Mexico. We also find that the volatility of the trade balance to GDP ratio is decreasing in θ. When θ decreases from 1 to the estimated values of 0.504 in Canada and 0.448 in Mexico, the volatility of the trade balance to GDP ratio increases and becomes 0.72 in Canada and 2.97 in Mexico. These values are close to the empirical values.

Finally, we find that when home production is absent (i.e., $\theta = 1$), $corr(\hat{b}_t, \hat{y}_t) = 0.12$

in Canada. This value differs significantly from the empirical value of -0.10 in Canada featuring a countercyclical trade balance to GDP ratio. As is clear from Part C of Figure 3, $corr(\hat{b}_t, \hat{y}_t)$ in Canada is increasing in θ for $\theta \geq 0.42$. We find that as home production emerges and θ converges to 0.504, $corr(\hat{b}_t, \hat{y}_t)$ equals -0.16, which is close to the empirical value for the Canadian economy. On the other hand, $corr(\hat{b}_t, \hat{y}_t)$ in Mexico is largely invariant with respect to θ for $\theta \geq 0.42$, and it is close to its empirical value of -0.60.

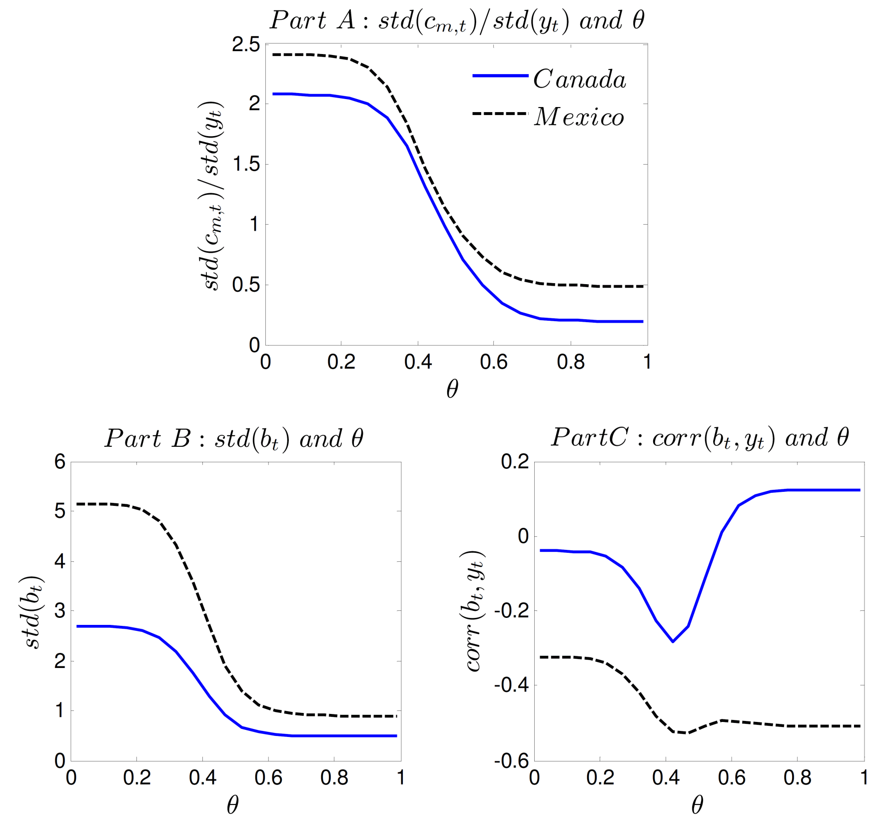

Figure 3: Sensitivity analysis

Notes: The effects of the market consumption share θ on $std(\hat{c}_{m,t})/std(\hat{y}_t)$, $std(\hat{b}_t)$, and $corr(\hat{b}_t, \hat{y}_t)$ are respectively presented in Parts A, B and C. The solid line and the dashed line denote the simulated moments of $std(\hat{c}_{m,t})/std(\hat{y}_t)$, $std(\hat{b}_t)$, and $corr(\hat{b}_t, \hat{y}_t)$ in Canada and Mexico, respectively. Each point is computed from the average across 1,000 replications under a value of θ. We take the estimated value of θ as our benchmark and vary its value while holding other parameter values constant.

Before ending this subsection, we should discuss two questions related to Part C of Figure 3. First, how can the trade balance to GDP ratio display a high degree of countercyclicality when home production is absent in the model of Mexico (i.e., $\theta = 1$)? This is because we estimate that the technology shocks in Mexico have high persistence; i.e., $\rho = 0.973$. In this case, a positive market technology shock leads to a large increase in capital gains from holding market capital due to the forward-looking property. Therefore, on the impact of a positive market technology shock, the household accumulates more market capital and borrows more foreign debt. The increased capital inflows in the capital account lead to a larger reduction in the trade balance to GDP ratio $\hat{b}_t$. Thus the trade balance to GDP ratio displays a higher degree of countercyclicality even when home production is absent in Mexico.

Second, why is the degree of countercyclicality of the trade balance to GDP ratio lowered when θ is close to zero? When θ is close to zero, it is implied that market consumption is small, and the household only allocates its market output to the accumulation of capital. In this case, even in the presence of a positive home shock, the household has very little room to raise its investment in home capital by reducing market consumption, which is small to begin with. Therefore, in order to accumulate more home capital, the household has to increase its market output. Recall that a positive home shock can increase the trade balance to GDP ratio. This implies that when θ is close to zero, the trade balance $\hat{b}_t$ and market output $\hat{y}_t$ have a synchronized relationship under home technology shocks. Consequently, this synchronized relationship leads to a lower degree of countercyclicality in the trade balance to GDP ratio.

5 Conclusion

In developed small open economies, output is more volatile than consumption but less volatile than investment, and the trade balance to GDP ratio is weakly countercyclical. It is commonly accepted that the presence of an income effect on labor supply would render the RBC model of a small open economy incapable of replicating these business cycle moments due to insufficient volatility of market consumption.[20] Moreover, it would cause the trade balance to GDP ratio to become procyclical. Given that empirical studies, such as Imbens *et al.* (2001), Kimball and Shapiro (2010) and Khan and Tsoukalas (2011, 2012), support the view that the income effect on labor supply is significant, it is necessary to find a plausible channel to explain the business cycles of developed small open economies. Furthermore, Neumeyer and Perri (2005) and Aguiar and Gopinath (2007) point out three important differences between emerging markets and developed economies. First, the volatility of output in emerging markets is higher than that in developed economies. Second, consumption is more volatile than output in emerging markets. Third, the trade balance to GDP ratio is more volatile and more countercyclical in emerging markets than in developed economies. In this paper, we argue that home production serves as a plausible vehicle to capture all these major features of business cycles in both developed and emerging small open economies.

Several main findings emerge from our analysis. First, we find that upon experiencing a positive technology shock in the market sector (or a negative technology shock in the home sector), the presence of home production will induce the representative household to consume more market goods and substitute away from home consumption. Therefore, this substitution effect between market and home consumption leads to a higher volatility of market consumption. Second, when a positive market technology shock increases market consumption, the household turns to borrow from the world market in order to finance the increase in aggregate investment, which in turn reduces the trade balance. This result implies that the trade balance to GDP ratio tends to become more volatile and more countercyclical in the presence of home production. As a result, home production is a helpful mechanism

[20] See, for example, Correia *et al.* (1995) and Schmitt-Grohé and Uribe (2003).

for the empirical patterns exhibited in developed economies; i.e., output is more volatile than market consumption, investment is more volatile than output, and the trade balance to GDP ratio is weakly countercyclical. Third, we find that the extent of substitution between market and home consumption is positively related to the scale of the home sector. Because the home sector in emerging markets is larger than that in developed economies, market consumption is more volatile in emerging markets than in developed economies. As a consequence, the larger home sector is helpful in capturing the stylized fact that the volatility of market consumption is higher than the volatility of GDP in emerging markets. Finally, the higher volatility of market consumption causes the trade balance to GDP ratio to be more volatile and more countercyclical in emerging markets than in developed economies. Accordingly, home production provides a plausible explanation for the empirical pattern of international business cycles in developed economies and emerging markets.

Appendix A

This appendix provides a brief derivation of the equilibrium conditions from the nonlinear form to the linearized version in terms of percentage deviations from the steady state. The full macroeconomic competitive equilibrium for the economy is composed of 21 equations: (2a)-(3b), (5) and (7a)-(10). The endogenous variables are the sequences of quantities $\{y_t, c_{m,t}, c_{h,t}, C_t, X_t, N_t, n_{m,t}, n_{h,t}, I_{m,t}, I_{h,t}, I_t, k_{m,t}, k_{h,t}, d_t, b_t\}$ and prices $\{r_t, g_t, \mu_t, \lambda_t, q_{m,t}, q_{h,t}\}$. Given $A_m = 1$ and $A_h = 1$ in the steady state, based on the full macroeconomic competitive equilibrium model, the stationary relationship can be stated as:

$$b = \frac{rd}{y}, \tag{A1}$$

$$r = \frac{1}{\beta} - 1, \tag{A2}$$

$$q_m = 1 + \psi_m \delta_m, \tag{A3}$$

$$q_h = 1 + \psi_h \delta_h, \tag{A4}$$

$$k_m = \left[\frac{\left(\frac{1}{\beta} - 1 + \delta_m\right) q_m - \frac{(q_m - 1)^2}{2\psi_m}}{\alpha_m} \right]^{\frac{1}{\alpha_m - 1}} n_m, \tag{A5}$$

$$k_h = \left[\frac{\left(\frac{1}{\beta} - 1 + \delta_h\right) q_h - \frac{(q_h - 1)^2}{2\psi_h}}{\frac{1-\alpha_m}{1-\alpha_h} \left(\frac{k_m}{n_m}\right)^{\alpha_m} \alpha_h} \right]^{-1} n_h, \tag{A6}$$

$$c_m = \left[\frac{\theta}{1-\theta} \frac{1-\alpha_m}{1-\alpha_h} \frac{(k_m/n_m)^{\alpha_m}}{(k_h/n_h)^{\alpha_h}} \right]^{\frac{1}{1-\phi}} c_h, \tag{A7}$$

$$n_m = \frac{\frac{c_m}{c_h}\left(\frac{k_h}{n_h}\right)^{\alpha_h} + \frac{q_h^2 - 1}{2\psi_h}\left(\frac{k_h}{n_h}\right)}{(1 - r\upsilon)\left(\frac{k_m}{n_m}\right)^{\alpha_m} - \frac{q_m^2 - 1}{2\psi_m}\left(\frac{k_m}{n_m}\right)} n_h, \tag{A8}$$

$$N = \left\{ \frac{\omega\xi}{1-\alpha_h} \left[\frac{\theta}{1-\theta} \left(\frac{c_m}{c_h}\right)^{\phi} + 1 \right] / \left(\frac{n_m}{n_h} + 1\right) - \frac{\omega\gamma}{\beta(1-\gamma) - 1} \right\}^{-\frac{1}{\xi}}, \tag{A9}$$

$$n_h = \frac{N}{\frac{n_m}{n_h} + 1}, \tag{A10}$$

$$c_h = A_h k_h^{\alpha_h} n_h^{1-\alpha_h}, \tag{A11}$$

$$y = A_m k_m^{\alpha_m} n_m^{1-\alpha_m}, \tag{A12}$$

$$I_m = \delta_m k_m, \tag{A13}$$

$$I_h = \delta_h k_h, \tag{A14}$$

$$I = I_m + I_h, \tag{A15}$$

$$C=\left[\theta c_m^{\phi}+(1-\theta)\,c_h^{\phi}\right]^{\frac{1}{\phi}}, \tag{A16}$$

$$X=C, \tag{A17}$$

$$d=\upsilon y, \tag{A18}$$

$$g=\frac{\left(C-\omega N^{\xi}C\right)^{-\sigma}\omega N^{\xi}}{\beta\,(1-\gamma)-1}, \tag{A19}$$

$$\lambda=\left[\left(C-\omega N^{\xi}C\right)^{-\sigma}+g\gamma\right]\theta\left(\frac{c_m}{C}\right)^{\phi-1}, \tag{A20}$$

$$\mu=\left[\left(C-\omega N^{\xi}C\right)^{-\sigma}+g\gamma\right](1-\theta)\left(\frac{c_h}{C}\right)^{\phi-1}. \tag{A21}$$

Let $\hat{d}_t=d_t-d$ and $\hat{b}_t=b_t-b$, and $\hat{z}_t=(z_t-z)/z$, where z_t can be any endogenous variable in the model except for d_t and b_t. By log-linearizing the macroeconomic model around its steady state, we can derive the following linear expressions in terms of percentage deviations:

$$\begin{aligned}\hat{\lambda}_t \;=\; & (\phi-1)\left(\hat{c}_{m,t}-\hat{C}_t\right)-\frac{\sigma\left(C-\omega N^{\xi}C\right)^{-\sigma-1}C\left[\hat{C}_t-\omega N^{\xi}\left(\xi\hat{N}_t+\hat{X}_t\right)\right]}{\left(C-\omega N^{\xi}C\right)^{-\sigma}+g\gamma}\\ & +\frac{g\gamma\left[\hat{g}_t+(\gamma-1)\left(\hat{C}_t-\hat{X}_{t-1}\right)\right]}{\left(C-\omega N^{\xi}C\right)^{-\sigma}+g\gamma},\end{aligned} \tag{A22}$$

$$(\phi-1)\left(\hat{c}_{m,t}-\hat{c}_{h,t}\right)=\hat{\lambda}_t-\hat{\mu}_t, \tag{A23}$$

$$\frac{\beta g\,(1-\gamma)\left[\hat{g}_{t+1}+\gamma\left(\hat{C}_{t+1}-\hat{X}_t\right)\right]-g\hat{g}_t}{\left(C-\omega N^{\xi}C\right)^{-\sigma}\omega N^{\xi}}=\xi\hat{N}_t-\sigma\frac{\hat{C}_t-\omega N^{\xi}\left(\xi\hat{N}_t+\hat{X}_t\right)}{1-\omega N^{\xi}}, \tag{A24}$$

$$(\xi-1)\,\hat{N}_t+\hat{X}_t-\sigma\frac{\hat{C}_t-\omega N^{\xi}\left(\xi\hat{N}_t+\hat{X}_t\right)}{1-\omega N^{\xi}}=\hat{\lambda}_t+\hat{y}_t-\hat{n}_{m,t}, \tag{A25}$$

$$\hat{\mu}_t-\hat{\lambda}_t=\hat{y}_t-\hat{n}_{m,t}-\hat{c}_{h,t}+\hat{n}_{h,t}, \tag{A26}$$

$$\hat{I}_{m,t}-\hat{k}_{m,t}=\frac{q_m}{\delta_m\psi_m}\hat{q}_{m,t}, \tag{A27}$$

$$\hat{I}_{h,t}-\hat{k}_{h,t}=\frac{q_h}{\delta_h\psi_h}\hat{q}_{h,t}, \tag{A28}$$

$$\hat{q}_{m,t}=\hat{\lambda}_{t+1}-\hat{\lambda}_t+\beta\left[\frac{\alpha_m y_m}{q_m k_m}\left(\hat{y}_{m,t+1}-\hat{k}_{m,t+1}\right)+\hat{q}_{m,t+1}\right], \tag{A29}$$

$$\hat{q}_{h,t}=\hat{\lambda}_{t+1}-\hat{\lambda}_t+\beta\left[\frac{\mu\alpha_h c_h}{\lambda q_h k_h}\left(\hat{\mu}_{t+1}-\hat{\lambda}_{t+1}+\hat{c}_{h,t+1}-\hat{k}_{h,t+1}\right)+\hat{q}_{h,t+1}\right], \tag{A30}$$

$$0=\hat{\lambda}_{t+1}-\hat{\lambda}_t+\beta r\hat{r}_{t+1}, \tag{A31}$$

$$\hat{d}_{t+1} - (1+r)\hat{d}_t - rd\hat{r}_t = c_m\hat{c}_{m,t} + \left(\frac{q_m^2}{\psi_m}k_m\hat{q}_{m,t} + \frac{q_m^2-1}{2\psi_m}k_m\hat{k}_{m,t}\right) + \left(\frac{q_h^2}{\psi_h}k_h\hat{q}_{h,t} + \frac{q_h^2-1}{2\psi_h}k_h\hat{k}_{h,t}\right) - y\hat{y}_t, \tag{A32}$$

$$\hat{X}_t = \gamma\hat{C}_t + (1-\gamma)\hat{X}_{t-1}, \tag{A33}$$

$$\hat{c}_{h,t} = \hat{A}_{h,t} + \alpha_h\hat{k}_{h,t} + (1-\alpha_h)\hat{n}_{h,t}, \tag{A34}$$

$$\hat{y}_t = \hat{A}_{m,t} + \alpha_m\hat{k}_{m,t} + (1-\alpha_m)\hat{n}_{m,t}, \tag{A35}$$

$$\hat{k}_{m,t+1} = (1-\delta_m)\hat{k}_{m,t} + \delta_m\hat{I}_{m,t}, \tag{A36}$$

$$\hat{k}_{h,t+1} = (1-\delta_h)\hat{k}_{h,t} + \delta_h\hat{I}_{h,t}, \tag{A37}$$

$$\hat{b}_t = \frac{(1+r)\hat{d}_t + rd\hat{r}_t - \hat{d}_{t+1}}{y} - \frac{rd}{y}\hat{y}_t \tag{A38}$$

$$\hat{r}_t = \frac{\eta\upsilon}{r}\left(\frac{\hat{d}_{t+1}}{d} - \hat{y}_t\right), \tag{A39}$$

$$\hat{C}_t = \frac{\frac{\theta}{1-\theta}\left(\frac{c_m}{c_h}\right)^{\phi}\hat{c}_{m,t} + \hat{c}_{h,t}}{\frac{\theta}{1-\theta}\left(\frac{c_m}{c_h}\right)^{\phi} + 1}, \tag{A40}$$

$$N\hat{N}_t = n_m\hat{n}_{m,t} + n_h\hat{n}_{h,t}, \tag{A41}$$

$$I\hat{I}_t = I_m\hat{I}_{m,t} + I_h\hat{I}_{h,t}. \tag{A42}$$

Appendix B

Given $\gamma = 1$ and $p_t = \frac{\lambda_t}{\mu_t}$, the linearized version of equations (2b), (8a), (8b), and (8d) can be expressed as:

$$\hat{C}_t = \frac{\frac{\theta}{1-\theta}\left(\frac{c_m}{c_h}\right)^{\phi}\hat{c}_{m,t} + \hat{c}_{h,t}}{\frac{\theta}{1-\theta}\left(\frac{c_m}{c_h}\right)^{\phi} + 1}, \tag{B1}$$

$$-(1-\sigma)\frac{\xi\omega N^{\xi}}{1-\omega N^{\xi}}\hat{N}_t + (\phi - 1)\,\hat{c}_{m,t} + (1-\phi-\sigma)\hat{C}_t = \hat{\lambda}_t, \tag{B2}$$

$$(\phi - 1)\left(\hat{c}_{m,t} - \hat{c}_{h,t}\right) = \hat{p}_t. \tag{B3}$$

$$(1-\sigma)\hat{C}_t + \left(\xi - 1 + \frac{\sigma\xi\omega N^{\xi}}{1-\omega N^{\xi}}\right)\hat{N}_t = \hat{\lambda}_t + \hat{y}_t - \hat{n}_{m,t} \tag{B4}$$

Then, substituting equations (B1), (B3), and (B4) into equation (B2), we have:

$$\hat{c}_{m,t} = \frac{1}{\sigma + (\sigma-1)\Omega}\left[(\sigma-1)\Omega(\hat{y}_t - \hat{n}_{m,t}) - \hat{\lambda}_t - \frac{1}{1-\phi}\frac{(\sigma-1)(1+\phi\Omega)+\phi}{\frac{\theta}{1-\theta}\left(\frac{c_m}{c_h}\right)^{\phi}+1}\hat{p}_t\right],$$

$$where\ 0 < \Omega = \frac{\xi\omega N^{\xi}}{(\xi-1)(1-\omega N^{\xi}) + \xi\omega N^{\xi}} < 1, \tag{B5}$$

Accordingly, based on equation (B5), we can derive equation (14a) in the main text.

In addition, from equations (A2)-(A7), the ratio between market consumption and home consumption in the steady state can be expressed as:

$$\frac{c_m}{c_h} = \left[\frac{\theta}{1-\theta}\frac{1-\alpha_m}{1-\alpha_h}\frac{(k_m/n_m)^{\alpha_m}}{(k_h/n_h)^{\alpha_h}}\right]^{\frac{1}{1-\phi}},$$

$$\text{where } \frac{k_m}{n_m} = \left[\frac{\left(\frac{1}{\beta} - 1 + \delta_m\right)(1+\psi_m\delta_m) - \frac{\psi_m(\delta_m)^2}{2}}{\alpha_m}\right]^{\frac{1}{\alpha_m - 1}};$$

$$\frac{k_h}{n_h} = \frac{\frac{1-\alpha_m}{1-\alpha_h}\left(\frac{\left(\frac{1}{\beta}-1+\delta_m\right)(1+\psi_m\delta_m) - \frac{\psi_m(\delta_m)^2}{2}}{\alpha_m}\right)^{\frac{\alpha_m}{\alpha_m-1}}\alpha_h}{\left(\frac{1}{\beta} - 1 + \delta_h\right)(1+\psi_h\delta_h) - \frac{\psi_h(\delta_h)^2}{2}}. \tag{B6}$$

By substituting equation (B6) into (B5), we can have:

$$\frac{\partial(\frac{\partial \hat{c}_{m,t}}{\partial \hat{p}_t})}{\partial \theta} = \left(\frac{1}{1-\phi}\right)^2 \frac{(\sigma-1)(1-\phi\Omega)+\phi}{[\frac{\theta}{1-\theta}\left(\frac{c_m}{c_h}\right)^{\phi}+1]^2} \frac{\left(\frac{c_m}{c_h}\right)^{\phi}}{(1-\theta)^2}. \tag{B7}$$

Given that most of the empirical studies support the view that the intertemporal elasticity of substitution in consumption is in general less than unity (i.e., $\sigma > 1$), from equation (B7) we can then infer that $\partial(\frac{\partial \hat{c}_{m,t}}{\partial \hat{p}_t})/\partial\theta > 0$.

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