Essays on Small Open Economy Models

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Abstract

Essays on Small Open Economy Models

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This thesis focuses on the financial imperfections, consumption and the trade balance in small open economies. Chapter 1 investigates the cause for the lower consumption-output correlation in the nontradable sector. This chapter confirms the existence of financial frictions in the international markets by showing: first, the consumption-output correlations in the tradable and nontradable sectors becomes identical in autarky; second, the difference in the correlations is reversed under a free trade economy.

Chapter 2 answers the question of why consumption is more volatile than output in developing countries while it is less volatile than output in developed economies. This paper shows that the relatively large home sector in developing economies contributes to this difference, and the driving force for this difference is technology. Thus this paper suggests that volatile market consumption is almost inevitable at the start of industrialization, when the technology level in the market sector is just above that of the home sector.

Chapter 3 explores why the trade balance is more sensitive to output changes in the emerging economies. This chapter argues that one possible explanation is the international borrowing constraints. By modeling the borrowing constraints as conditional on macroeconomic performance, the paper shows that when a positive shock takes place in emerging economies, *GDP* increases and the borrowing constraint becomes less binding, which results in less incentive to accumulate foreign assets. When a negative shock is present, in contrast, *GDP* decreases, and the representative household has to increase the trade balance to avoid the possibly binding borrowing constraints.

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Contents

List of Tables

List of Figures

Chapter 1

Introduction

In open macroeconomics, research on small open economies has never waned and the related literature is vast. Research on small open economy models covers a wide range of topics, including exchange rates, the trade balance, and currency crises.

Small open economy models explain many problems facing countries, and deliver important policy suggestions for open economies. In recent years, however, there have been few developments in the literature. Perhaps the reason for the dirth of path-breaking research in open economy macroeconomics is the lack of new topics for study, and that much of the literature has been mining existing areas of research.

This thesis tries to establishing some new directions by proposing new research topics. It consists of three separate chapters, in which three different topics are fully addressed. The unifying theme is the use of an open economy macroeconomic model. The first chapter raises a less well know fact, the difference between the sector specific consumption-output correlations, and investigates the causes for this difference.

In Canada, the tradable sector has a different consumption-output correlation than that of the nontradable sector. The topic of nontradable goods is not new, but most of the existing literature has concentrated on explaining the terms of trade as in Mendoza (1995), current account dynamics as as in Edwards (1989), the home premium puzzle as in Baxter et al. (1998) and Pesenti and van Wincoop (2002), the exchange rate as in Rogoff (2002), or purchasing power parity as in Backus and Smith (1993), and Sarno and Taylor (2002); little attention has been paid to the statistical properties of the tradable and nontradable sectors within a single country. This less well know fact, however, has rich implications.

The data indicates that the tradable sector has a different consumption-output correlation than that of the nontradable sector. The main conclusion of the first chapter is that international frictions may play a key role in generating business cycle moments in small open economies. This is shown in the following manner. First, it is shown that the tradable and nontradable sectors have almost equivalent consumption-output correlations in autarky; and second, this order is reversed in a completely open economy. These observations suggest that the "truth" lies somewhere in between, meaning an open economy with frictions. Indeed, of the mechanisms explored in Chapter 1, only the model with international financial frictions generates consistent results with the data.

Although the international financial frictions are not trivial, they fails to account for the volatility of consumption relative to output, one of the stylized facts for emerging economies. Higher consumption variability violates the theory of consumption and stands in sharp contrast to the pattern observed in developed economies. For this reason, consumption volatility in emerging countries has drawn much attention recently. The existing studies rely on specific productivity processes or preference forms to generate more volatile consumption in an ad hoc fashion. Moreover, almost all these studies admit the failure of consumption smoothing.

Chapter 2 tries to explain this fact from the basic difference between the emerging and developed economies. Emerging economies typically lag behind in the process of industrialization and encompass a relatively large home sector, whose economic activities are not fully reflected in the data. The author conjectures that it is possible to have more volatile consumption in one sector (the market) while aggregate consumption (market and home) may still be less volatile than aggregate output. Chapter 2 shows that when productivity in the market sector is less advanced, and the technology diffusion from the market sector to the home sector is strong, relatively volatile market consumption is likely to occur. A less advanced market sector and stronger technology transmission are typical characteristics of emerging economies, thus it is almost inevitable that more volatile market consumption will be observed.

If the topic of excessively volatile consumption in emerging economies has been increasingly noticed, the more responsive trade balance ratio-output comovement has received much less attention. Although the trade balance ratio-output comovement differs from country to country, on average the trade balance is more negatively correlated in emerging countries, posing another difference with the developed economies. Chapter 3 focus on this issue and investigates the possible cause.

Since the trade balance is counter-cyclical for most economies, and since the trade balance decreases foreign indebtedness, foreign debt is pro-cyclical. A stronger trade balance ratio-output comovement in emerging economies implies that their foreign debt is more responsive to output changes, which suggests that there may exist output-continent credit constraints. Chapter 3 confirms this hypothesis and shows that borrowing constraints indeed cause stronger trade balance ratio-output comovement. With an output-continent borrowing ceiling, when there is a negative shock, the representative household has to save more by exporting more to avoid the more binding constraints. Put differently, the stronger trade balance ratio-output comovement is the optimal response for the representative household in emerging economies.

Moreover, Chapter 3 compares the borrowing cycle model with the existing emerging small open economy models, and demonstrates that the borrowing cycle model better captures the stylized facts for emerging economies: volatile consumption and a stronger trade balance ratio-output comovement. Therefore for studies on emerging economies, borrowing constraints may be an important factor to consider.

In summary, this thesis exploits research topics in the area of small open economies that have been newly developed in this thesis. For some existing topics, it re-investigates and offers another explanation. The thesis confirms that international financial frictions exist even in developed economies like Canada(see Chapter 1); it reveals that a relatively large home sector leads to volatile market consumption in Chapter 2; and it demonstrates that credit constraints result in a closer trade balance-output comovement in emerging economies in Chapter 3.

Chapter 2

Financial frictions and the consumption-output correlations

2.1 Introduction

In open economy macroeconomics or international finance, the topic of non-tradable goods is not new and the relating literature is vast. Almost all of the existing literature concentrated on explaining the terms of trade as in Mendoza (1995), current account dynamics as in Edwards (1989), the home premium puzzle as in Baxter et al. (1998) and Pesenti and van Wincoop (2002), the exchange rate as in Rogoff (2002), or purchasing power parity as in Backus and Smith (1993), and Sarno and Taylor (2002).

Less attention has been paid to the statistical properties of the tradable and nontradable sectors within a single country. There are two facts of interest. The first is related to economic fluctuations. The Canadian economy displays a striking difference between the two sectors in terms of volatility. All tradable sector variables like capital, investment, consumption and output are more volatile than their nontradable counterparts. Especially for output, the tradable sector is more than two times as volatile. The non tradable sector accounts for almost half in both GDP and total consumption. Understanding the sources of volatility by sector may help in understanding the sources of aggregate fluctuations, the effects of shocks on the macroeconomy, and the likely impact of alternative public policies.

The second question is about consumption-output correlations. The consumption-output correlation is smaller in tradable sector than that in the nontradable sector. By definition, tradable sector differs from the nontradable sector in only one aspect, that is, its products can move across the border. Are the differences in the consumption-output correlations across the tradable and non tradable sectors due to the tradable nature of the tradable sector, and what specific factors contribute to this difference in correlations?

So far in literature, these two questions remain untouched except in Povoledo (2007) and Stockman and Tesar (1995). Both papers, however, only mention the fact that the tradable sector is generally more volatile without further investigation. The discrepancy in the sector specific consumption-output correlations is paid little attention. This paper attempts to construct a small open economy model with the focus on consumption-output correlations.

The benchmark model in this paper is a two sector model without any frictions. This artificial economy generates too much volatility compared with the data, especially for investment and the trade balance. Capital adjustment cost and financial friction are generally adopted to overcome this excess volatility. Both capital adjustment costs and financial frictions are put to the test. It turns out that, with the typical parameter values adopted in the literature, the capital adjustment cost has little effect in suppressing the volatility, even when applied to both sectors simultaneously. The reason for the failure of the capital adjustment cost to reduce volatility is that technology spillovers are allowed in this paper, and thus the capital adjustment cost parameter must be increased to a higher level (more than 20 times) to fit with the data, which is far beyond reasonable estimates. Instead, the model with modest international transaction cost reduces the excess volatility substantially and improves the fit.

More importantly, only the model with financial frictions succeeds in generating a lower consumption-output correlation in the tradable sector relative to that in the nontradable secytor, as observed in the data. The success does not result from a lower value of tradable sector consumption-output correlation. In fact, the tradable sector displays the same correlation in the capital adjustment and financial frictions models. Instead, this success comes from an increased consumption-output correlation in the nontradable sector in the financial friction model. Compared with the model with capital adjustment the financial friction model treats the two sectors asymmetrically by penalizing movements in the tradable sector operating through the trade balance. The absence of any restrictions on nontradable sector leads consumption and output to move more closely together.

In addition, the conjecture that international openness results in a smaller consumption-output correlation in the tradable sector is elucidated by solving the corresponding closed economy model. In autarky when the trade balance is restricted to nil for all the periods, even though both sectors experience an increased consumption-output comovement, the two sectors yields almost identical consumption-output correlations.

To this point, the paper has demonstrated that the financial friction is essential for generating results consistent with the data, in terms of both volatility and correlation. It is of interest to further check the role that international financial frictions by incorporating different model features. Two additional models that are widely used in the small open economy literature are selected as the experimental settings. One is the model with an interest rate shock and the other one is the model with standard preferences. The experiment is performed in the following manner. In each model, three distinct settings are simulated: without any restrictions, with capital adjustment costs only, and with financial frictions only.

The essentiality of financial frictions is found to be robust to different model features. For the two experimental models, only the setting with financial frictions yields consistent results. For the model with an interest rate shock, the absence of frictions results in a higher consumption-output correlation in the tradable sector, similar to the benchmark model; capital adjustment costs yields a consistent order, yet the correlation difference is only 5 percent, much lower than the 19 percent in the data. In contrast, the model with financial frictions generates a difference of 22 percent.

For the model with standard preferences, although all the three settings generates a consistent order of sector-specific consumption-output correlations, the correlation in the tradable sector is exceptionally low. The model without frictions yields a correlation of only -0.04, and the capital adjustment cost model generates 0.15, much lower than 0.59 as in the data. The setting with financial frictions produces the best match, 0.57. It is worth noting that standard prefernces fail to generate a countercyclical trade balance, the same as in a one sector model. Thus the failure of standard preferences in small open economy models is not the result of ignoring of nontradable sector.

The results from these experiments reinforce the conclusion that financial frictions is essential. In summary, the excess volatilities call for the introduction of frictions in small open economy models. Meanwhile, unrestricted movement in the nontradable sector is required to increase the comovement between its consumption and output. These two conditions imply that applying restrictions only in the tradable sector is necessary to generate results consistent with the data.

Since the two sectors display almost identical consumption-output correlations in autarky, and the difference in the correlations is reversed under a free trade economy, the results of the paper strongly suggest the existence of international financial frictions.

The rest of this paper is organized as follows. Section 2 provides the benchmark model with some remarks about the small open economy models in the beginning; Section 3 calibrates and simulates the benchmark model; Section 4 describes the models with frictions and the autarkic model economy; Section 5 provides further discussion, in which the model with an interest rate shock, and the model with standard preferences are presented as the experimental environment. Section VI concludes the paper.

2.2 Model Setup

2.2.1 Some remarks about small open economy models

Compared with the closed economy models, small open economy models are generally less successful in terms of mimicking the stylized facts. Typical small open economy models raise at least two problems. The first is the indeterminacy problem. Consider the standard Euler equation that governs the wealth accumulation in steady state, $\beta(1+r) = 1$. In the small open economy with the underlying assumption that real interest rate r is exogenously given, this Euler equation implies that any level of foreign asset is compatible with the steady state, and will bring about serious computation difficulties.

Researchers have come up with various techniques to induce well defined dynamics, among which endogenous discount factor is the most straightforward: β can be modeled as a function of some specific economic variables, given the fixed interest rate r. In this paper,the discount factor is modeled as a function of past consumption and leisure.

The second problem is oversensitivity to the form of the utility function, as Correia et al. (1995) shows that when calculating the moments in a small open economy, the results depends crucially on preference forms. Particularly, the standard utility of Cobb-Douglas form, such as

$$U(c,n) = \frac{[c^{\psi}(1-n)^{1-\psi}]^{1-\gamma}}{1-\gamma} \tag{2.1}$$

generates lower consumption-output correlation than the data and fails to produce a countercycle trade balance. The procyclical trade balance is especially problematic given that the countercycle trade balance is one of the most important stylized facts for open economies and its central status in the open economy macroeconomics research. Alternatively, the Greenwood-Hercowitz-Huffman (GHH) preferences first proposed by Greenwood et al. (1988) would perform better and thus it is commonly used in small open economy literature. The typical GHH preferences have the form,

$$U(c,n) = \frac{[c - \frac{n^{\omega}}{\omega}]^{1-\gamma}}{1-\gamma} \tag{2.2}$$

The zero wealth effect of GHH preference suggests that the marginal rate of substitution between consumption and leisure is independent of the consumption level, $MRS = -n_t^{\omega-1}$.

This specific preference, however, is costly in that it would predict a perfect labor-output correlation if the production function is Cobb-Douglas as $y_t = z_t k_t^{\alpha} n_t^{1-\alpha}$. The mechanism is that, when utility is GHH form and production is standard, and if there is only one sector, then utility maximization requires that the relative marginal utility between leisure and consumption equates their relative price, wage, or marginal productivity of labor, suggesting the following equation,

$$n_t^{\omega} = (1-\alpha) y_t \tag{2.3}$$

Equation (2.3) indicates that labor supply is perfectly correlated with output up to a first-order approximation. This perfect labor-output correlation is often seen in small economy papers such as Mendoza (1991), Schmitt-Grohe and Uribe (2003), and Letendre (2004). Although the labor-output correlation is high in the data, it is still not perfect. A two sector model can correct this problem. The above linear labor supply equation will break down as long as aggregate consumption involves a nonlinear combination of both tradable and nontradable products, as shown in this paper later.

2.2.2 Preferences

In the model of this paper, the infinitely living representative agent derives his or her life time utility from a composite good which consists of tradable C^T, and nontradable goods C^N, and disutility from working either in tradable goods sector, N^T,or nontradable goods sector, N^N. In what follows, the superscript denotes the sector, tradable T or nontradable N, while subscript denotes time.

The agent's preference are summarized by:

$$E_0 \sum_{t=0}^{\infty} \theta_t U(C_t^T, C_t^N, N_t^T, N_t^N) \tag{2.4}$$

$$\theta_0 = 1 \tag{2.5}$$

$$\theta_{t+1} = \beta[U(C_t^T, C_t^N, N_t^T, N_t^N)]\theta_t \tag{2.6}$$

where θ_t is the endogenous discount factor, β is a function of past utility with the restriction that its first order derivatives are negative, $\beta' < 0$. This restriction implies that the more people consume, the less patient they become. Any increase in the current consumption reduces the subjective discount weight of all the future periods.

Specifically,the utility function takes the GHH form,[1]

$$U(C_t^T, C_t^N, N_t^T, N_t^N) = \frac{[(C_t^T)^{\psi}(C_t^N)^{1-\psi} - \mu\frac{(N_t^T+N_t^N)^{\omega}}{\omega}]^{1-\gamma}}{1-\gamma} \tag{2.7}$$

where ψ is the share of tradable goods in total consumption, μ is a parameter adjusting labor supply, ω is the elasticity of labor supply, and γ denotes the risk aversion. Accordingly, the function form of β is

$$\beta(C_t^T, C_t^N, N_t^T, N_t^N) = [1 + (C_t^T)^{\psi}(C_t^N)^{1-\psi} - \mu\frac{(N_t^T + N_t^N)^{\omega}}{\omega}]^{-b} \tag{2.8}$$

where b is the elasticity of discount factor.

2.2.3 Technology and investment

The production function for tradable goods sector and nontradable goods sector are of standard forms, with the restriction that labor is immobile across the border:

$$Y_t^i = exp^{Z_t^i}(K_t^i)^{\alpha_i}(N_t^i)^{1-\alpha_i}, \quad i = T, N \tag{2.9}$$

[1] The standard GHH preference is not consistent with balanced growth. Adding growth will overcome this problem. With the focus on consumption-output correlations, however, growth is ignored in this paper.

where K_t^i is the capital used in sector i, N_t^i is the labor supply, α_i is sector specific capital share. Z_t^i is the sector specific technology shock. Let $Z_t = [Z_t^T, Z_t^N]'$, the productivity shocks evolve according to,

$$Z_t = \nu * Z_{t-1} + \epsilon_t \tag{2.10}$$

where $\epsilon_t = [\epsilon_t^T, \epsilon_t^{NT}]'$, the error terms, which could be correlated, have the variance-covariance matrix ξ. The matrix ν is of the form

$$\nu = \begin{bmatrix} \rho_{11} & \rho_{12} \\ \rho_{21} & \rho_{22} \end{bmatrix} \tag{2.11}$$

where diagonal elements ρ_{ii} denotes the technology persistence, off-diagonal elements ρ_{ij} stand for the technology spillover from sector j to sector i.[2]

The law of motion for capital is

$$K_{t+1}^i = (1 - \delta^i)K_t^i + I_t^i, \quad i = T, N \tag{2.12}$$

where δ^i is the capital depreciation rate, and I_t^i is the investment.

2.2.4 Linkage to the international markets

Individuals in this small open economy can lend or borrow freely from the outside of the world at a fixed interest rate, $r^\star$. Nontradable goods clear within the border,

$$C_t^N + I_t^N = Y_t^N \tag{2.13}$$

[2] The spill over between the two sectors is allowed because independent technology results in negative correlation between Y^T and Y^N, which is contrary to the data.

Unlike the nontradable goods, tradable goods can be used not only to consume or invest, but also to accumulate the foreign asset holdings.

$$C^T + D_{t+1} + I_t^T = Y^T + (1+r^\star)D_t \tag{2.14}$$

where the foreign asset(or debt) D_t evolves according to

$$D_{t+1} = (1+r^\star)D_t + TB_t \tag{2.15}$$

TB_t denotes the trade balance in period t.

Finally, neither home nor foreign can play a ponzi-game, which implies:

$$lim_{T\to\infty}(1+r)^{-T}D_{t+T} = 0 \tag{2.16}$$

2.2.5 First order conditions

Let η_t, λ_t^T, and λ_t^N denote the Lagrangian multipliers associated with the discount factor (3.7), tradable sector resource constraint, equation(2.14) and nontradable sector clearance condition, equation (3.11) respectively. The Lagrangian for this problem can be written as,

$$\begin{aligned}\mathcal{L} = \sum_{t=0}^{\infty}\theta_t\{&U(C_t^T, C_t^N, N_t^T, N_t^N) + \frac{\eta_t}{\theta_t}[\theta_{t+1} - \beta(C_t^T, C_t^N, N_t^T, N_t^N)\theta_t] + \\ &\lambda_t^N[exp^{Z_t^N}(K_t^N)^{\alpha_N}(N_t^N)^{1-\alpha_N} + (1-\delta_t^N)K_t^N - K_{t+1}^N] + \\ &\lambda_t^T[exp^{Z_t^T}(K_t^T)^{\alpha_T}(N_t^T)^{1-\alpha_T} + (1+r^\star)D_t - C_t^T - D_{t+1} + (1-\delta_t^T)K_t^T - K_{t+1}^T]\}\end{aligned} \tag{2.17}$$

Accordingly, the social planner's solution can be characterized by the following first order conditions:

$$U_1(.) = \eta\beta_1(.) + \lambda^T \tag{2.18}$$

$$U_2(.) = \eta\beta_2(.) + \lambda^N \tag{2.19}$$

$$U_3(.) = \eta\beta_3(.) - \lambda^T MP_L^T \tag{2.20}$$

$$U_4(.) = \eta\beta_4(.) - \lambda^N MP_L^N \tag{2.21}$$

$$\lambda^T = \beta(.)(\lambda^T)'[(MP_K^T)' + 1 - \delta^T] \tag{2.22}$$

$$\lambda^N = \beta(.)(\lambda^N)'[(MP_K^N)' + 1 - \delta^N] \tag{2.23}$$

$$\lambda^T = \beta(.)(\lambda^T)'(1 + r^\star) \tag{2.24}$$

$$\eta = -E[U(.)]' + E\eta'[\beta(.)]' \tag{2.25}$$

where $U_i(.)$, $i = 1,2,3,4$ is the partial derivative with respect to the ith argument in equation (4.3), MP_K and MP_L denotes the marginal productivity for capital and labor, and with the convention that X' denotes the next period variable,i.e. X_{t+1}.

In equations (2.18) and (2.19), λ_t^T and λ_t^N denote the marginal utility of tradable and nontradable consumption, respectively. Equations (2.20) and (2.21) state the conditions for the labor-leisure choice. The endogenous discount factor implies that past consumption and leisure have an impact on current utility, therefore these four equations look different from the standard first order equations with fixed discount factor.

Equations (2.22) and (2.23) determine the optimal investment. Equation (2.24) governs the decisions rule for foreign asset accumulation: the cost of giving up one unit of tradable goods to accumulate foreign asset holdings in the current period must be equal to the discounted future benefit. The last first-order equation (2.25) is the sum of utility of period $t + 1$ and the discounted utility from then on, thus η_t can be interpreted as the value function in dynamic programming.

As mentioned in the beginning of this section, another advantage of the two-sector model is that the perfect labor-output correlation will collapse, even when preferences are of the GHH form. To see this, substitute λ_t^T in equation (2.18) into equation (2.20), to get

$$MPL_t^T = \mu \frac{N_t^{\omega-1} C_t^T}{\psi C_t} \tag{2.26}$$

where $C_t = C_t^{T\psi} C_t^{N1-\psi}$ which implies that, as long as $\psi \neq 1$, equation (2.26) will not reduce to equation (2.3), which results in the perfect labor-output correlation. Similarly, equation (2.19) and (2.21) yields $MPL_t^T = \mu \frac{N_t^{\omega-1} C_t^N}{(1-\psi) C_t}$, implying that whenever $\psi \neq 0$, perfect labor-output correlation will not occur.

2.3 Calibration & Simulation

2.3.1 Calibration

This section calibrates the parameters in the benchmark model. The division between the two sectors is based on the work of Stockman and Tesar (1990), and the updated category of Statistics Canada.[3] The average share of nontradable is half in GDP, and shows a secular increasing trend, as shown in Figure 2.1.

For the purpose of comparison with Mendoza (1991) and Schmitt-Grohe and Uribe (2003), this paper also adopts annual data. The benchmark model is calibrated to the Canadian data from year 1961 to 2008. The average share of tradable goods in total consumption is estimated to be 51 percent. The capital

[3]Tradable Sectors: crop and animal production + forestry and logging + fishing,hunting and trapping + mining,oil and gas extraction + manufacturing + retail trade + wholesale trade + transportation and warehousing + information and cultural industries.

Nontradable Sectors: construction + finance,insurance,real estate and rental and leasing + professional,scientific and technical services + administrative and support,waste management and remediation services + educational services + heal care and social assistance + arts, entertainment and recreation + accommodation and food services + public administration.

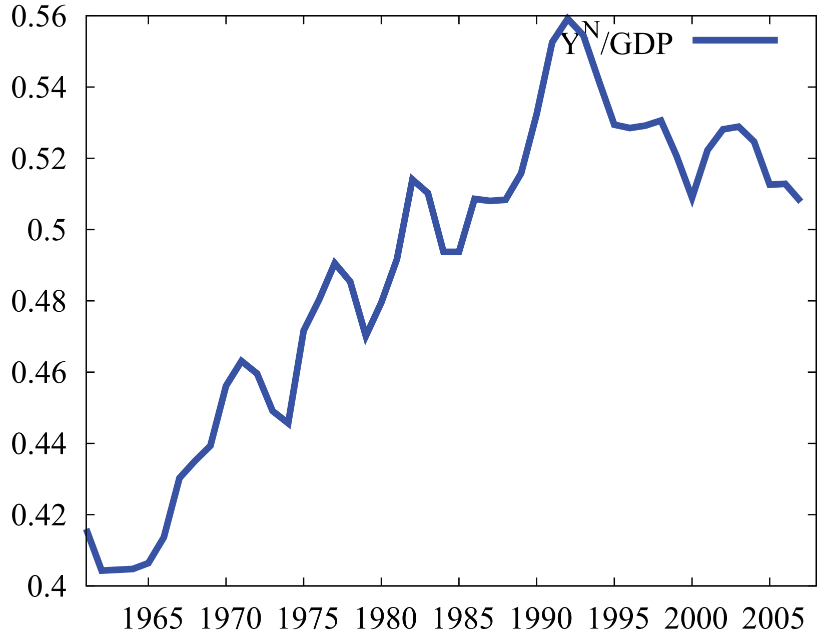


Figure 2.1: Share of Nontradable Sector

share in production, α^T, and α^N,are calibrated to be 0.35, and 0.25, respectively.[4] The depreciation rates, δ^T, and δ^N are estimated to be 10.4 and 7 percent.[5]

The international real interest rate set to be 4 percent, suggesting that β at equilibrium is 0.96. The parameter ω is set as 1.6, implying that the labor supply elasticity $1/(\omega - 1) = 1.7$. The two parameters, μ and b are jointly determined to meet the following two facts. The first is that people spend 1/3 of time working; and the second is that the average trade balance ratio is 1.6 percent.[6] The risk aversion parameter, γ, is widely regarded to lie in the range of 1 to 2, and in this paper it is set to be the 1.5, the middle value of this range.

To estimate the two matrices V and ξ describing the technology process, the first step is to get the Solow residuals in the two sectors. The Solow residuals

[4]The aggregate capital share in this period is calculated to be 0.31, close with Mendoza(1991)'s estimation, 0.32.

[5]The aggregate depreciation is 8.6 percent.

[6]The average export share in GDP is 28.4 percent and import share is 26.8 percent.

are calculated following Gomme and Rupert (2007). Then ν and ξ are estimated using vector autoregression (VAR) model, and the results are,

$$\nu = \begin{bmatrix} 0.72 & 0.14 \\ (6.20) & (2.40) \\ 0.05 & 0.92 \\ (0.94) & (11.40) \end{bmatrix} \tag{2.27}$$

where numbers in parenthesis are t statistics.

$$\xi = 10^{-4} \begin{bmatrix} 4.99 & 0.46 \\ 0.46 & 2.55 \end{bmatrix} \tag{2.28}$$

The value in matrix ν indicates that the technology shock in nontradable sector is more persistent, and the spillover effect from nontradable to tradable sector is stronger than the reverse. The parameter values are summarized in Table 2.1.

Table 2.1: Calibration Summary

Parameter	Description	Value
ψ	weight of tradable consumption	0.51
ω	labor supply elasticity	1.60
μ	adjusting parameter of labor supply	0.99
γ	measure of risk aversion	1.5
$r^{\star}$	risk free international interest rate	0.04
α_T	capital share in tradable sector	0.35
α_N	capital share in nontradable sector	0.25
b	discount factor coefficient	0.49
δ^T	tradable capital depreciation rate	0.104
δ^N	nontradable capital depreciation rate	0.070

2.3.2 Simulation results

The social planner problem is solved using log-linearization method, and then the model is simulated for 1000 replications with 47 periods in each replication, the length of the sample period. To obtain the moments of aggregate variables, the relative price of nontradable goods (normalizing $P^T = 1$), p, is constructed as,

$$p_t = \frac{\lambda_t^N}{\lambda_t^T} \tag{2.29}$$

where λ_t^T and λ_t^T are marginal utilities associated with equation (2.18) and (2.19).[7]

The simulation results are presented in Table 2.3 and Table 2.4. The benchmark model mimics the data poorly whether in terms of volatility or correlation. For volatilities, the model's prediction is too high, especially for investment and trade balance, both are almost 6 times as high as seen in the data. For correlations, nontradable sector output, labor and investment are shown to be countercyclical.

The trade balance is procyclical, and it is significant, with a correlation with GDP 0.24. This indicates that GHH preference is not a sufficient condition to generate countercyclical trade balance. As stated in the introduction, to generate countercyclical trade balance is the primary reason to employ GHH preference. The failure of GHH preference in the benchmark model, however, must be read with caution. Careful review of the literature reveals that models that successfully generate consistent trade balance correlations all virtually incorporates frictions. In the latter part of this paper, GHH preference's unique function is demonstrated with the inclusion of frictions and the comparison with

[7] With equation (2.29), the aggregate variables can be written as: $C_t = C_t^T + p * C_t^N$, $Y_t = Y_t^T + p * Y_t^N$, $K_t = K_t^T + p * K_t^N$, and $I_t = I_t^T + p * I_t^N$; for labor aggregate, it is $N_t = N_t^T + N_t^N$.

the standard preference.

2.3.3 Impulse response functions

Assume that the economy is at steady state in period 1, and in period 2 a one standard deviation shock occurs. The corresponding responses are plotted in Figure (2.8) and Figure (2.9). For the temporary shock, resources will shift to more productive sector with the permission of resource constraint. For example, for a one time tradable shock, Z^T, the representative agent increases labor supply in tradable sector and decrease the working time in nontradable sector. In tradable sector, resources shifts from trade balance to investment. The increase in labor, investment and improved technology contribute to output increase. Consumption also increases.

In nontradable sector, consumption increases at the cost of decrease in investment. The lower labor supply leads to the the output decrease. The increase in tradable output outperforms the decrease in nontradable sector, and as a result, GDP rises. The relative price reflects the Balassa-Samuelson effect: p_t remains above the steady state whenever tradable sector technology progress dominates, while starts to move below the steady state when nontradable sector technology level gets larger.

2.4 Models with Frictions

2.4.1 Model with capital adjustment cost

With technology spillover, the technology innovation in any sector will cause investment movement not only in that sector, but also in the other sector. Further, the adjustment in investment causes movement in consumption and eventually the trade balance.

The too frequent adjustment implied by the associated excess volatility in the benchmark model strongly suggests that the some restriction on capital or trade balance movement should be introduced. In practice, the former is featured by capital adjustment cost, and the latter is characterized by international financial friction. For comparison, both models are simulated in this section.

The capital adjustment cost is modeled as increasing with the speed of adjustment, $K^i_{t+1} - K^i_t$. With this configuration, the available resource, S^i_t, is output net of adjustment cost,

$$S^i_t = exp^{Z^i_t}(K^i_t)^{\alpha_i}(N^i_t)^{1-\alpha_i} - \frac{\phi^i}{2}(K^i_{t+1} - K^i_t)^2, \quad i = T, N \tag{2.30}$$

where ϕ^i is the capital adjustment parameter in sector i.

The specific value of ϕ^i is hard to estimate. Given that capital adjustment cost is widely believed to be small, Mendoza (1991) suggests that the average cost is about 0.1 percent of output, and it should not exceed 0.028. The simulation results presented in Table 2.3 and Table 2.4 are based on this maximum value. The two tables indicates that the effect of capital adjustment cost is unsatisfactory in terms of suppressing volatility. The standard deviations for investment and trade balance still remain 4 times higher than the data. Further experiment suggests that ϕ^i must be increased simultaneously by 20 times for both sectors, which is beyond reasonable estimation, to yield consistent investment volatility with the data.

The impotent capital adjustment cost in the two sector model stands in sharp contrast with its effect in the one sector model, in which capital adjustment cost succeeded in mitigating the excess volatility. It is worth noting that capital adjustment cost is applied to both sectors, however, technology spillover and innovation correlation across sectors are allowed for. The spillover and innovation correlation is strong, thus unreasonable higher capital adjustment parameter is needed to achieve the ideal volatility.

Capital adjustment cost is, however, not trivial. In Table 2.4, the correlation coefficient of trade balance is reduced from 0.24 in the benchmark model to 0.04.[8] It is shown that when ϕ^i is increased to 0.038, the trade balance becomes countercyclical. And with the increase of ϕ^i, the trade balance displays monotonically decreasing correlation with GDP, as Figure 2.2 suggests. This implies that, for model with capital adjustment cost, results must be interpreted with the examination of the magnitude of capital adjustment cost parameter.

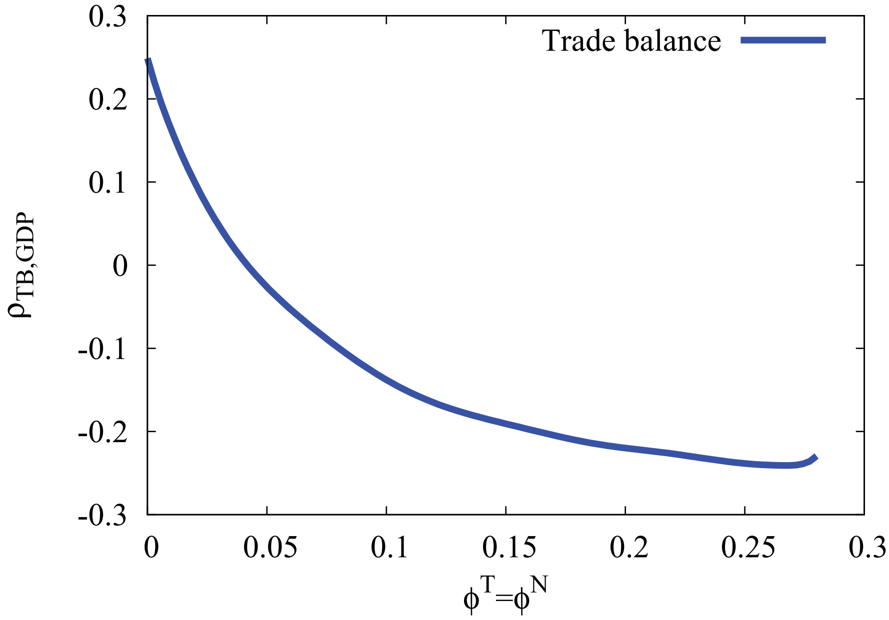


Figure 2.2: Capital Adjustment Cost and Trade Balance Correlation with output

[8] Schmitt-Grohe and Uribe (2003) obtain insignificant trade balance correlation, with -0.04 as the best shot when $\phi^i = 0.028$.

2.4.2 Model with international financial friction

Besides capital adjustment cost, international financial friction is also another widely used option to suppress the volatility. For example, Backus et al. (1992) finds that international financial friction is crucial to their two-country model in mimicking the stylized facts. As in Backus et al. (1992), this friction is approximated as a quadratic function of trade balance, $\frac{\tau}{2}TB^2$.[9] The resource constraint, equation (2.14) becomes

$$C^T + D_{t+1} + I_t^T = Y^T + (1 + r^\star)D_t - \frac{\tau}{2}TB_t^2 \tag{2.31}$$

Accordingly, the first order equation for trade balance accumulation, equation (2.7) now is

$$\lambda_t^T(1 + \tau TB_t) = \beta(.)\lambda_{t+1}^T(1 + r^\star)(1 + \tau TB_{t+1}) \tag{2.32}$$

The marginal cost for changing foreign asset position in period t is τTB_t. Similar to Backus et al. (1992), τ is set such that the marginal cost is 0.58 percent in the steady state. This implies that $\tau = 0.36/GDP$, where GDP is steady state aggregate output.[10]

The same as the one sector two country model in Backus et al. (1992), international financial friction, even when set to be small, displays a significant role in matching with the data. The model's fit with improves in terms of both volatilities and correlations. The aggregate investment is reduced from 24.81 to 3.60, pretty close to the data 3.66. For the standard deviation of trade balance, it is reduced from 3.26 to less than unity (0.85), which is what the data shows. As of correlation, trade balance displays countercyclical movement with GDP,

[9] Backus et al. (1992) calls this as trading friction. This is not correct because as the net of exports and imports, trade balance serves to change the amount of foreign asset(or debt) holding in essence.

[10] $\tau TB = 0.58\% \Longrightarrow \tau = 0.58\%/TB = \frac{0.58\%/GDP}{TB/GDP} \Longrightarrow \tau = \frac{0.58/1.6}{GDP} = 0.36/GDP$, given that TB/GDP=1.6 percent in the steady state.

and this correlation is as low as -0.23, an improved value compared with the one reported in Schmitt-Grohe and Uribe (2003).

Backus et al. (1992) attributes the improvement to the quantity property of the gain from trade:the smaller the gain trade, the larger quantity effect of international financial friction has. The impulse response suggests this. The new responses Figure (2.12) and Figure (2.13) are similar with the benchmark model in shape, but are different in magnitude. With transaction cost, the adjustment magnitude is reduced to half as with benchmark model.

More important, of the three models presented so far, the model with international financial friction is the only model that generates the consistent order of consumption-output correlations. In the data, $corr(C^T, Y^T) = 0.59$, which is smaller than that of nontradable sector counterpart, $corr(C^N, Y^N) = 0.78$. The model with capital adjustment cost yields inconsistent order(0.71 v.s. 0.67). With international financial friction, $corr(C^T, Y^T) = 0.71$, and $corr(C^N, Y^N) = 0.86$. Careful examination of the values reported in Table 2.4 reveals that this consistency comes from a increased consumption-output correlation in nontradable sector, from 0.67 to 0.86. Meanwhile, tradable sector displays identical values. It can be inferred that, with the revoke of restriction on nontradable sector in international financial friction model, nontradable consumption moves more closely with its output.

2.4.3 Autarky model

If the discrepancy in consumption-output correlations is the result international openness, then it is expected that this discrepancy may disappear when the small open economy becomes isolated from the outside world. This conjecture is tested by solving the corresponding autarky model.

Since the only purpose of adopting the endogenous discount factor is to resolve the indeterminacy problem, standard discount factor is used in the closed economy. The discount factor is fixed at 0.96, the same as the steady state value in the benchmark model. For consistency, the GHH preference is still maintained. The standard preference is discussed in details later.

The simulation results for autarky confirms the above conjecture. Although the consumption-output correlations increases in both sectors, the discrepancy in the two sectors vanishes, as shown in Table 2.4. For illustrative purpose, the model of autarky with capital adjustment cost is also simulated. Not surprisingly, the correlation coefficients remain the same when common capital adjustment cost are placed symmetrically.

It is notable that, the autarky economy displays low volatility. Although the standard deviation of GDP mimics the data very well (2.57 with 2.59), the investment can not generate enough fluctuation (1.99 with 3.66 in the data). This suggest that, modeling the Canadian economy, which is a typical example of small open economy, maybe inappropriate without any international link.

2.5 Further Discussion: International Financial Friction and Consumption-output Correlations

2.5.1 Model with interest rate shock

The role of international financial friction has been demonstrated in the previous models. Financial friction is effective in suppressing the excessive volatilities; more importantly, it is essential to generate a lower consumption-output correlation in tradable sector. In this section, the role of international financial friction plays is further put to test to see its robustness to different model features. The selection criterion of other models is based on the width of the concern in the small open economy literature.

One common concern is the on the randomness of the international interest rate. The real interest rate, $r^\star$ is the capital return, also it is the relative price of consumption. Thus the change of interest rate has both substitution effect and income effect on the dynamics of trade balance, investment and consumption. For this reason, investigating the role of interest rate shocks is often seen in open economy models.

So far, however, there is still no definite answer to the question whether introducing randomness into the exogenous interest rate is beneficial. For example, Mendoza (1991) compares various simulation experiment and shows that interest rate shock is of little importance; Correia et al. (1995) reach the same result by showing that the change of consumption, labor and output is quantatively small. Blankenau et al. (2001), on the other hand, argues that the shock of interest rate is quantatively large using variance decomposition; Nason and Rogers (2006) find that interest rate shock is essential to explain the present-value model of current account. Mixed evidence as it is in the one sector model, the effect of interest rat shock has not been examined yet in a two-sector model. Thus, introducing the randomness in the interest rate is a contribution to this debate.

With randomness, the real interest rate is expressed as

$$r_t = r^\star + z_t^r \tag{2.33}$$

where the shock z^r denotes the deviation from the steady state real interest rate $r^\star$.

With replacing all the $r^\star$ in the benchmark model with r_t as equation (2.5.1), Z_t in equation (4.5) is now written as $Z_t = [Z_t^T, Z_t^N, z_t^r]'$, and $\epsilon_t = [\epsilon_t^T, \epsilon_t^N, \epsilon_t^r]'$. Accordingly, using VAR approach, the first order autoregressive parameter matrix V and variance-covariance matrix ξ are estimated to be

$$\mathbf{V} = \begin{bmatrix} 0.71 & 0.14 & -0.16 \\ (6.23) & (2.40) & (-0.49) \\ 0.06 & 0.92 & -0.31 \\ (0.88) & (11.47) & (-1.18) \\ 0.03 & -0.02 & 0.11 \\ (0.55) & (-0.50) & (0.76) \end{bmatrix} \tag{2.34}$$

where numbers in parenthesis are t statistics.[11]

$$\xi = 10^{-4} \begin{bmatrix} 4.99 & 0.46 & 0 \\ 0.46 & 2.55 & 0 \\ 0 & 0 & 0.80 \end{bmatrix} \tag{2.35}$$

with the new calibration of the shocks, the simulation result is reported in Table (2.3).

The comparison of simulations results in Table (2.3) and (2.4) suggests that the interest rate in the two sector model is neutral: there is no significant difference between the model with interest rate shock and the model with international financial friction. Mendoza (1991) attributes this neutrality to the relative small share of trade balance. When trade balance is small, the effect of international shock is limited. In this paper, the trade balance ratio is 1.6 percent, smaller than the 2 percent in Mendoza (1991), therefore it is not surprising to get the limited effect of interest rate shock.

[11]The interest rate here is the three month U.S. treasury bond.

The randomness in the interest rate does generate some difference. It is worthy noting that the trade balance displays a slightly higher standard deviation, from 0.85 in the model with international financial friction to 0.92. The difference suggests that, for a paper with the focus on trade balance or foreign debt or exchange rate, interest rate shock may help to obtain a more detailed picture.

To see the robustness of international financial friction, three settings as Table 2.2 are independently simulated. Since the purpose is to see which setting generate lower consumption-output correlation in the tradable sector, it is necessary to set the principles to follow when assessing these settings. The primary principle is to check whether the setting can generate consistent order. The second one is to see if the difference in the two correlations is large enough. This principle requires that the difference between the two sectors in terms of consumption-output correlation should be significant. And the last principle is to compare with the data. The more close to the data, the more convincing the setting is. These three principles together characterizes the settings in terms of both quality and quantity.

Following the above principles, only the setting 3 with international financial friction yields consistent order of consumption-output correlations and with significant gap. Setting 1 causes inconsistent order (0.70 V.S. 0.51); setting 2 produces consistent order, yet the discrepancy of the two correlations is only 5 percent (0.64 V.S. 0.69), while the data shows a gap of 19 percent; meanwhile, setting 3 generates a gap as large as 22 percent (0.63 V.S. 0.85).

Table 2.2: Robustness Check Settings

Setting	ϕ^i	τ
1	0	0
2	0.028	0
3	0	0.36/GDP

2.5.2 Model with standard preference

The other issue of common concern in small open economy models is the oversensivy to utility forms. As remarked before, it is well agreed that by and large GHH preference outperforms standard preference for small open economy models. Particularly, it helps to correct the countercyclical behavior of trade balance. The results of benchmark model with GHH preference, however, suggests that GHH preference is not a sufficient condition to generate countercyclical trade balance ratio. The correlation between trade balance ratio and GDP is positive and as high as 24 percent.

The usefulness of GHH preference is not realized until frictions is incorporated into the benchmark model. With frictions, the correlation of trade balance with GDP improves, as shown in the previous section. This nevertheless suggests that an explicit modelling with standard preference will clarify GHH utility's effect. There is another reason to select the model with standard preference as the experiment: GHH preference's performance has not been checked in a two sector model yet.

The standard preference is of the form

$$U(C_t^T, C_t^N, N_t^T, N_t^N) = \frac{\left[[(C_t^T)^{\psi}(C_t^N)^{1-\psi}]^{\pi}[(1 - N_t^T - N_t^N)]^{1-\pi}\right]^{1-\gamma}}{1-\gamma} \tag{2.36}$$

where π is the parameter. Accordingly, the function form of discount factor becomes

$$\beta(C_t^T, C_t^N, N_t^T, N_t^N) = \left[1 + [(C_t^T)^{\psi}(C_t^N)^{1-\psi}]^{\pi}[(1 - N_t^T - N_t^N)]^{1-\pi}\right]^{-b} \tag{2.37}$$

π is set to be 0.36 to meet the same calibration criterion with the benchmark model. With international financial friction included in the same manner as before, the simulation results are reported in the last column of Table (2.3) and

Table (2.4). There are two notable difference compared with the model with international financial friction. The first is the low volatilities and correlation coefficients for consumption; the second is the positively high trade balance correlation (0.23).

These two major differences are the result of consumption smoothing incentive implied by standard preference. In contrast, GHH preference implies zero wealth effect, thus the consumption smoothing effect is eliminated. When a positive productivity shock starts in the tradable sector, for instance, tradable consumption increases more with GHH preference, and correspondingly, trade balance must decrease more to satisfy the resource constraint. Meanwhile, the larger decrease in trade balance helps to generate the countercyclical trade balance. This smoother consumption adjustment for standard preference is reflected in the impulse response functions as in Figure 2.3 and Figure 2.4.

The same as the previous experiment, the robustness of international financial friction to models with standard preference is tested with the three settings as Table 2.2. Following the principles laid out for assessing the settings, only setting 3 generates consistent results (0.57 vs. 0.90). For setting 1 (-0.04 vs. 0.88) and 2 (0.15 vs. 0.90), they did generate consistent order and sufficient gap, whereas the setting is not reliable: the tradable consumption-output is too low and even negative with setting 1.

The comparison between the models offers rich interpretations. Examining the volatility of GDP in each model is a simple yet effective way to summarize all the models considered in this paper. The benchmark model is the model with completely free adjustment, thus it generates the highest volatility (4.92), much higher than the data (2.57). The capital adjustment cost model can not reduce the volatility of GDP much (4.15) , suggesting that when spillover is allowed for, modest penalty on capital adjustment has limited effect in mitigating volatilities. The substantially decreased volatility with international financial friction (2.80) strongly suggests that international financial friction is much more effective in suppressing the excess fluctuations. The almost unchanged volatility for model with international shock (2.83) implies that randomness in the interest rate is neutral in this paper. Because of the strong consumption smoothing incentive, the model with standard preference displays the lowest volatility (2.44) instead of autarky (2.59).

2.6 Conclusion

This paper covers various models that are typically featured in the small open economy literature. Each model is presented together with its simulation results, making the comparison across models easier and illustrative. Thus as one contribution, this paper serves as a technical guidance.

The comparisons across different models shed light on some fundamental issues of small open economy models. For example, this paper shows that GH-H preference is indeed helpful, yet not sufficient, to generate the countercyclical trade balance ratio, one of the most important stylized facts in open economies. Incorporating frictions is also important to generate the consistent trade balance correlation. In addition, this paper suggests that any model with capital adjustment cost that generates the countercyclical trade balance must be interpreted with the magnitude of adjustment parameter.

More important, as the major contribution, this paper investigates the sector-specific consumption-output correlations thoroughly. The benchmark model calls for the restrictions on capital movement to mitigate the excessive volatilities. On the other hand, unrestricted movement in the nontradable sector is required to produce higher consumption-output correlation. Compared with capital adjustment cost, the international financial friction impose asymmetric penalty, and thus is crucial to generate consistent result with the data.

The essential of international financial friction is robust to different model settings. Two other models, the model with an interest rate shock and the model with standard preferences, are employed as the experimental environment. In either model, only the setting with international financial frictions can generate consistent results.

The autarky model has almost identical consumption-output correlations, while the open economy without any frictions displays contrary result with the data. These results strongly suggests the existence of international financial frictions.

Obstfeld and Rogoff (2000) claim that frictions in international transactions accounts for many of the puzzles in open macroeconomics for different models, whether on the pricing or quantity. This pretty strong claim does not seem radical at all, at least for this paper.

Table 2.3: Standard Deviations

Variable	Data	Benchmark Model	Model with capital adjustment cost	Model with financial friction	Autarky	Model with international shock	Model with standard preference[a]
K^T	1.03	1.87	1.51	0.78	0.54	0.72	1.03
K^{NT}	0.99	0.54	0.52	0.58	0.31	0.59	0.48
C^T	0.85	0.71	0.76	0.83	0.90	0.85	0.31
C^N	0.60	0.53	0.57	0.70	0.79	0.75	0.49
N^T	1.03	1.40	1.21	1.05	0.73	1.09	1.46
N^N	0.71	0.88	0.88	0.99	0.48	1.01	0.73
I^T	3.5	29.24	25.10	5.67	3.78	5.18	7.71
I^N	2.6	6.105	5.54	5.33	3.11	5.78	4.41
Y^T	1.68	1.78	1.59	1.46	1.27	1.45	1.84
Y^N	0.74	0.90	0.98	1.15	0.87	1.30	1.03
K	0.88	1.20	1.01	0.60	0.48	0.53	0.67
C	0.67	0.71	0.76	0.83	0.87	0.85	0.31
N	0.79	0.52	0.53	0.54	0.47	0.55	0.48
I	3.66	24.81	15.16	3.60	1.99	3.39	4.37
$TB1$	0.51	3.26	2.25	0.85	N/A	0.92	1.05
GDP	2.57	4.92	4.15	2.80	2.59	2.83	2.44

Notes:

1. TB1 is the trade balance ratio over GDP.
2. The standard deviations of GDP are reported in the last line in percentage. The value for all the other variables are relative to it in each model.
3. Each model is simulated with 1000 replications with 47 periods each. All variables except $TB1$ are first logged, then applied with HP filter with the smoothing parameter $\lambda = 100$.

[a] For model with international shock and model with standard preference, please note that financial friction is included.

Table 2.4: Correlation Coefficients

Variable	Data	Benchmark Model	Model with capital adjustment cost	Model with financial friction	Autarky	Model with international shock	Model with standard preference[a]
K^T	0.42	0.81	0.73	0.41	0.20	0.36	0.43
K^{NT}	0.64	0.27	0.28	0.05	-0.29	0.05	-0.12
C^T	0.82	0.96	0.96	0.97	0.98	0.96	0.78
C^N	0.50	0.77	0.77	0.67	0.50	0.72	-0.02
N^T	0.79	0.84	0.78	0.72	0.90	0.65	0.85
N^N	0.73	-0.20	0.06	0.26	0.46	0.30	-0.50
I^T	0.54	-0.01	0.16	0.53	0.77	0.72	0.73
I^N	0.76	-0.40	-0.19	0.05	-0.25	0.06	-0.19
Y^T	0.89	0.90	0.88	0.85	0.97	0.81	0.94
Y^N	0.60	-0.01	0.21	0.33	0.34	0.39	-0.14
K	0.70	0.86	0.81	0.60	0.41	0.52	0.51
C	0.77	0.95	0.96	0.94	0.98	0.96	0.78
N	0.83	0.98	0.98	0.96	0.92	0.96	0.98
I	0.90	-0.05	0.16	0.55	0.90	0.77	0.76
$TB1$	-0.17	0.24	0.04	-0.23	N/A	-0.21	0.23
(C^T, Y^T)	0.59	0.76	0.71	0.71	0.941	0.63	0.57
	$\wedge$	$\vee$	$\vee$	$\wedge$	$\approx$	$\wedge$	$\wedge$
(C^N, Y^N)	0.78	0.46	0.67	0.86	0.948	0.85	0.90

Notes:

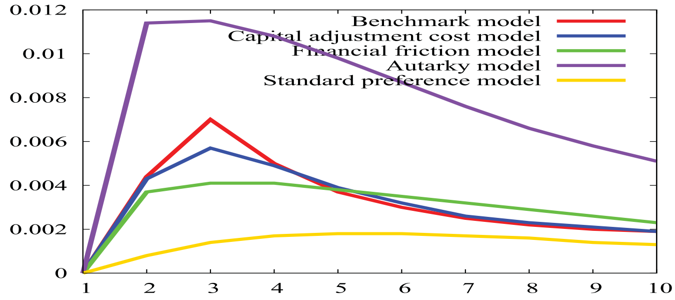
1. TB1 is the trade balance ratio over GDP.
2. All correlation coefficients are with the GDP in each corresponding model except in the last two rows, which reports sector specific consumption-output correlations with binary relationship description in between.
3. Each model is simulated with 1000 replications with 47 periods each. All variables except $TB1$ are first logged, then applied with HP filter with the smoothing parameter $\lambda = 100$.

[a] For model with international shock and model with standard preference, please note that financial friction is included.

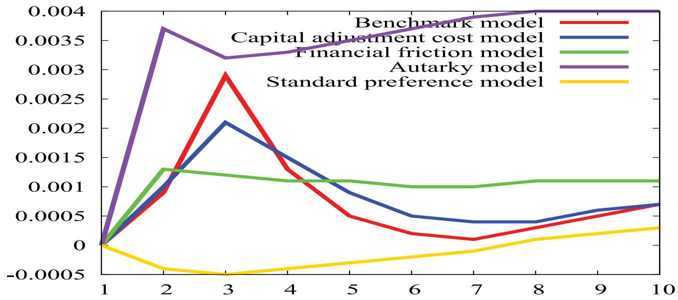
2.7 Appendix: Impulse Responses

Model Comparison: Response of Consumption

a: Tradable Sector



b: Nontradable Sector



c: Aggregate

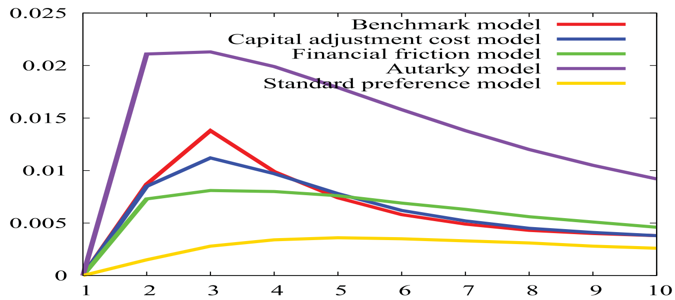
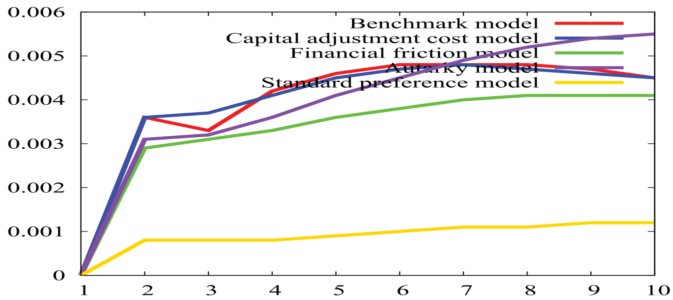


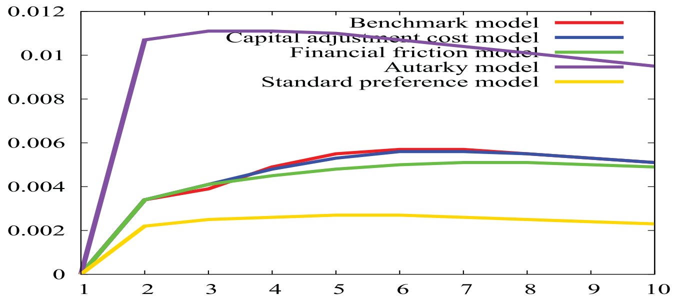
Figure 2.3: Shock to Z^T: consumption

Model Comparison:Impulse of Consumption

a: Tradable Sector



b: Nontradable Sector



c: Aggregate

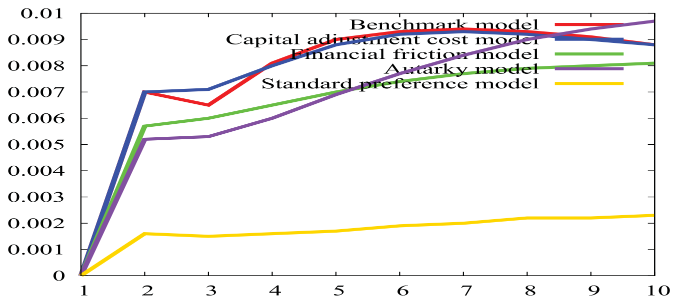


Figure 2.4: Shock to Z^N: consumption

Model Comparison: Response of Investment

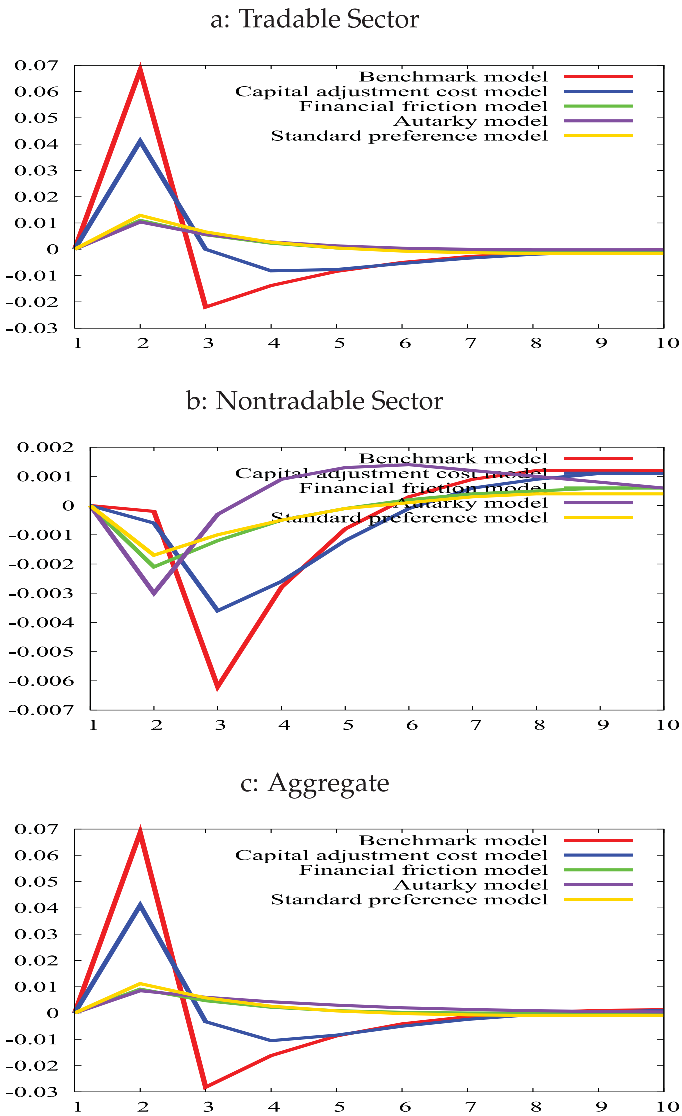


Figure 2.5: Shock to Z^T: investment

Model Comparison:Impulse of Investment

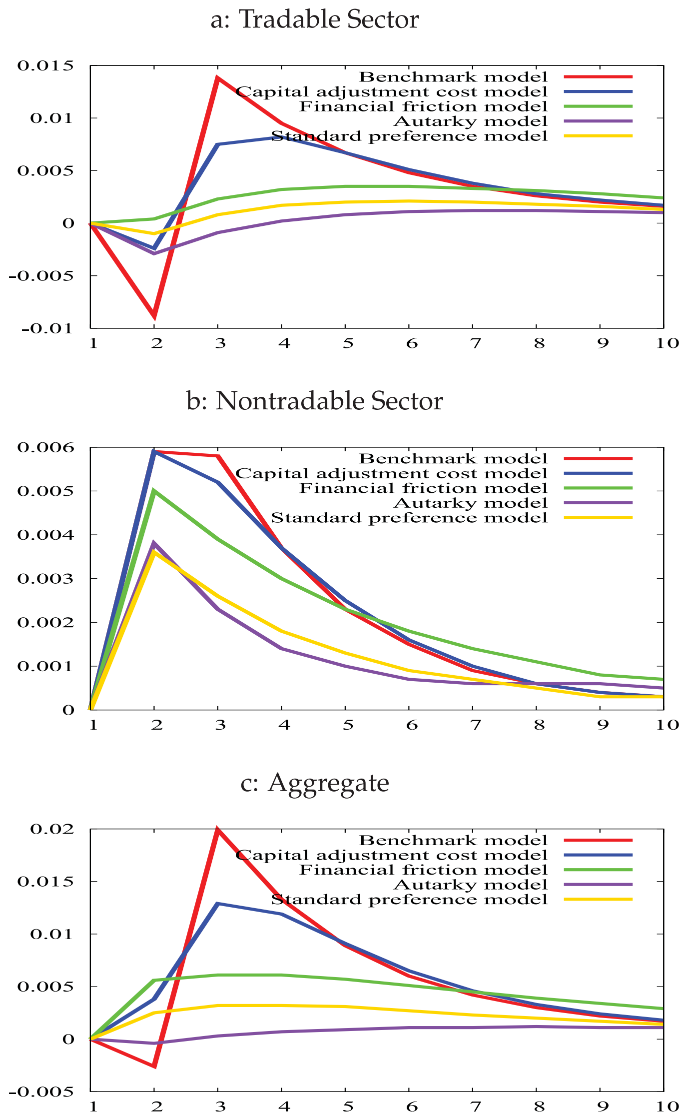
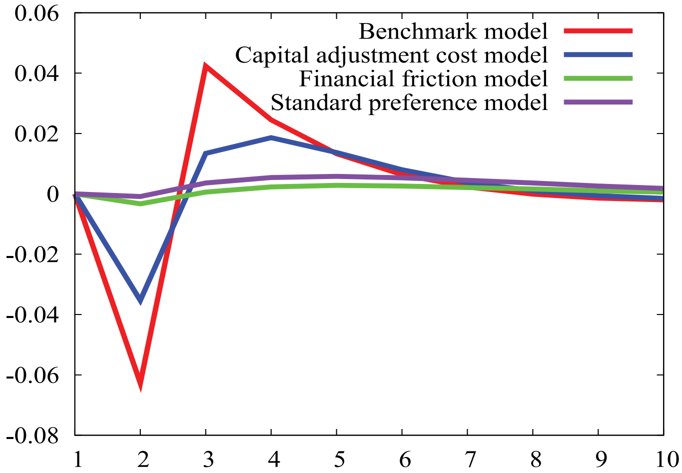


Figure 2.6: Shock to Z^N: investment

Model Comparison: Response of the Trade Balance

a: Tradable Sector Shock



b: Nontradable Sector Shock

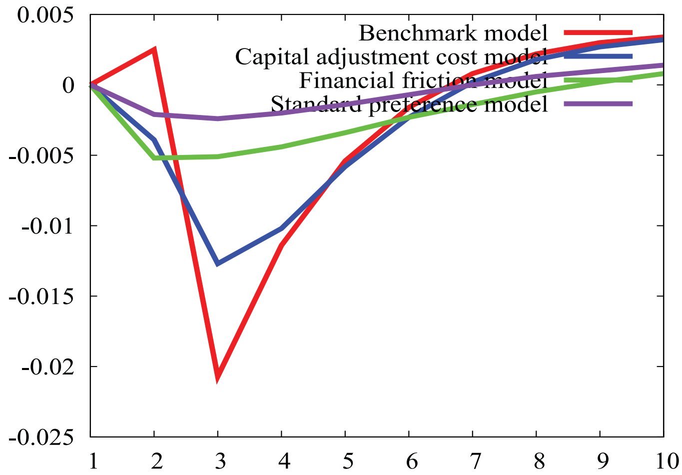


Figure 2.7: Impulse Responses: the Trade Balance

Benchmark Model

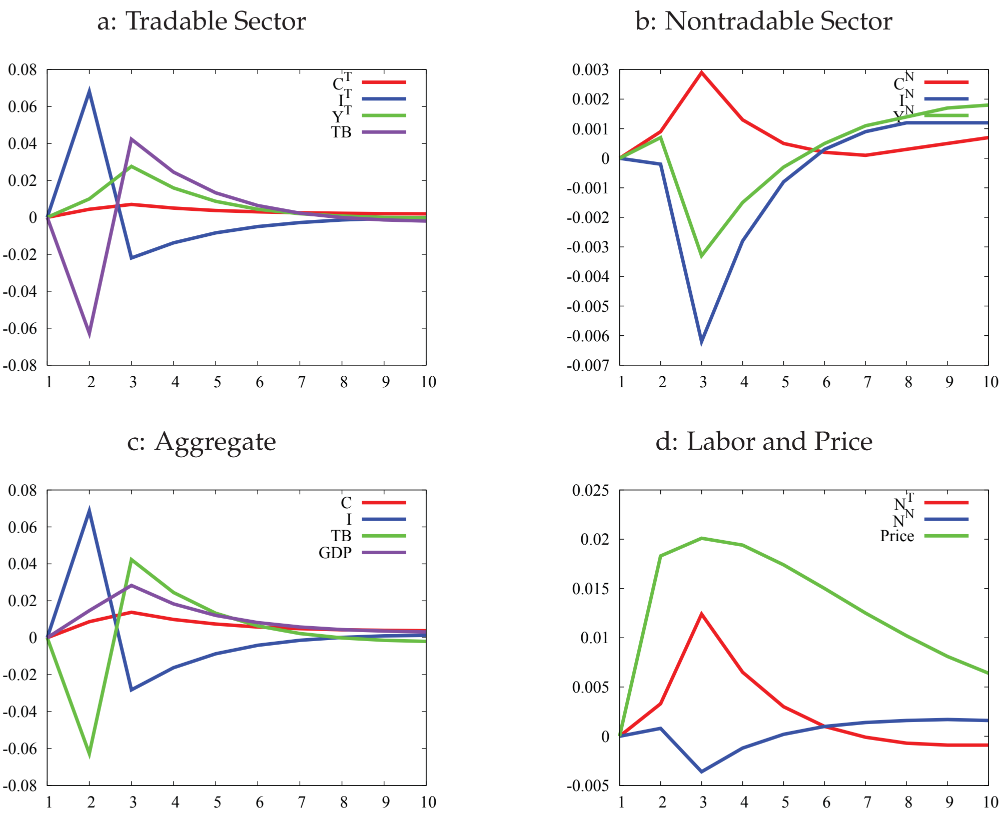


Figure 2.8: Shock to Z^T: the Benchmark Model

Benchmark Model

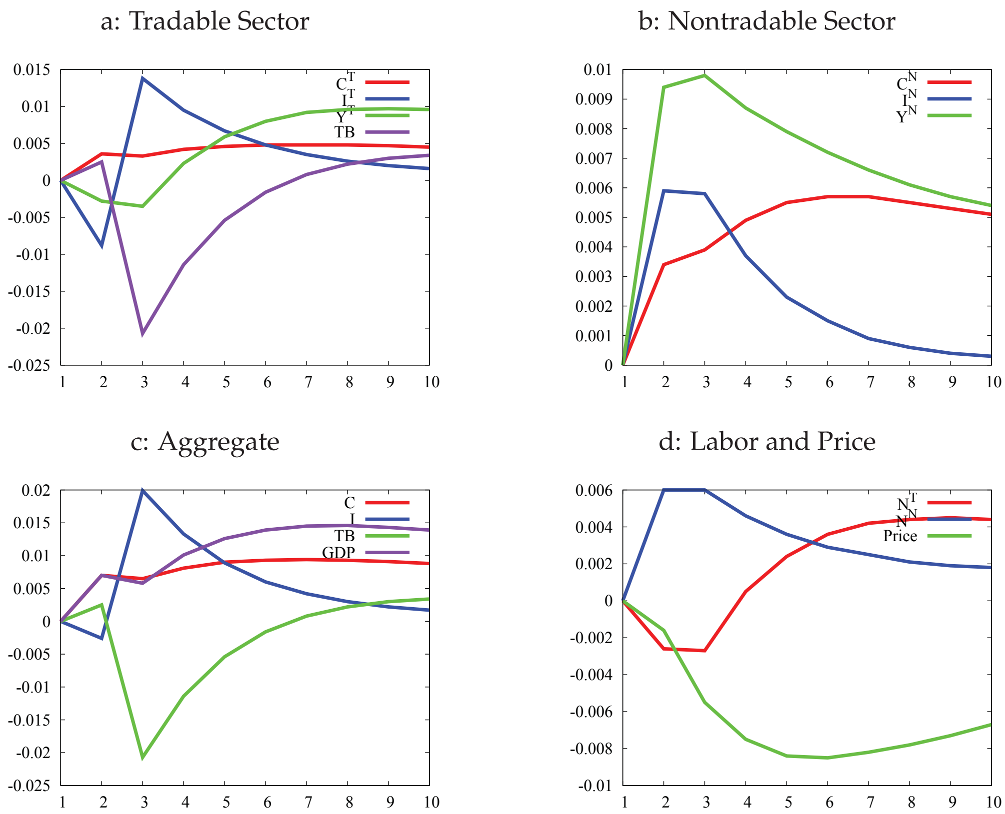


Figure 2.9: Shock to Z^N: the Benchmark Model

Model with Capital Adjustment Cost

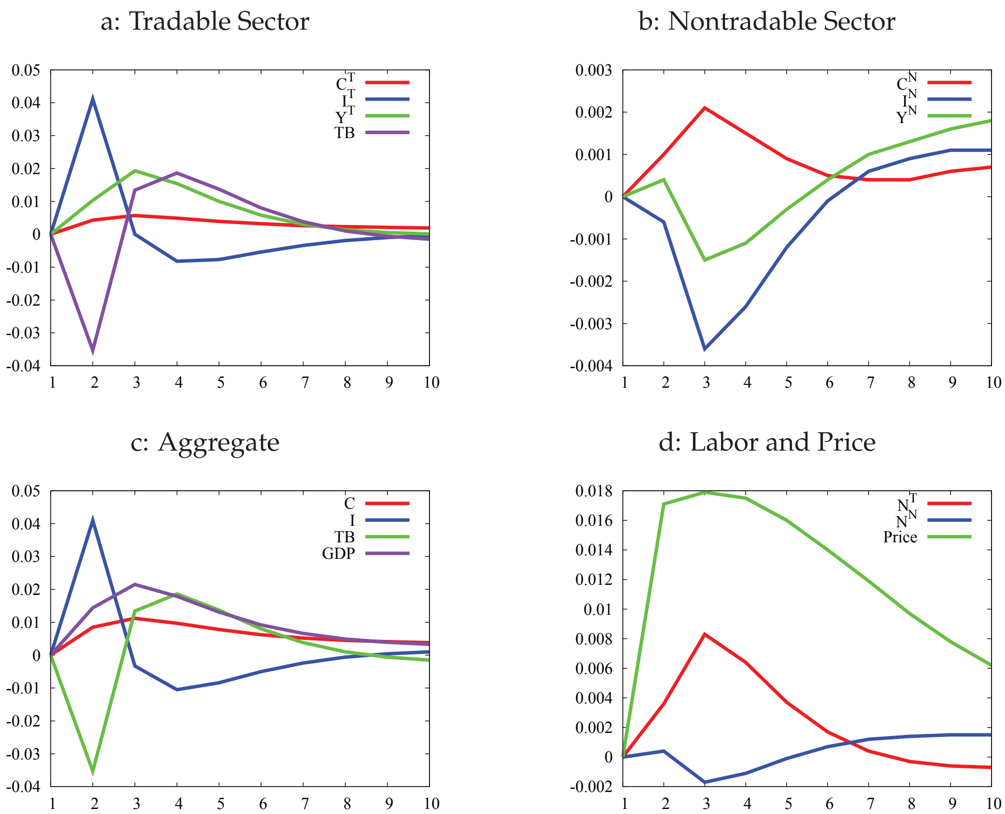


Figure 2.10: Shock to Z^T: the model with capital adjustment cost

Model with Capital Adjustment Cost

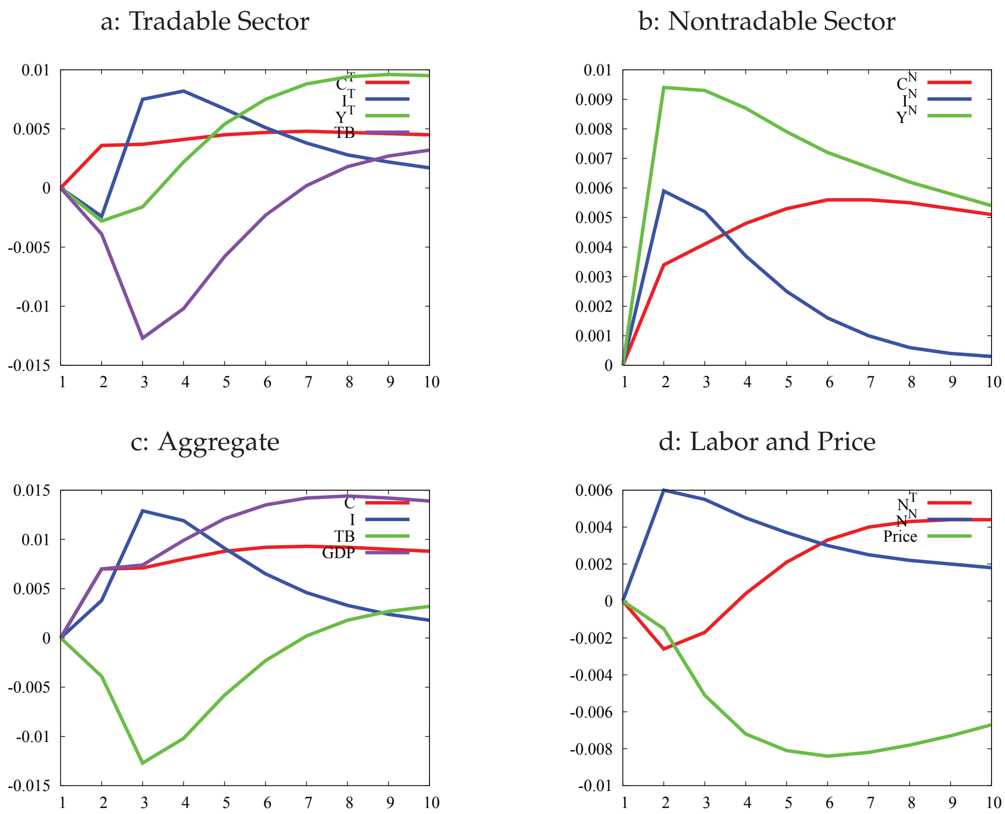


Figure 2.11: Shock to Z^N: the model with capital adjustment cost

Model with Financial Friction

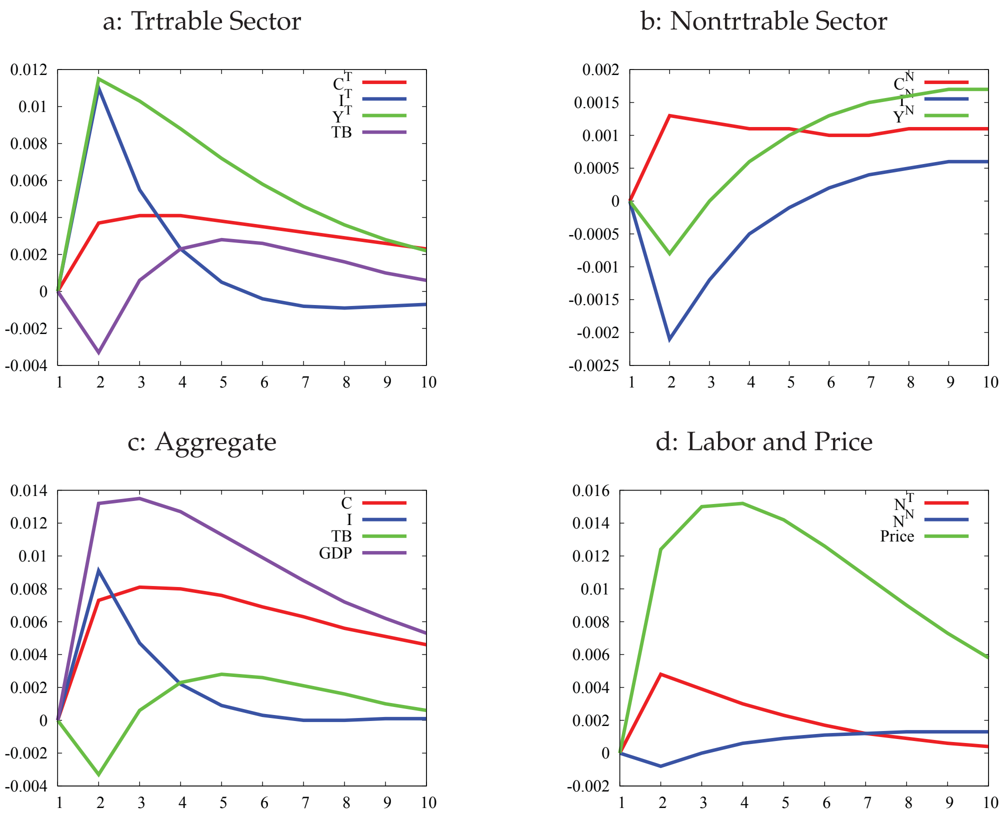


Figure 2.12: Shock to Z^T: the model with financial friction

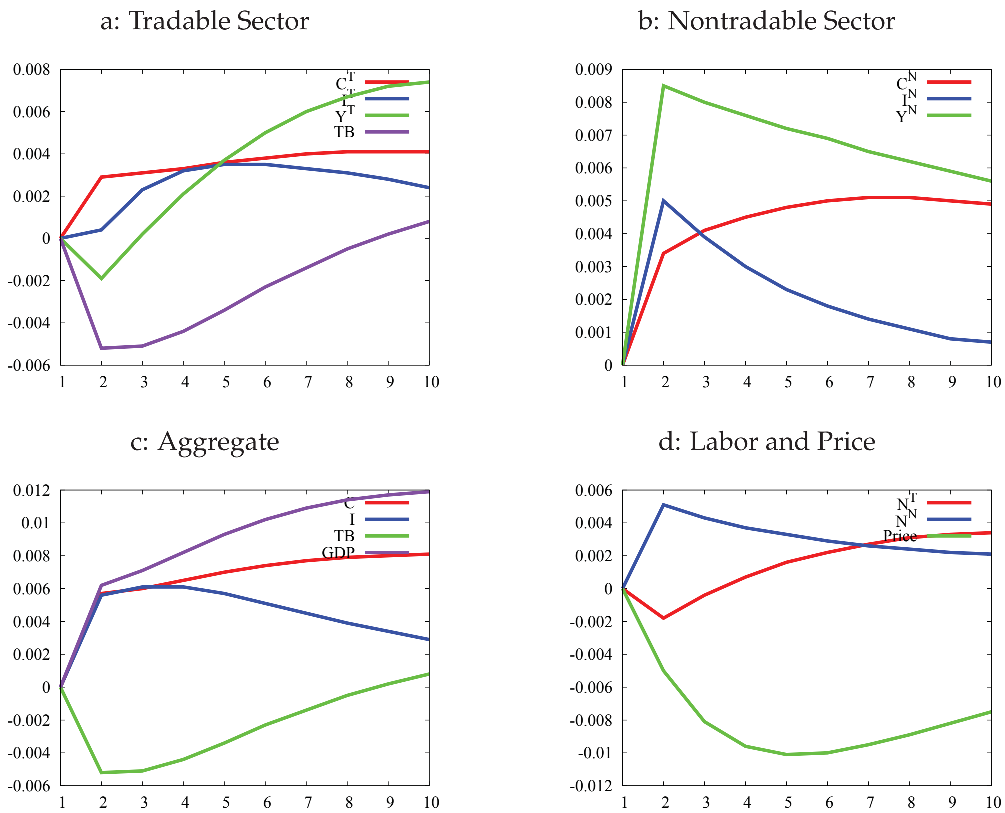


Figure 2.13: Shock to Z^N: the model with financial friction

Autarky Model

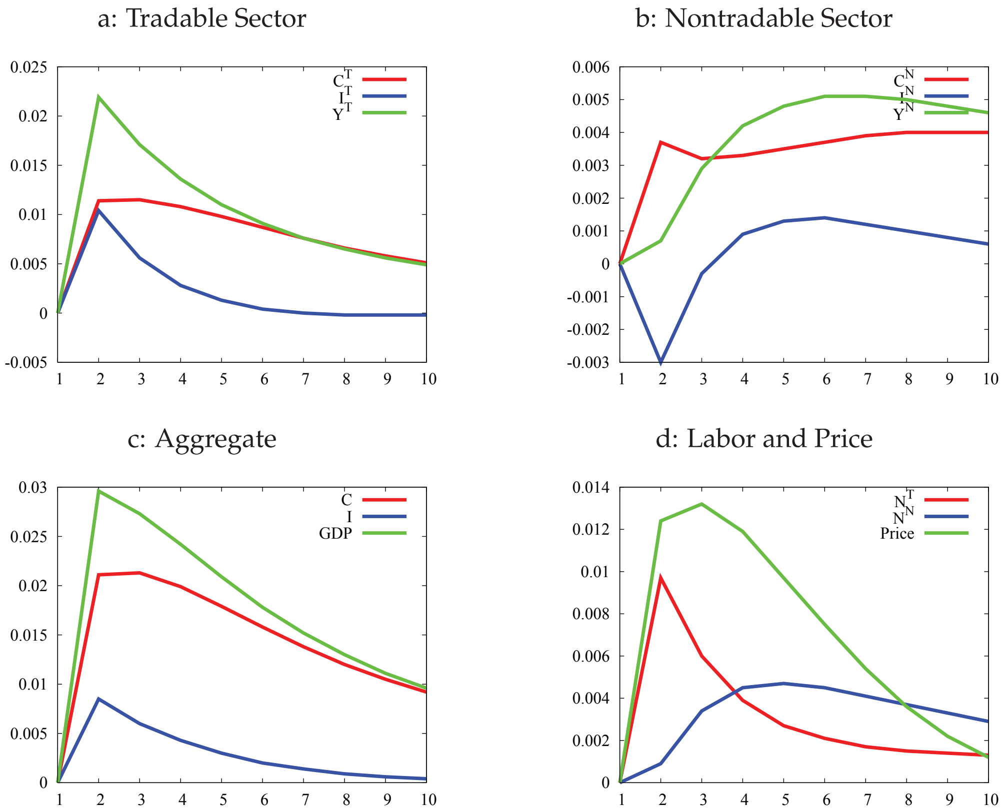


Figure 2.14: Shock to Z^T: Autarky Model

Autarky Model

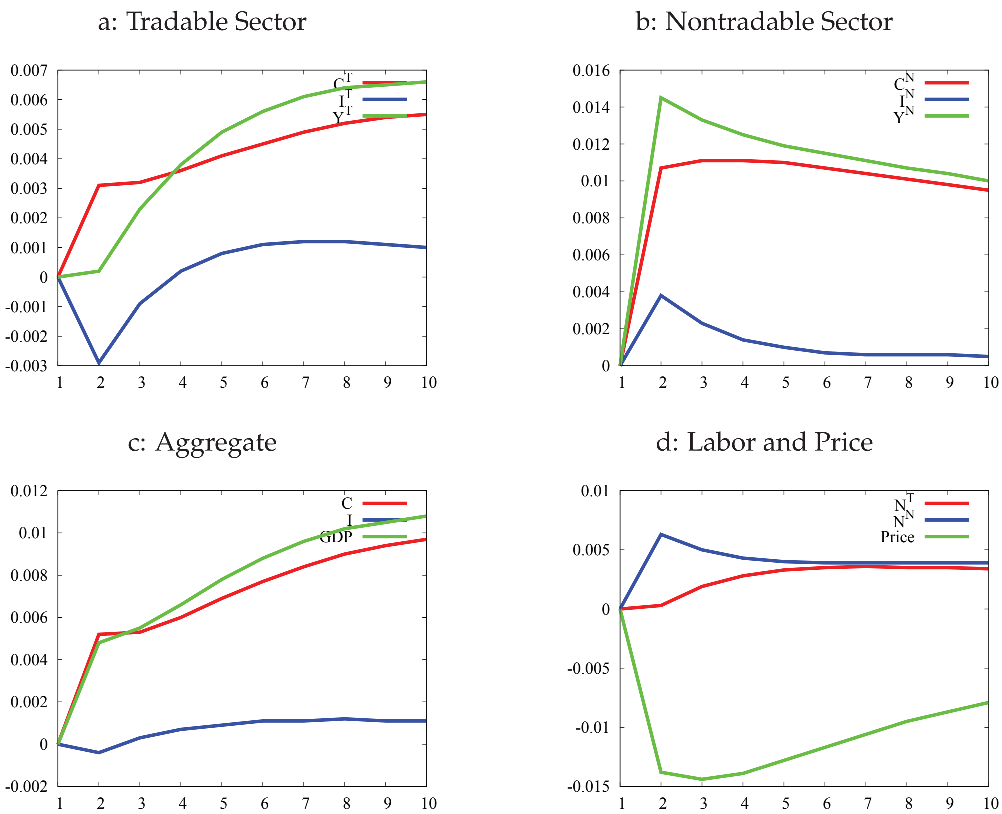


Figure 2.15: Shock to Z^N: Autarky Model

Model with Standard Preference

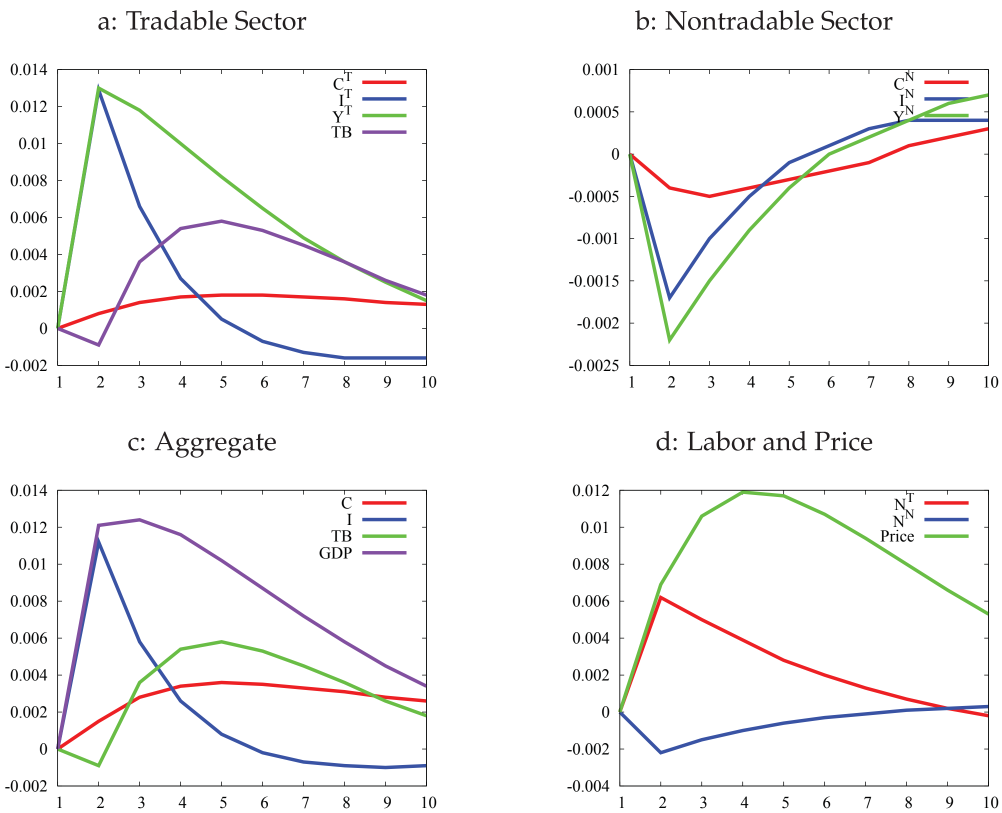


Figure 2.16: Shock to Z^T: standard preference

Model with Standard Preference

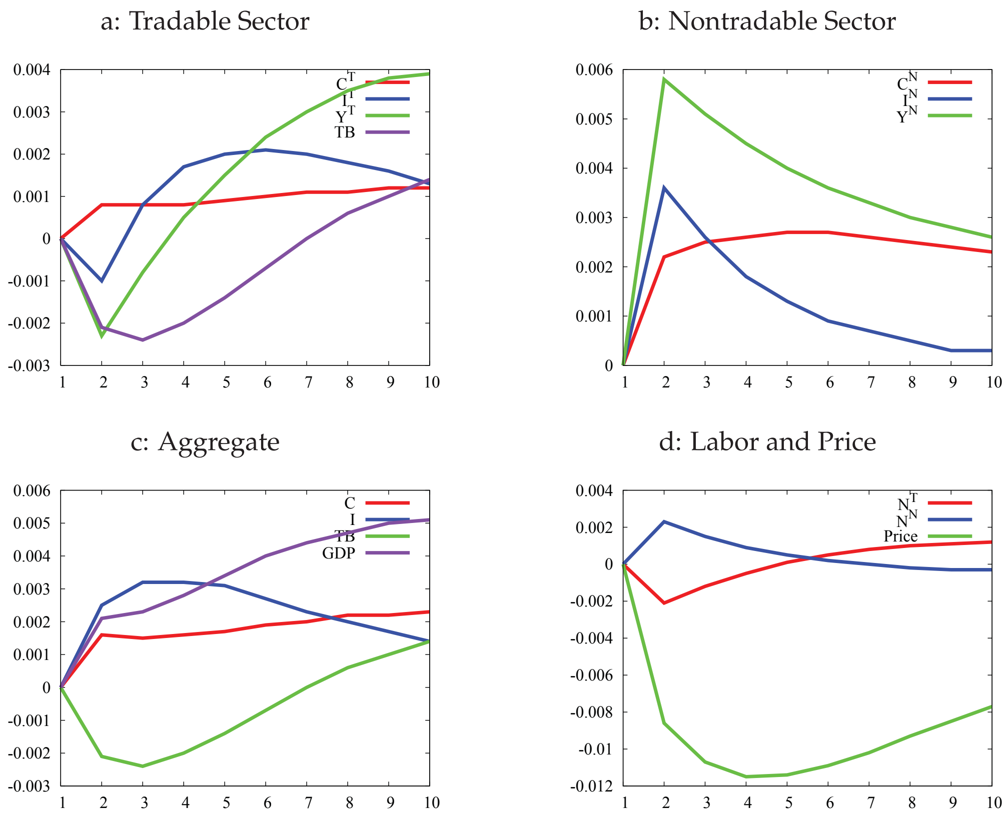


Figure 2.17: Shock to Z^N: standard preference

Chapter 3

The volatility of consumption and output with increasing industrialization

3.1 Introduction

In the business cycle literature, the notion that consumption is generally less volatile than output, is commonly known and widely accepted. Implied by the theory of consumption smoothing and supported by the data, less volatile consumption relative to output seems commonsense.

This rule, however, is not universally observed in the data. For many developing countries, such as Argentina, Brazil, Mexico, and South Africa, consumption is more volatile than output. Recently, this fact has been noticed and the related literature is growing. For example, Garcia-Cicco et al. (2010) calculate the ratio of the volatility of consumption to that of output for Argentina, $1900 - 2005$, to be 1.4; Aguiar and Gopinath (2007) find the same ratio to be

2.01 for Brazil and 1.24 for Mexico, and the average for developing countries is 1.45. The former attributes the relatively greater volatility of consumption in developing countries to preference shocks, but do not investigate the corresponding impact of the same shocks on developed countries. It cannot be argued that preference shocks cause the greater volatility of consumption relative to output in developing countries without first checking whether the same shocks cause the same or different effects in developed countries. Insofar as the effects are the same, the difference in relative volatilities remains unexplained. Insofar as they are different, and of the right size and direction, there may be an explanation, at least to some degree. The same methodology must hold for any factor proposed as a potential cause of the difference in relative volatilities, for example, productivity, literacy or mortality, and a check of the effects on each block, developing and developed, must be undertaken to establish potential causation.

Aguiar and Gopinath (2007) adopt the right methodology but concentrate on technology shocks. In their view, technology shocks are trend-growth related in developing countries, but transitory fluctuations around a stable trend for developed economies. When there is a shock on an economy, the representative agent in developed countries will not adjust consumption much because the agent knows that the shock is not permanent, with the expectation that output will return to the long-run trend. By contrast, in developing counties, the agent will adjust consumption accordingly because the shock implies a permanent change in output.

This paper seeks to explain the difference in consumption volatility across economies in general, and between developed and developing economies in particular, by first asking a fundamental question: What is the principal difference between a developed and a developing economy, and how is such difference reflected in the data of each? The principal difference is that a developed economy, which is generally in an advanced stage of industrialization, encompasses a proportionally greater market sector, while a developing economy has a proportionally greater non-market or home sector. Moreover, the available data for consumption and output generally concentrate on market activity, the home sector being ignored to a large extent. Indeed, the home sector is evidently an important component of total output, whether on the household level or the aggregate level. For example, the U.S. time-use survey indicates that market work and home work constitute 33 and 25 percent of discretionary time for a typical household. On the aggregate level, Eisner (1988) suggests that household production is between 20 to 50 percent of GNP; more recently, Blankenau and Kose (2007) argue that this ratio is 40 to 50 percent for most industrialized economies. For its importance on data, more recently, Gomme and Rupert (2007) argue that

> "For the purposes of calibration and measurement, it is useful to include a home production sector even if the specific questions being studied do not explicitly call for a home sector."

The main objective of this paper is to investigate whether the difference in consumption volatility across countries can be explained by the difference in the relative importance of home sectors. The intuition is straightforward: the home sector in developing countries is considered to constitute a bigger share in total output than in developed economies. Aggregate consumption, which includes both market produced and home produced goods, may not be as volatile in developing countries as the data suggest.

The main work concentrates on finding key differences across countries that can affect relative volatility. The various factors taken into consideration here include differences in preferences, international linkages and technology. The difference in preferences is represented by the share of market consumption in total consumption and the elasticity of substitution between market goods and home produced goods. Sensitivity analysis shows that the effect of preferences on consumption volatility is ambiguous: the relationship between the volatility of market consumption and preferences is nonlinear. When the share of market consumption or the elasticity of substitution increases, the volatility of market consumption first increases and then decreases. This suggests that consumption tends to be volatile within the moderate range, not at the extremes.

Another notable difference between the developing and developed countries is the degree of international financial integration. Developed economies have access to world financial markets with fewer constraints and smaller costs, either because of more reliable financial systems or because of the large number of financial products available. Extensively discussed, the relationship between financial markets and macroeconomic volatility is still ambiguous. Mendoza (1994) finds that changes in the volatility of consumption and output are negligible in response to changes of financial openness. Baxter and Crucini (1995) find that financial integration increases the volatility of output while decreasing the volatility of consumption. Gavin et al. (1996) study the sources of macroeconomic volatility in developing countries over the period $1970-92$, and find that there is a significant positive association between the volatility of capital flows and output volatility.

This paper contributes to this debate by investigating the relationship between financial integration and consumption's relative volatility. The degree of financial integration is modeled as the ease with which a country's foreign assets may be adjusted through lending or borrowing. The paper shows that, relative consumption volatility decreases monotonically with international financial integration. This result is consistent with conventional wisdom that financial markets help to smooth consumption through lending or borrowing.

One of the most salient differences between developed and developing countries is the disparity in total factor productivity, that is the market sector's productivity relative to the home sector. Since factors of production, like capital and labor, will flow to the sector that offers the greatest return (expressed in terms of utility), it is relative productivity, not absolute productivity, in the market and home sectors that determines the allocation of factors of production. It is generally believed that the productivity discrepancy between the two sectors is larger in the developed economies, for two reasons. First, one characteristic of developed economies is economies of scale, which typically occurs in the advanced stage of the process of industrialization. Developing countries lag behind in this process. Second and more important, developed economies characteristically invest more funds in research and development, the primary source of production enhancement. Even when measured as a percentage of GDP, the top eight countries are all from the developed group. [1]

Not only is the discrepancy in productivity levels different across countries, the technology transmission between sectors is also not the same. It is assumed that technology can only be transmitted from a more advanced sector to less advanced sectors, namely from the market sector to the home sector in this paper. For developed economies, advanced technology and sophisticated equipment are common in the market sector, and such equipment is virtually unattainable for households. Thus even when there is technological innovation in the market

[1] According to OECD, the top eight are Israel (4.53%), Sweden (3.73%), Finland (3.45%) Japan (3.39%), South Korea (3.23%), Switzerland (2.9%), Iceland (2.78%) and the United States (2.62%).

sector, it is difficult to adopt such innovation in the home sector. For developing economies, where domestic workshops are common, the situation is different; technological innovation in one sector will be applicable to the other sector. The paper shows that, the less productive the market sector is relative to the home sector, and the stronger the transmission effect, the more volatile market consumption(relative to market output) will become. Moreover, the volatility of market consumption varies to a greater extent with technology than with preferences and the international linkage; further changes to production are the only way to generate more volatile consumption, which implies that technology is the driving force for excess volatile consumption in many developing countries.

The structure of the paper is as follows. The next section, Section 2 sets up a two sector model; Section 3 calibrates the parameters and provides the simulation results for the benchmark economy; Section 4 undertakes sensitivity analysis, in which differences in preferences, production and the international linkage are presented and their effects on the volatility of consumption are analyzed. Section 5 summarizes the conclusions of this paper.

3.2 The Economic Environment

3.2.1 Preferences

In a small open economy, the infinitely lived representative agent derives utility from streams of a composite good c_t, and disutility from working n_t. The agent's preferences are summarized by:

$$E_0 \sum_{t=0}^{\infty} \theta_t U(c_t, n_t) \tag{3.1}$$

$$\theta_0 = 1 \tag{3.2}$$

$$\theta_{t+1} = \beta[U(c_t, n_t)]\theta_t \tag{3.3}$$

where θ_t is the endogenous discount factor, β is a function of past utility with the restriction that its first-order derivatives are negative, $\beta' < 0$. [2] This restriction implies that the more people consume, the less patient they become. Any increase in current consumption reduces the subjective discount weight of all future periods.

In the small open economy literature, the functional form for preferences receives particular attention. The standard form for utility generally fails to produce a counter-cyclical trade balance, one of the stylized facts for open economies. The GHH utility, first proposed by Greenwood et al. (1988), performs better and is widely adopted in open economy models. Moreover, Chapter 1 shows that, in a two sector model, standard preferences lead to macroeconomic volatility, especially for consumption. For the purpose of concentrating on consumption volatility in this paper, the GHH form is preferred. GHH preferences have the form

$$u(c_t, n_t) = \frac{[c_t - \mu \frac{n_t^{\omega}}{\omega}]^{1-\gamma}}{1-\gamma} \tag{3.4}$$

in which aggregate consumption c_t consists of market goods c_t^m and home-produced goods c_t^h, and

$$c_t = [\pi(c_t^m)^{\frac{\rho-1}{\rho}} + (1-\pi)(c_t^h)^{\frac{\rho-1}{\rho}}]^{\frac{\rho}{\rho-1}} \tag{3.5}$$

n_t in equation (4.3) is the sum of working time in the market sector n_t^m, and the home sector n_t^h:

$$n_t = n_t^m + n_t^h \tag{3.6}$$

[2] The endogenous discount factor is to overcome the indeterminacy problem, see Mendoza (1991) and Schmitt-Grohe and Uribe (2003) for details.

Finally μ in equation (4.3) is the weight in preferences on labor supply, ω is the elasticity of labor supply, and γ denotes risk aversion. In equation (3.5), π is the weight given to market consumption, and ρ is the elasticity of substitution between market produced goods and home made goods. Accordingly, the functional form of β is

$$\beta(c_t, n_t) = (1 + c_t - \mu \frac{n_t^{\omega}}{\omega})^{-b} \tag{3.7}$$

where b is the elasticity of discount factor.

3.2.2 Technology and investment

The production function for each sector has the standard form:

$$y_t^i = exp^{z_t^i} (k_t^i)^{\alpha^i} (n_t^i)^{1-\alpha^i}, \quad i = m, h \tag{3.8}$$

where in sector i, k_t^i is the capital stock, n_t^i is the labor supply, α^i is capital share in output and z_t^i is the sector specific technology shock with mean $\bar{z}^i$.

Let z_t be the 2×1 vector $[z_t^m, z_t^h]'$ with mean $\bar{z}$. Productivity shocks evolve according to,

$$z_t = \nu * z_{t-1} + (\mathcal{I} - \nu) * \bar{z} + \epsilon_t, \tag{3.9}$$

where $\mathcal{I}$ stands for the identity matrix, and $\epsilon_t = [\epsilon_t^m, \epsilon_t^h]'$ denotes the error terms with correlation coefficient $\xi = corr(\epsilon_t^m, \epsilon_t^h)$. The matrix ν is of the form,

$$\nu = \begin{bmatrix} \rho_{mm} & \rho_{mh} \\ \rho_{hm} & \rho_{hh} \end{bmatrix}$$

where diagonal elements ρ_{ii} denote the technology persistence, off-diagonal elements ρ_{ij} stand for the technology spill over from sector j to sector i.

The law of motion for capital in sector i is

$$k^i_{t+1} = (1 - \delta^i)k^i_t + x^i_t, \tag{3.10}$$

where for sector i, δ^i is the capital depreciation rate, and x^i_t is investment. As is common in the home production literature, it is assumed that home made products are used only for consumption. Thus investment can be formed only from market sector products. It is also assumed that a cost occurs to capital adjustment: the more rapid adjustment, the greater this cost. Capital adjustment cost is modeled as $\frac{\phi^i}{2}(k^i_{t+1} - k^i_t)^2$, and ϕ^i is the the capital adjustment cost parameter.

3.2.3 Linkage to international markets

In this small open economy, the representative consumer can export goods to accumulate foreign asset holdings, or import goods to finance domestic spending, with the restriction that only market sector goods can be exported or imported. Together with the condition that home produced goods can not be invested, this implies

$$y^h_t = c^h_t. \tag{3.11}$$

It is further assumed that whenever borrowing or lending, this consumer faces a fixed international interest rate r^*. Let tb_t denote the trade balance in period t, and d_t stand for the foreign asset (or debt) holdings, then

$$d_{t+1} = (1 + r^*)d_t + tb_t. \tag{3.12}$$

Since the ease of lending and borrowing reflects the degree of financial integration, it is appropriate to employ a cost, which depends on the amount of borrowing or lending, to represent the financial openness of a country. Specifically, this borrowing or lending cost is approximated as a quadratic function of trade balance, $\frac{\tau}{2}tb^2$. Backus et al. (1992) call this cost a trading cost. Whereas tb_t is the net of exports and imports, this term $\frac{\tau}{2}tb^2$ is called a financial friction in this paper.

Accordingly, the resource constraint for the market sector is,

$$c_t^m + d_{t+1} + x_t^m + x_t^h = y_t^m + (1+r^*)d_t - \frac{\tau}{2}tb_t^2 - \frac{\phi^m}{2}(k_{t+1}^m - k_t^m)^2 - \frac{\phi^h}{2}(k_{t+1}^h - k_t^h)^2. \tag{3.13}$$

Finally, neither the home country nor the foreign country can play a Ponzi-game, which implies:

$$lim_{T\to\infty}(1+r)^{-T}d_{t+T} = 0. \tag{3.14}$$

3.3 Calibration and Simulation

As stated in the introduction, the methodology of this paper concentrates on the differences between developed and developing countries, to identify the factors which explain consumption volatility. There is, however, no unanimous agreement on how to categorize a country as either developed or developing. Even in the same group, the level of development may vary widely. Therefore the difference across groups might become less apparent if averaged by groups. For this reason, it is, perhaps, more illustrative to focus on two countries, one representing the developed group and the other representing the developing group, than to average data from each of the groups. For data convenience and convention, Canada and Mexico, two typical small open economies, are chosen to represent each group respectively.[3]

For the market sector in Canada, the share of labor income is calculated to be

[3]Data source: Statistics Canada & OECD.

68% from the year 1961 to 2008. Accordingly, the capital share in production, α^m, is set to be 32%. For Mexico, since there is no income based GDP data available, this number is also set as 32%. For the home sector, the data is scant for both countries. It is assumed that the home sector is more labor intensive, so labor share lies in the range $[.68, 1.00]$. In particular, the labor shares in the home sector for both countries are set as 86%, the middle value of this range, and this suggests that the capital share in home sector is 14%. This value is also adopted in Ingram et al. (1997).

Capital depreciation rates in the market sectors, δ^m, are calculated to be 2.2% for Canada (see Chapter 1), and 2% for Mexico (see Garcia-Cicco et al. (2010)). Since capital formation in the home sector comes from the market sector, it is assumed that $\delta^m = \delta^h$ for simplicity. This symmetric treatment also applies to the capital adjustment cost parameters, ϕ^m and ϕ^h, which are assumed to be equal, and their magnitude is calibrated to match with the volatility of market investment.

For the share of market sector goods in total consumption, π, and the elasticity of substitution between the two goods, ρ, there are no available measurement. Various papers estimate that the share is around 40%, while the elasticity is 2 for the United States (Ingram et al. (1997); Blankenau and Kose (2007)). Canada and United States are both developed countries, and the two countries share many common consumption habits, therefore it is reasonable to use the same number for Canada. For Mexico, the market share in consumption is intuitively smaller. For developing countries, market goods are not prevalent, and the relative price is high. Nevertheless, it is set to be the same as in Canada for the benchmark economy, and sensitivity analysis on these two parameters will be conducted in the following section.

As in most papers in the related literature, the international real interest rate, r^*, is set to be 1 percent, suggesting that β in steady state is 0.99. The parameter ω is set at 1.6, implying that the labor supply elasticity $1/(\omega - 1) = 1.7$. The two parameters, μ and b are jointly determined to meet two ratios: the fraction of time spent working, and the trade balance to GDP. For time spent working, this is set as 61%, the same for both countries, in which 33% goes to the market sector and 28% is spent in the home sector (see Benhabib et al. (1991)). For the trade balance ratio, the number is calculated to be 1.6% for Canada and 1.25% for Mexico. The risk aversion parameter, γ, is widely regarded to lie in the range of 1 to 2, and it is set to be 1.5, the middle value of this range.

For τ, the financial friction parameter, this is chosen so that the marginal cost τtb is 0.58 percent of GDP as in Backus et al. (1992). This implies that $\tau = \frac{0.58\%}{tb/GDP}$. As mentioned earlier, since this parameter represents one key difference across countries, a reasonable guess is that it indeed varies from country to country.

To estimate the matrix V describing the technological process, the first step is to find the Solow residuals in the two sectors. Solow residuals in the market sectors can be obtained with the available series of output, capital and hours worked. The Solow residual in the home sector, however, is virtually impossible to compute for lack of data, especially for home hours. Three approaches have been proposed to overcome this problem. The first is to estimate the parameters in an $AR(1)$ process of the Solow residuals by maximum likelihood to match with moments in the data as proposed by McGrattan et al. (1997). The second is to recover output, the capital stock and hours worked in the home sector from the first order conditions of the model, and then compute the Solow residual, as was originated by Ingram et al. (1997). The third approach is to assume the shock in the home sector has the same process as that of the market sector as in Gomme et al. (2001). For simplicity, this paper adopts the third approach. Thus, the diagonal elements in matrix V are identical, $\rho_{mm} = \rho_{hh}$.

For the off-diagonal elements, ρ_{mh} and ρ_{hm}, it is assumed that the technology spill over effect is asymmetric: technology can only spill from more advanced sectors to less advanced sectors. The market sector is relatively efficient by assumption, and therefore there is no spill over from home sector, implying that $\rho_{mh} = 0$. In contrast, ρ_{hm} represents the spill over effect from the market sector to the home sector, and is assumed to be positive. It is further assumed that spill overs are only partial, implying that ρ_{hm} is within the range $[0, 1.0]$. The value of this parameter is to set to match with the consumption volatility ratio in the market sector. For Mexico, this value is 0.90, and for Canada it is 0.52. It is worth noting that the spill over effect may vary across countries. It is easier for technology to spill to sectors with similar levels of development, or TFP. In particular, if the gap between the market sector and the home sector is big, this effect will be limited. Another reason for the stronger transmission effect in emerging countries is the lack of patent protection. Therefore in emerging economies, it is less costly to adopt the new technology, which typically developed in the advanced sector. [4] For this reason, ρ_{hm} is of particular interest in the sensitivity analysis. $\xi = corr(\epsilon^m, \epsilon^h)$, and its value is set at 0.6, as suggested by Blankenau and Kose (2007).

The last parameter to be set is the technology level in both sectors, $\bar{z}^m$, and $\bar{z}^h$. By normalizing $\bar{z}^h = 1$, $\bar{z}^m$ represents the relative technology advantage in the market sector. The relative technology advantage varies across countries.

[4]The transmission effect discussed here should be described as *effective transmission* rather than *potential transmission*. When the technology discrepancy is big, the available transmission may be potentially large but the effect is limited because it may need adjustment for other production factors such as capital and labor. That is, it is easier for a sector to assimilate technology from similar sectors.

For extremely underdeveloped economies, where family workshops are being transformed to factories in the early stage of industrialization, it is expected that relative technology is just above unity. With the development of technology and the expansion of markets, which are characteristic of further industrialization, established factories or firms may have additional economies of scale and the technology advantage will grow. Therefore, it seems plausible that the relative technology advantage is bigger in developed economies. [5] Although it is not possible to obtain an exact value to conduct the simulation in the benchmark model, the market sector is set to be three times as productive as the home sector for Canada, and 1.5 times for Mexico. These values imply that $\bar{z_m} = 1.1$ for Canada and $\bar{z_m} = 0.4$ for Mexico. The relative technology advantage is perceived to represent one of the major differences between developed and developing countries, and so it is necessary to perform sensitivity analysis in the following section.

Table 3.1: Relative Volatility

Country	Data: $\frac{\sigma_{cm}}{\sigma_{ym}}$	Model: $\frac{\sigma_{cm}}{\sigma_{ym}}$	Model: $\frac{\sigma_c}{\sigma_y}$
Canada	0.67	0.67	0.59
Mexico	1.21	1.21	0.97

The parameter values are summarized in Table 4.2. With the parameters set in the benchmark economy, the ratio of market consumption volatility to market output volatility, $\frac{\sigma_c}{\sigma_{ym}}$ is 0.53 for Canada, less than the corresponding ratio in the data which is 0.67. For Mexico, this ratio is 0.803, which is also less

[5] Gollin et al. (2002) examined data for the 1960-90 period for 62 countries and found that the share of employment in agriculture is negatively correlated with the relative technology advantage. The share of agriculture employment in Mexico is bigger than that in Canada. Agriculture is an analogue to home sector at the start of industrialization, thus Gollin et al. (2002)'s result support the claim that $\bar{z_m}$ is greater in Canada.

than in the data at 1.21, as shown in Table 3.1. Nevertheless, the benchmark model generates higher relative volatility in market consumption in Mexico, which suggests that adding home sector in the model is in the right direction to explain the puzzle. It is worthy noting that the *aggregate consumption* is less volatile than *aggregate output* in the model, although the market consumption is more volatile than market output in the data.

Table 3.2: Calibration Summary

Parameter	Description	Canada	Mexico
ω	labor supply elasticity	1.60	1.60
μ	adjustment parameter of labor supply	0.99	0.99
γ	measure of risk aversion	1.5	1.5
$r^{\star}$	risk free international interest rate	0.01	0.01
π	share of market goods in consumption	0.40	0.40
ρ	elasticity of substitution between c^m and c^h	2	2
α^m	capital share in market production	0.32	0.32
α^h	capital share in home production	0.14	0.14
δ^m, δ^h	capital depreciation	0.02	0.02
τ	Financial friction parameter	0.36	0.46
ν	matrix of technological spill over	$\begin{bmatrix} 0.97 & 0.00 \\ 0.00 & 0.97 \end{bmatrix}$	$\begin{bmatrix} 0.95 & 0.00 \\ 0.50 & 0.95 \end{bmatrix}$
ξ	correlation coefficient of technology shocks	0.6	0.6
$\bar{z}^m$	relative technology advantage of the market sector	1.10	0.40
σ^m, σ^h	standard deviation of technology shock	0.0063	0.0073

3.4 Further Discussion

3.4.1 Sensitivity analysis

As shown in the calibration there is some uncertainty concerning the values of some parameters either because of a lack of data or of related empirical studies. Notwithstanding this uncertainty, these parameters were set to some particular ad hoc values for simulation purposes. The ranges for most of these parameters, however, can be determined from economic theory or stylized facts. Performing a sensitivity analysis gives some feel for how the results vary with these parameters.

More importantly, some of the parameters vary across countries, and represent some of the key differences between developed countries and developing countries. As discussed earlier, the methodology of this paper is to identify these differences and see which of them contributes to the excessive consumption volatility in developing countries. Therefore, performing sensitivity analysis is essential to determine the factors which contribute to the difference in consumption volatility between developed and developing economies.

Developing countries differ from developed countries in many aspects including preferences, production and international linkages. The difference in preference is represented by the share of market consumption, π, and the elasticity of substitution, ψ. The difference in international linkages is embodied in τ, the ease of access to foreign financial markets. As for different levels of production, this is indicated by ρ_{hm}, the technology transmission from the market sector to the home sector, and $\bar{z}^m$, the relative technology advantage in the market sector.

The share parameter of market consumption is set at 40 percent for both

Mexico and Canada in the benchmark economy. The home-sector produced goods (and services) in emerging countries, however, are considered to have a bigger share in total consumption. The main reason is that when the market sector is not prevalent, the price of market goods is high. For example, professional day care and old care institutions in some developing countries are rare, and these services are mostly offered at home. π is within $[0.0, 1.0]$, and the binary relationship between $\frac{\sigma_{cm}}{\sigma_{ym}}$ and π is plotted as Figure 3.1, with all other parameters fixed in the benchmark model for Mexico. Figure 3.1 indicates that as the share of market consumption increases, its volatility first increases and then decreases. Specifically, market consumption becomes volatile when this share is around half.

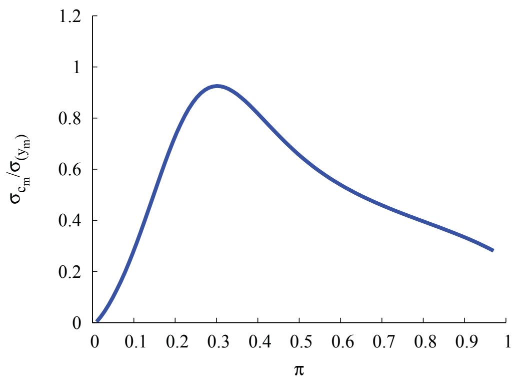


Figure 3.1: π and $\frac{\sigma_{cm}}{\sigma_{ym}}$

Another factor that represents the difference in preferences is the elasticity of substitution, ψ. The simulation results are presented in Figure 3.2, which also suggests that the relationship between $\frac{\sigma_{cm}}{\sigma_{ym}}$ and ψ is nonlinear, with a peak around $\psi = 2$. Careful examination of Figures 3.1 and 3.2 reveals that the maximum consumption volatility $\frac{\sigma_{cm}}{\sigma_{ym}}$ is less than unity, suggesting that the difference in preference is not the main cause for excessive consumption volatility in developing countries.

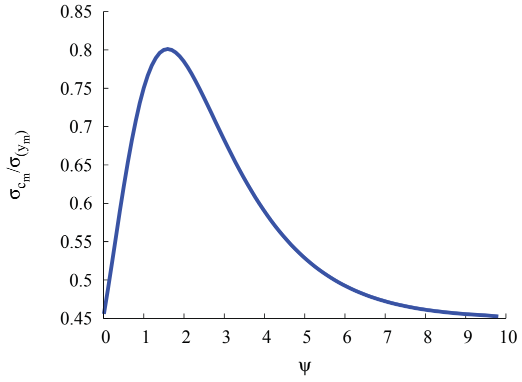


Figure 3.2: ψ and $\frac{\sigma_{cm}}{\sigma_{ym}}$

τ is the parameter that represents ease of international asset adjustment. Developed countries can access the international finance markets more easily owing to their more transparent financial system and sound financial position. Developing countries, on the other hand, may have to pay an extra cost to enter into the foreign capital market when lending or borrowing, particular during a financial crisis. Figure 3.3 illustrates that the relative volatility of market consumption increases with the financial friction parameter τ. However, the effect of financial friction is limited: when τ varies from 0 to 45, 100 times as the benchmark value, $\frac{\sigma_{cm}}{\sigma_{ym}}$ changes less then 10 percent.

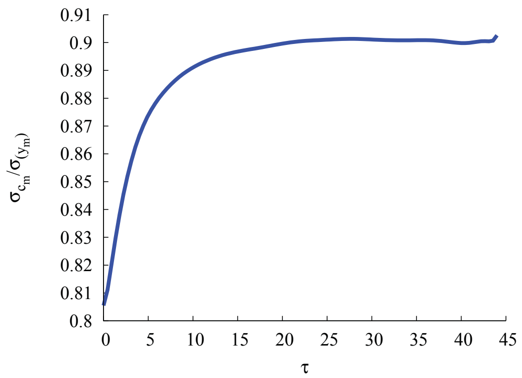


Figure 3.3: τ and $\frac{\sigma_{cm}}{\sigma_{ym}}$

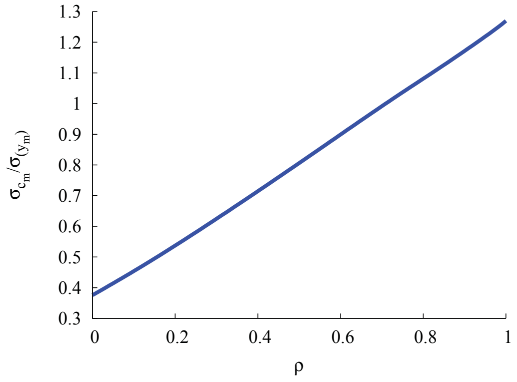


Figure 3.4: ρ_{hm} and $\frac{\sigma_{cm}}{\sigma_{ym}}$

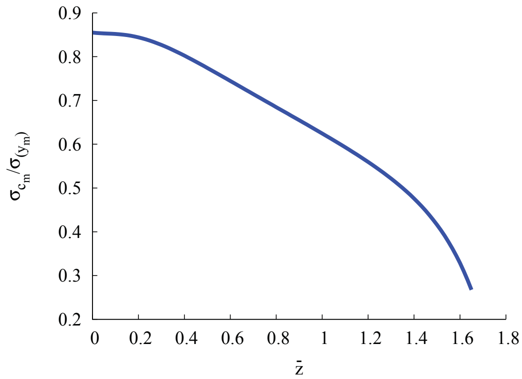


Figure 3.5: $\bar{z}^m$ and $\frac{\sigma_{cm}}{\sigma_{ym}}$

The sensitivity analysis on differences in production is presented in Figure 3.4 and 3.5. Figure 3.4 indicates that when the transmission effect gets stronger, volatility of market consumption becomes larger. As discussed earlier, the transmission effect (from the market sector to the home sector) is bigger when the productivity gap between sectors is closer, as it is in developing countries.

The productivity gap between the two sectors is indicated by $\bar{z}^m$, and Figure 3.5 suggests that a more productive market sector leads to smoother market consumption. Further investigation reveals that the maximum volatility exceeds unity in Figure 3.4, and $\frac{\sigma_{cm}}{\sigma_{ym}}$ varies more than in Figure 3.1, 3.2 and 3.3, implying that a difference in technology is the main cause for excess consumption volatility in developing countries.

3.4.2 Benchmark discussion

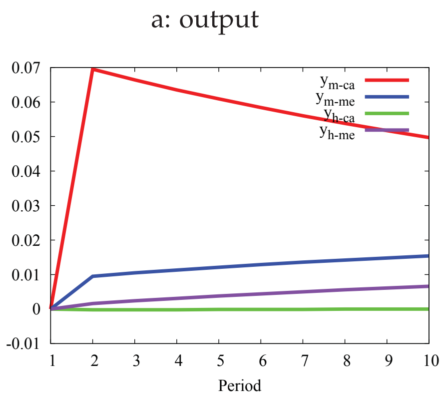
In Canada, the relative volatility of market consumption is lower because its market sector is much more important, or dominant. This dominance results from the relative technology advantage in the market sector. Market sector's status calls for particular consumption smoothing incentives for market consumption. [6]

In Mexico, the market sector is not dominant. The main reason for this is the relative small technology level difference across sectors, i.e., market sector in Mexico has not developed enough to make home sector trivial. As a result, the market sector consumption is not smoothed as in Canada.

The impulse responses suggest that, for one shock that hits the market sector in Canada, the market sector expands and the home sector shrinks in that $y_h(c_h)$ decreases. In contrast, for the same shock in Mexico, because of the stronger technology transmission effect, both sectors expands. Actually, the home sector in Mexico changes more than 20 times in absolute value of the change in Canada.

Also, because of the stronger transmission effect, consumption in Mexico increases to a greater extent because the agent knows that the positive shock is more persistent. The consumption change in Canada is small relative to output, reflecting that consumption smoothing is strong with the expectation the shock is more transitory.

[6] In the extreme case where home sector is nil, the two-sector model reduces to a standard one-sector model with $\frac{\sigma_c}{\sigma_{ym}} < 1$.



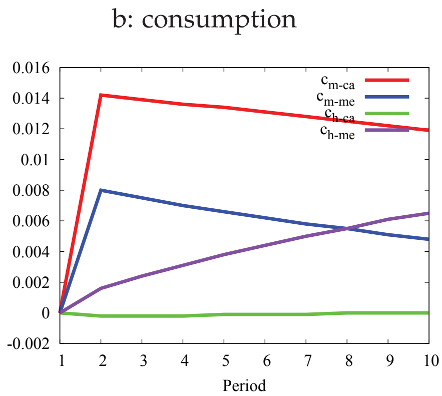


Figure 3.6: Shock to z_m: Output and Consumption

3.5 Conclusion

This paper offers an explanation for why consumption is generally less volatile than output in developed countries, while it tends to be more volatile than output in developed countries. By constructing a two sector small open economy model, this paper proposes for the first time that a relatively large home sector, characteristically found in developing countries, can explain this phenomenon.

The methodology of the paper has been to extract different factors across countries and examine which of them generates excessive volatility of market consumption relative to market output under reasonable conditions. These factors include differences in preferences, technology and international linkages.

For differences in preferences, the simulation results suggests that their effect on the relative volatility of consumption is ambiguous. For both the share of consumption and the elasticity of substitution, the volatility of consumption first increases and then decreases, implying that market consumption tends to be most volatile when preferences for market and home goods are relatively moderate.

For differences in international linkages, this paper refers to frictions in international financial transactions, which is modeled as an adjustment cost on foreign assets. The results suggests that financial openness helps to smooth market consumption. This effect, however, is limited in that the variation in consumption volatility is relatively small.

As to the differences in technology, these are embodied in two factors: one is the market sector's relative productivity and the other is the technology transmission effect across sectors. The sensitivity analysis indicates that the more advanced is a market sector, or the less effective the transmission effect, both of which correspond to the group of developing countries, the smoother will be market consumption. The volatility of consumption exceeds that of output when technology varies, and it is more sensitive to changes in technology, suggesting that differences in technology are the main cause for excessive volatility in consumption in some countries.

The conclusion that technology is the driving force for the relative volatility of consumption predicts that volatile market consumption is almost inevitable at the start of industrialization, when the technology level in the market sector is just above that of the home sector. With the advancement of the market sector, its consumption will become less volatile. For this reason, relative volatility of market consumption could be regarded as an indicator to assess a country's stage of economic development.

Since excessive volatility leads to a welfare loss, the paper has significant implications. First, it is implied that the international financial integration helps to smooth consumption. Second and more important, it is also implied that technology enhancement is vital to reduce the excessive volatility in consumption. Therefore, investment in R&D may be an effective way to gain smoother consumption.

Chapter 4

Borrowing constraints and the trade balance-output comovement

4.1 Introduction

The dynamics of the trade balance is one of the most important research topics in international economics. As the net of exports and imports, the trade balance reflects the terms of trade for one country within a period. The trade balance has a direct effect on the exchange rate and the level of the national debt. As world economies become more and more integrated, the trade balance also has a substantial effect on almost all macroeconomic variables, including economic growth, the level of output, economic fluctuations and unemployment ratio. For this reason, it draws wide public attention and the research on it has never waned.

While extensively discussed in various papers including Mendoza (1991), Backus et al. (1992), Correia et al. (1995), Blankenau et al. (2001), and Letendre (2004), there are, however, still some properties of the trade balance that have yet to be investigated. Most of these existing studies focused on the countercyclical behaviour regarding the trade balance.[1] Further examination of the trade balance across countries reveals not only that it is countercyclical for almost all open economies, but also it varies largely from country to country. In particular, the trade balance is more negatively correlated with GDP in emerging countries than in developed countries. As shown in Table 4.1, Aguiar and Gopinath (2007) document that the average of this correlation coefficient is -0.51 for developing countries, and -0.17 for developed countries, indicating that the comovement between trade balance and GDP is stronger in the former group.[2]

Table 4.1: $corr(tb1_t, y_t)$ across countries

Emerging countries		Developed countries	
Country	$corr(tb1_t, y_t)$	Country	$corr(tb1_t, y_t)$
Argentina	-0.70	*Australia*	-0.43
Brazil	0.01	*Austria*	0.10
Ecuador	-0.79	*Belgium*	-0.04
Israel	0.12	*Canada*	-0.20
Korea	-0.70	*Denmark*	-0.08
Malaysia	0.01	*Finland*	-0.45
Mexico	-0.79	*Netherlands*	-0.19
Peru	0.12	*NewZealand*	-0.26
Philippines	-0.70	*Norway*	0.11
SlovakRepublic	0.01	*Portugal*	-0.11
SouthAfrica	-0.79	*Spain*	-0.60
Thailand	0.12	*Sweden*	0.01
Turkey	0.12	*Switzerland*	-0.17
$average = -0.51$		$average = -0.17$	

Moreover the difference in trade balance-GDP comovement has been expanding in recent years for some countries. Table 4.1 covers the period of

[1]Producing a countercyclical trade balance is challenging in small open economy literature because this is in contradiction with predictions of standard preference.

[2]This table is excerpted from Aguiar and Gopinath (2007). $tb1_t$ is the trade balance ratio over GDP, i.e. $tb1_t = \frac{tb_t}{y_t}$.

1980 − 2003. Using the newly released Canadian and Mexican data till year 2009, the correlation coefficient becomes 0.0043 and −0.75, respectively. The small correlation in Canada implies an almost zero comovement between trade balance and output.

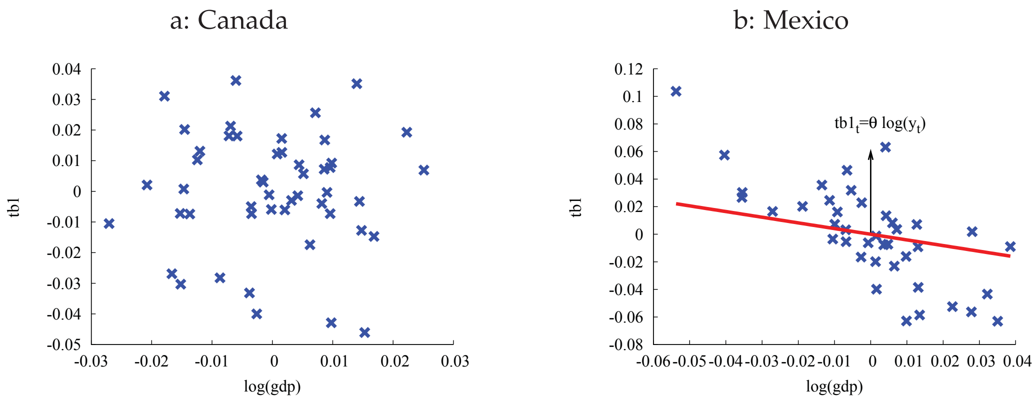


Figure 4.1: Trade balance ratio and GDP

Figure 4.1 plots the trade balance ratio and HP filtered real GDP (in logs) for Canada and Mexico. As Figure 4.1 suggests, it is more difficult to tell the relationship between trade balance ratio and output for Canada. The fact that trade balance is more responsive to output changes in emerging economies can be further confirmed by performing the following regression:

$$tb1_t = \theta log(y_t) + \nu_t \tag{4.1}$$

where y_t is output per capita.[3] The estimated value of θ is 0.0026 (0.0884) for Canada, and −0.4115 (0.0614) for Mexico. The values in parenthesis are standard deviations of the estimated parameters. These results indicate that the trade balance ratio is almost independent of the output changes in Canada, and is significantly countercyclical for Mexico.

[3] All variables have been detrended by applying the HP filter, and thus there is no need to add a regressor of a constant term.

The larger correlation coefficient (in absolute value) indicates that the trade balance in some countries, especially in some emerging countries, is more responsive to GDP changes. Together with the fact that the trade balance is countercyclical, which suggests that the trade balance deteriorates more in the booms, and improves more in recessions for emerging countries, one possible explanation for this difference in magnitude across countries is that some countries face international borrowing constraint. Insofar that these borrowing constraints depends on GDP, one country may have to increase its trade balance during recessions to avoid the possibly binding constraint, and may not accumulate foreign assets during booms when the borrowing constraint becomes less binding.

Since their introduction by Eaton and Gersovitz (1981), borrowing constraints have frequently been used in open economy macroeconomic models, and international borrowing constraints cover a wide range of topics including currency crisis as in Aghion et al. (2001), foreign debt crisis as in Caballero and Krishnamurthy (2001), economic growth as in De Gregorio (1996), "sudden stops" as in Mendoza (2001), and abnormally high consumption volatility in emerging economies as in Resende (2006).[4] Arellano and Mendoza (2002) survey the literature on borrowing constraints in small open economy models and illustrate the effects of the borrowing constraint. Their central findings are that the borrowing constraint introduces large distortion to relative prices including wages, the real interest rate, and the terms of trade, which in turn causes abrupt changes

[4] Eaton and Gersovitz (1981) outline the theory of borrowing ceilings to answer the question of why countries choose not to default even when there is no forcible debt repaying mechanism. According to Eaton and Gersovitz (1981), borrowers refrain from defaulting when the disutility of exclusion from outside capital markets in the future exceeds a certain limit. De Gregorio (1996) investigates the relationship between borrowing constraints and economic growth. De Gregorio (1996) argues that borrowing constraints increases saving, which increases growth; in the meantime, borrowing constraints reduces the time devoted to human capital accumulation, which decreases growth.

in the trade balance, even when the borrowing constraint is only "occasionally" binding.[5]

While the effects of borrowing constraint on open economy macroeconomic model have been widely discussed, their effects on the correlation of the trade balance with GDP has yet to be investigated. This paper is concerned with answering the following question: to what extent can borrowing constraints explain the larger correlation coefficient in emerging economies?

As the first paper to investigate the relationship between borrowing constraints and the trade balance correlation with output, this paper is focused on this primary question of whether borrowing constraints make a difference in the trade balance ratio-GDP comovement. From this point of view, the model is set as standard as possible, and the borrowing constraint is modeled as generally as possible. This paper adopts the standard small open economy real business framework as presented by Schmitt-Grohe and Uribe (2003). The borrowing constraint is modeled as a ceiling limit: the existing debt can not exceed a certain fraction of the output. This simple setting reflects the lender's needs for default risk management. In particular, considering that there hardly exists forcible repaying mechanism on sovereign debt, the lender is more concerned of the borrower's ability to pay, rather than the will to pay. Debt limit reduces the likelihood of overborrowing and falling into the the foreign debt crisis trap, in which case borrowers often loses the ability to repay the debt.

With the assumption that it is chiefly emerging economies that face borrowing constraints, the methodology of this paper is to study one typical emerging country and compare the predictions of the credit constrained and uncon-

[5] Arellano and Mendoza (2002) divide the various models into two categories "ability-to-pay" and "willingness-to-pay". The former rules out the possibility of voluntary default and assumes that borrowers always repay whenever they have the ability. The latter permits the borrower to optimally default.

strained models, respectively. In the small open economy literature, Mexico is frequently chosen as a representative emerging country. In this paper, Mexico is also chosen as the subject of analysis.

By including borrowing constraints in an otherwise the standard small open economy real business cycle model, the paper confirms the aforementioned conjecture, i.e., the debt ceiling makes the trade balance move more closely with output changes, and shows that borrowing constraints generate a more sensitive response of the trade balance to output. Whereas the correlation between the trade balance ratio and GDP is -0.22 for the model without constraints, it rises to -0.59 when a borrowing constraint is applied. Two factors contributed to the result. The first factor is that the trade balance is more volatile in the model with a borrowing constraint. When there is a negative productivity shock, for example, the standard model without financial market imperfections predicts that the trade balance will increase. In the model with a borrowing constraint, the representative household needs to reduce its foreign debt position to avoid the borrowing constraint bind. The second factor is that labor decreases less in the constrained model with negative productivity shock, and accordingly, output drops less. Less drop in labor and output serves the purpose to increase trade balance, which is also an optimal response to the borrowing constraint. Put together, the larger increase in the trade balance and the smaller decrease in output result in a larger correlation (in absolute value) between the trade balance ratio and output.

The structure of the paper is as follows. The next section, Section 2 presents the standard small open economy model as in Schmitt-Grohe and Uribe (2003); Section 3 calibrates the model to the Mexican economy and provides the simulation results. It also undertakes impulse response analysis to reveal the mechanism of why the borrowing constraint generates more comovement between the trade balance and the output; Section 4 provides the discussion, in which the role of interest rate is studied first, then the benchmark model is compared with existing literature on emerging economies. Section 5 concludes this paper, and gives directions for future research.

4.2 The Economic Environment

4.2.1 Preferences

In a small open economy, the infinitely lived representative agent derives utility from streams of consumption c_t, and disutility from working n_t. The agent's preferences are summarized by:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, n_t) \tag{4.2}$$

where β is the discount factor.

In the small open economy literature, the functional form for preferences receives particular attention because standard preferences fail to generate a counter-cyclical trade balance ratio. The counter-cyclical behavior is in contradiction with standard business cycle models. The usual intuition is that the individual should increase her asset holdings in booms so that she may consume more in the following periods as well, as implied by consumption smoothing.

To explain this countercyclical trade balance, researchers have come up with various explanations, of which two theories are widely accepted. The first explanation is that technological change, and accordingly the change in real income may contain two components, the long-term trend and a transitory fluctuation, as Aguiar and Gopinath (2007) argue. When changes in the long-term trend component dominates, consumption will increase enough to crowd out the trade balance, as the permanent income hypothesis suggests. The second explanation is that preferences may not be standard. In particular, when preferences are of GHH form, first proposed by Greenwood et al. (1988), the trade balance could be countercyclical. The reason is that GHH preferences have zero wealth effect, and consumption absorbs the effect of the wealth change. Adopting GHH preferences is a popular approach to generating a countercyclical trade balance ratio, as in Mendoza (1991), Correia et al. (1995), Schmitt-Grohe and Uribe (2003) among others.

For the purpose of concentrating on the trade balance in this paper, the GHH form is preferred. GHH preferences have the form

$$u(c_t, n_t) = \frac{[c_t - \mu \frac{n_t^{\omega}}{\omega}]^{1-\gamma}}{1-\gamma} \tag{4.3}$$

where μ in equation (4.3) is the weight in preferences on labor supply, ω is the elasticity of labor supply, and γ denotes risk aversion.

4.2.2 Technology and investment

This economy produces a single tradable goods according to

$$y_t = e^{z_t} k_t^{\alpha} n_t^{1-\alpha}, \tag{4.4}$$

where k_t is the capital stock, n_t is the labor supply, α is capital share in output and z_t is the productivity shock.

The productivity shock z_t evolves according to,

$$z_t = \rho z_{t-1} + \epsilon_t, \tag{4.5}$$

where the disturbance ϵ_t is distributed normally with variance σ_ϵ^2.

The law of motion for capital is

$$k_{t+1} = (1-\delta)k_t + x_t, \tag{4.6}$$

where δ is the capital depreciation rate, and x_t is investment. It is also assumed that a cost occurs to capital adjustment: the more rapid is adjustment, the greater this cost. The capital adjustment cost is modeled as $\frac{\phi}{2}(k_{t+1}-k_t)^2$, where ϕ is the the capital adjustment cost parameter.

4.2.3 Linkage to international markets

In this small open economy, the representative consumer can export goods to accumulate foreign asset holdings, or import goods to finance domestic spending. Let tb_t denote the trade balance in period t, and d_t stand for the foreign debt level, then

$$d_{t+1} = (1+r_t)d_t - tb_t. \tag{4.7}$$

where r_t is the world real interest rate.

It is further assumed that whenever borrowing or lending, this consumer faces a country-specific interest rate r_t

$$r_t = r^* + \psi(e^{(d_t-\bar{d})} - 1), \tag{4.8}$$

where ψ is a constant, and $\bar{d}$ is the long-run foreign debt level. It is worthy noting that the parameter ψ usually serves two purposes. On the one hand, it affects the borrowing cost: the more the country borrows, the higher interest rate the country has to pay. On the other hand, it serves to introduce stationarity in the model, as discussed in Schmitt-Grohe and Uribe (2003).[6]

[6] Schmitt-Grohe and Uribe (2003) introduce five settings to induce stationarity and illustrates that all settings deliver identical dynamics at business-cycle frequencies. In this paper, the debt elastic interest rate setting is preferred to compare with the "country premium cycle" model as

Finally, it is assumed that debtors face borrowing constraints. The borrowing constraint depends on the performance of its GDP. When GDP increases, lenders take this as an indicator that borrowers have more resources ; accordingly, they are less likely to default. Specifically, it is assumed that its debt can not exceed $\xi\%$ of GDP, i.e.,

$$d_t \leq \xi\% y_t \tag{4.9}$$

This borrowing constraint differs from that assumed by Mendoza (2001) and Uribe (2006). Mendoza (2001)'s model stipulates that some fraction of output must be used as collateral before contracting any new borrowing. Uribe (2006) sets the upper limit as a constant. Here this borrowing constraint is not collateral, since there hardly exist forcible repaying mechanisms in international financial markets.[7]

Accordingly, the resource constraint for the representative household is,

$$c_t + tb_t + x_t = y_t - \frac{\phi}{2}(k_{t+1} - k_t)^2. \tag{4.10}$$

Finally, neither the home country nor the foreign country can play a Ponzi-game, which implies:

$$lim_{T\to\infty}(1 + r_t)^{-T} d_{t+T} = 0. \tag{4.11}$$

discussed later.

[7] Uribe (2006) argues that it is costly for creditors to monitor the individual projects and instead, creditors make their lending decision on a few macroeconomic indicators.

4.3 Parameter Values & Simulation

4.3.1 Calibration

As Table 4.1 shows, the trade balance ratio varies greatly even for countries in a similar development stage. For example, in emerging countries, this coefficient varies from -0.79 (Ecuador, Mexico and South Africa) to 0.12 (Thailand, Turkey, Israel and Peru); in developed economies, it ranges from -0.60 (Spain) to 0.11 (Norway). The methodology of this paper is to study one emerging economy and check whether borrowing constraints delivers a stronger trade balance-output comovement.

Mexico is chosen as the subject economy for three reasons. The first is data convenience. Mexico is one of the a few emerging countries that has a consistent data set. For this reason, it has been frequently studied as in Cole and Kehoe (1996), Durdu et al. (2009) and Gelos (2003) among others. Secondly, Mexico has the largest negative comovement between the trade balance and output, as Table 4.1 shows, and serves the purpose of this paper well. Thirdly, Mexico has experienced borrowing constraint, for example, during the period of year $1994 - 1995$.

Apart from the borrowing constraint, the model in this paper is the same model as Schmitt-Grohe and Uribe (2003). Schmitt-Grohe and Uribe (2003) calibrate their model to Canada economy. Here the parameters are re-calibrated except for those that are impossible to set owning to unavailability of data. For example, there is no labor income report in the national accounts of Mexico, and therefore, the parameter α is set to be 0.32, the same value in Canada.

The discount factor β is set as 0.93, implying an average annual real interest rate of 8 percent, which is consistent with the Mexican economy from 1970 to

2009. The capital depreciation rate δ is calibrated to be 0.08 to match Mexican average investment-output ratio(12.7 percent) over the sample period.

The risk aversion parameter γ takes the value of 2, as is commonly used number in real business cycle literature. As suggested by Garcia-Cicco et al. (2010), ω is set as 1.6, implying a labor supply elasticity of $\frac{1}{\omega-1} = 1.7$ in Mexico. The preference parameter μ is assigned a value of 2 to ensure that the household allocates around 30 percent of its time to market work in steady state.

The steady state value of foreign debt is set as 0.12 to match with the average trade balance-output ratio(1.26 percent). The degree of capital adjustment cost ϕ is set to match the volatility of investment. For the debt elastic interest rate parameter, ψ, it is worthy noting that this parameter also represents the international borrowing cost. To focus on the borrowing constraint and to eliminate the noise introduced by borrowing cost, the debt elastic interest rate parameter is set to the smallest possible value that induces stationarity in the model.

The $AR(1)$ parameter of productivity shock process, ρ and the standard deviation of its shock, σ_ϵ are estimated from the Solow residual in the data. Since capital stock data is not available for Mexico, the Solow residual is computed without capital stock. As shown by Gomme and Rupert (2007), omitting capital stock will not change the time series property of Solow residual. Finally, the borrowing constraint parameter ξ is set to be 37 so that the probability of the debt constraint binding is 8 percent, as set in Benigno et al. (2010). The parameter values are summarized in Table 4.2.

4.3.2 Model solution and simulation

The model can be solved by a variety of dynamic programming methods. As argued in Arellano and Mendoza (2002), however, value function iteration is

Table 4.2: Parameter Values

Parameter	Value	Parameter	Value
γ	2	ω	1.6
α	0.32	ϕ	0.017
δ	0.08	ρ	0.93
σ_ϵ	0.0262	$\bar{z}$	0
r^*	0.08	ψ	0.00004
ξ	37	μ	2

preferred to policy function iteration which involves linear approximation or continuous differentiable iterations because of the non-linearity property implied by occasionally binding constraint. In this paper, the model is also solved with value function iteration.

Let z_l, z_m, and z_h denote the "low", "middle", and "high" state of the total factor productivity. The three-state Markov chain $z = [z_l, z_m, z_h]$, and the associated transition probability matrix π, are specified as: $z = [-0.0477, 0, 0.0477]$, and

$$\pi = \begin{bmatrix} 0.6642 & 0.3016 & 0.0342 \\ 0.1508 & 0.6985 & 0.1508 \\ 0.0342 & 0.3016 & 0.6642 \end{bmatrix}$$

where

$$\pi_{i,j} = prob(z_t = z_j | z_{t-1} = z_i) \tag{4.12}$$

is the transition probability from state i to j.[8]

Let s denote the state vector, it consists of one exogenous state variable, the technology shock z, and two endogenous state variables, the capital stock k and

[8]Here, The process z_t is approximated by a three-state Markov chain using the method of Rouwenhorst (1995). Galindev and Lkhagvasuren (2010) show that for highly persistent autoregressive processes, the method of Rouwenhorst (1995) outperforms other commonly-used discretization methods.

the level of foreign debt d. The control vectors include the labor input n, next period's capital stock k', next period's foreign debt d', and finally consumption c. According, the dynamic programming problem is the following:

$$V(z,k,d) = max\{u(c,n) + \beta E[V(z',k',d']\} \tag{4.13}$$

subject to the international interest rate equation (4.8), the borrowing constraint equation (4.9) and budget constraint equation (4.10).

For the purpose of comparison, the model without a borrowing constraint, which is obtained by setting ξ to an arbitrarily large number, is also solved with value function iteration. The model with $\xi \to +\infty$ is referred to the "unconstrained model", in contrast to the "constrained model" with $\xi = 37$. Table 4.3 displays the simulation results together with the second moments of the data.

The question of whether adding a borrowing constraint explains the countercyclicality of the trade balance ratio in some countries can be answered by comparing $corr(tb1_t, y_t)$ in the constrained and unconstrained models. Absent with the borrowing constraint, the correlation is -0.22. With a borrowing limit conditional on GDP, this correlation coefficient increase in absolute value, to -0.59. Since $corr(tb1_t, y_t) = -0.73$ in the data, the borrowing constraint brings the model much closer to the data.

Unfortunately, the borrowing constraint causes the model to match with other moments not well, especially for the trade balance volatility, and its serial correlation. The volatilities for trade balance in becomes lower in the constrained model. This is because some levels of the foreign debt are unavailable with the borrowing constraint. The lower serial correlation could be corrected by introducing a country premium, which can be obtained by increasing the debt elastic real interest rate parameter, ψ, as demonstrated by Garcia-Cicco et al. (2010). The country premium model, however, is not preferred here because it fails to capture the excess volatility in consumption, as detailed in the next section.

As summarized by Arellano and Mendoza (2002), the small open economy real business cycle framework with occasionally binding borrowing constraints is endowed with a self-adjustment mechanism that can mitigate the negative effects of financial frictions. The mechanism here is that debtors will respond to changes in GDP by adjusting the foreign debt level to decrease the possibility of the constraint binding. When the economy is in an upturn, the borrowing constraint becomes less binding, and the representative household will decrease the trade balance more and in turn, to increase consumption more; when the economy is in the downtown, the borrowing constraint becomes tighter, and the household has to save more by increasing the trade balance to avoid the borrowing limit.

Performing impulse responses helps to illustrate the effect of the borrowing constraint. Suppose that the economy is in steady state, and the technology moves from the "middle" to the "low" state in the next period, which means that z moves from 0 to -0.0477. The average changes of the variables of interest from the 1000 simulated paths are plotted. Figure 4.2 displays the movement of the these economic variables in the unconstrained and constrained models, respectively.

As Figure 4.2 shows, when the productivity falls to the "low" state, the labor supply decreases less in the constrained model than that in the unconstrained model. Accordingly, the output drop is larger in the unconstrained model. These less decrease in labor and output are optimal responses with

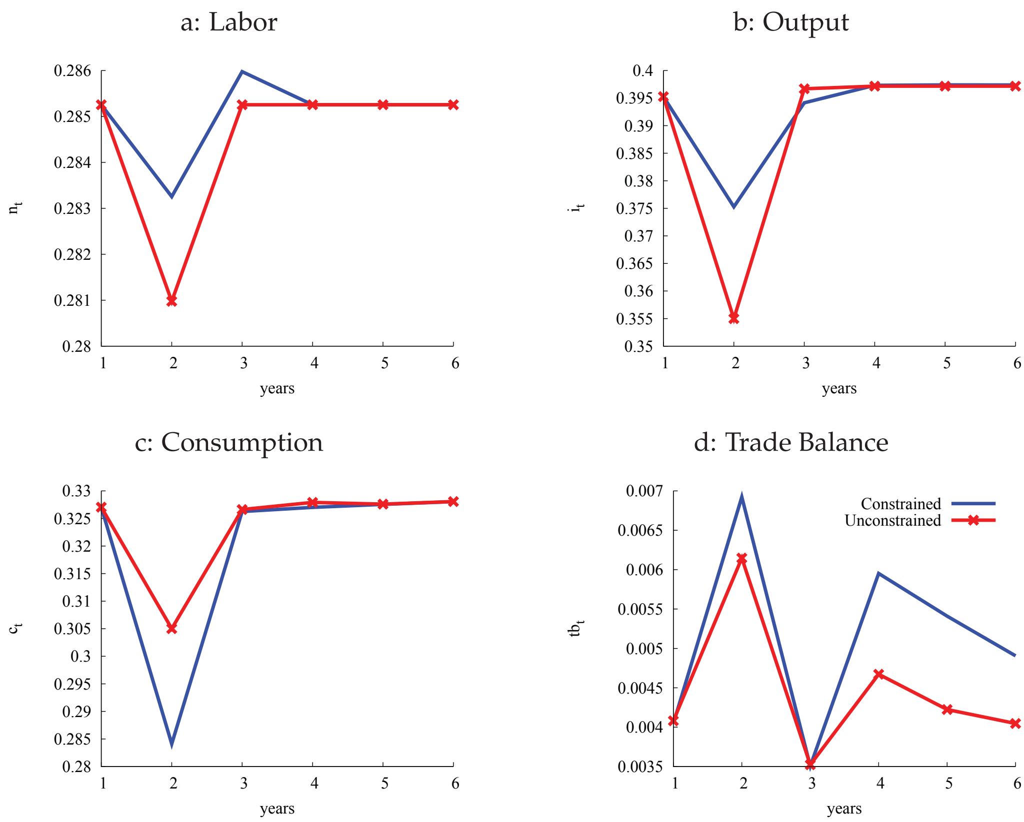


Figure 4.2: Impulse Responses

the borrowing constraint: to avoid the tighter constraint in "low" state. Not surprisingly, the trade balance in the model with the borrowing constraint increases more, which serves to decrease the level of debt to avoid the binding constraint. As a result, there is a larger trade balance adjustment along with a smaller output change in the model with the borrowing constraint, leading to a larger correlation between the trade balance ratio and output.

Table 4.3: Observed and simulated moments

Variable	Data	Model with $\xi \to +\infty$	Model with $\xi = 37$	Model with interest rate shock	Model with unit-root trend	Model with country premium
volatility of GDP						
$std(y_t)$	3.60	3.36	3.13	3.45	3.27	3.40
volatilities relative to GDP						
$std(c_t)$	1.21	0.97	1.10	1.20	2.10	0.80
$std(x_t)$	3.28	3.68	3.28	3.68	3.11	3.43
$std(n_t)$	0.40	0.38	0.62	0.32	0.12	0.35
$std(tb1_t)$	0.56	0.30	0.26	0.65	0.23	0.29
Serial correlations						
$corr(c_t, c_{t-1})$	0.60	0.46	0.47	0.45	0.49	0.51
$corr(x_t, x_{t-1})$	0.41	0.38	0.55	0.32	0.51	0.43
$corr(h_t, h_{t-1})$	0.38	0.19	0.25	0.23	0.27	0.20
$corr(tb1_t, tb1_{t-1})$	0.55	0.25	0.21	0.34	0.33	0.46
$corr(y_t, y_{t-1})$	0.57	0.43	0.60	0.47	0.58	0.62
correlations with GDP						
$corr(c_t, y_t)$	0.93	0.97	0.88	0.98	0.87	0.95
$corr(x_t, y_t)$	0.93	0.88	0.87	0.87	0.89	0.84
$corr(h_t, y_t)$	0.03	0.98	0.99	0.98	1.00	0.99
$corr(tb1_t, y_t)$	-0.73	-0.22	-0.59	-0.24	-0.98	-0.17

Notes:

1. $tb1_t$ is the trade balance ratio over GDP, i.e. $tb1_t = \frac{tb_t}{y_t}$.
2. In the data, labor input is only available from year 1991.
3. Each model is simulated with 1000 replications with 39 periods each. All variables except $tb1_t$ are first logged, then applied with HP filter with the smoothing parameter $\lambda = 100$.

4.4 Further Discussion

4.4.1 Interest rate shock

In the small open economy literature, the role of interest rate shock is frequently discussed. So far, however, there is still no definite answer to the question whether introducing randomness into the exogenous interest rate is beneficial. For example, Mendoza (1991) compares various simulation experiment and shows that interest rate shock is of little importance; Correia et al. (1995) reach the same result by showing that the change of consumption, labor and output is quantitatively small. Blankenau et al. (2001), on the other hand, argue that the shock of interest rate is quantitatively large using variance decomposition; Nason and Rogers (2006) find that interest rate shock is essential to explain the present-value model of current account.

Introducing randomness in the interest rate is a contribution to this debate. Moreover, the role of interest rate shock is of particular interest because it has direct effect on the dynamics of foreign debt, and in turn, on the trade balance evolvement. As in Garcia-Cicco et al. (2010), the interest rate shock is modeled as

$$r_t = r^* + \psi(exp^{(d_t - \bar{d})} - 1) + exp^{(\eta_t - 1)} - 1, \tag{4.14}$$

where η_t is the exogenous interest rate shock following an $AR(1)$ process

$$ln(\eta_t) = \rho_\eta ln(\eta_{t-1}) + \nu_t, \qquad \nu_t \sim i.i.d. \quad N(0, \sigma_\nu^2) \tag{4.15}$$

Using the data of real interest rate, ρ_η and σ_ν are estimated to be 0.87 and 0.033, respectively. Accordingly, the discretinized process is approximated as

$\eta_t = [1.0131, 1.1469]$, and the associated transition probability matrix π is

$$\pi = \begin{bmatrix} 0.9350 & 0.0650 \\ 0.0650 & 0.9350 \end{bmatrix}$$

where

$$\pi_{i,j} = prob(z_t = z_j | z_{t-1} = z_i) \tag{4.16}$$

is the transition probability from state i to j.

The model with both borrowing constraint and interest rate shock is simulated and its results are reported in Table 4.3. The comparison of simulations results in Table 4.3 suggests that the interest rate shock increases the volatility of the trade balance. Other than this, there is no notable difference from the benchmark model. Mendoza (1991) attributes this neutrality to the relative small share of the trade balance. When the trade balance is small, the effect of international shock is limited. In this paper, the trade balance ratio is 1.26 percent, smaller than the 2 percent in Mendoza (1991), therefore it is not surprising to get the limited effect of interest rate shock.

4.4.2 The "trend cycle", "country premium cycle", or the "borrowing cycle" ?

The success of the borrowing constraint in this paper strongly suggests that for emerging economies, the business cycle is the borrowing constraint cycle. This section will compare the "borrowing cycle" model with the mainstream of existing literature on emerging economies: the "trend cycle" model and the "country premium cycle" model.

One common motivation for these two models is that some macroeconomics variables, especially consumption, are more volatile in emerging countries.

More volatile consumption violates the the theory of consumption smoothing and stands in sharp contrast with developed economies. It is also in contradiction with the predictions of standard real business cycle model and thus makes it a challenging task to match with the data for research on emerging economies.

The "trend cycle" model attributes the excess volatility in consumption to the permanent component of productivity shocks. Also known as "the cycle is the trend", Aguiar and Gopinath (2007) argue that the productivity shock is more trend-growth related rather than transitory fluctuations around a stable trend in emerging countries, as it is for most developed economies. When there is a shock on an economy, the representative agent in developed countries will not adjust consumption much because the agent knows that the shock is not permanent, with the expectation that output will return to the long-run trend. In contrast, in developing counties, the agent will adjust consumption accordingly because the shock implies a permanent change in output.

The "country premium cycle" model, as proposed by Garcia-Cicco et al. (2010), argue that the real interest rate is not fixed and is dependent on the foreign debt level: when the debt level is above the long-run trend, the country has to pay a premium in the interest rate. It is the change in the "country premium" that drives the business cycles in emerging economies. Garcia-Cicco et al. (2010) show that permanent movements in productivity explain little excess volatility in consumption using the historical data for emerging economies. Instead, the authors find that the country premium model matches with the data better.

By emphasizing different factors that drive the business cycle in emerging economies, these two hypothesis divide the small open economy models into two distinct categories. Each hypothesis, however, has its own limitations. For "trend cycle" hypothesis, as criticized by Garcia-Cicco et al. (2010), it is problematic to use short sample data to identify the permanent component of productivity shocks because the productivity shock in the pre-war period is significantly different from data afterwards.

More importantly, the "trend cycle" hypothesis results in a too strong trade balance ratio-output comovement. This can be seen by setting the $AR(1)$ coefficient $\rho = 1$ in the productivity shock process $z_t = \rho * z_{t-1} + \epsilon_t$. By setting $\rho = 1$, the productivity shock becomes non-stationary, and any innovation ϵ_t has permanent effect on z_t and output y_t. As implied by permanent income hypothesis, the movement in consumption is larger than that of output. Accordingly, trade balance is crowded out and becomes strongly counter-cyclical. As shown in Table 4.3, the trade balance ratio-output comovement, $corr(tb1_t, y_t)$ becomes -0.98, and the relative volatility of consumption is 2.1. In short, matching the excess volatility in consumption in "trend cycle" model is at the cost of overshooting the comovement between the trade balance ratio and output.

For the "country premium" hypothesis, it is worthy noting that in Garcia-Cicco et al. (2010), the country premium alone can not generate the excess volatility in consumption. It is the preference shock together with stationary productivity shock that explains most excess volatility. The predictions of the "country premium" model can be obtained by increasing the debt elastic real interest rate parameter, ψ, to 2.8, as adopted by Garcia-Cicco et al. (2010). The simulation exercise shows that the "country premium" alone fails to produce the high consumption-output volatility ratio in the data. The borrowing constraint generates a relative volatility 1.10, while the country premium model generates the relative volatility as 0.80. The reason for consumption to be more volatile in the model with borrowing constraint is that relatively radical changes in the trade balance results in larger adjustments in consumption as well. As plotted in Figure 4.2, when the economy transits from the "median" to the "low" state, for instance, the trade balance experiences a larger increase to avoid the binding constraint, and this larger increase causes a larger decrease in consumption as well, compared with the unconstrained model and the country premium model. This result is in line with the idea that borrowing constraints imposed on emerging countries limits their ability to smooth consumption, as discussed in Resende (2006).

In summary, in matching with the trade balance ratio-output comovement and excess volatility in consumption, two typical phenomenon in emerging economies, the model with explicit borrowing constraint outperforms both the "trend cycle" and the "country premium" hypothesis. This suggests that the current research on emerging economies might be problematic, and the "borrowing cycle" should not be overlooked in studying emerging economies.

In addition, the "borrowing cycle" hypothesis in this paper goes beyond the emerging economies and sheds light on the business cycles in the developed counterparts. Although not documented yet, some developed economies start displaying procyclical trade balance ratio in the recent years, as shown in the first section of this paper. For Canada, although $corr(tb1_t, y_t) = 0.0043$ for the period of 1961-2009, this correlation coefficient is 0.38 after Canada joined the North American Free Trade Agreement in 1994.[9]. This reversal of the trade balance ratio calls for new developments in small open economy models because almost all existing literature is based on the fact that the trade balance is countercyclical.

The "borrowing cycle" can explain this new change. One country's borrowing is another country's lending. Without loss of generality, Mexico's borrowing, for instance, could be the lending of Canada. When there is a global

[9] $corr(tb1_t, y_t) = -0.34$ for 1961 to 1993.

negative productivity shock, the output will decrease in both countries.[10] Mexico's trade balance will increase, and accordingly, its foreign borrowing will decrease, as indicated by the previous discussion. This decrease in Mexico's borrowing is the decrease in Canada's lending, which in turn, leads to the decrease in the trade balance of Canada. The negative change in output and the trade balance in Canada results in the positive trade balance ratio-output comovement. Without the borrowing constraint, the changes in Canada's trade balance might not be enough to become procyclical.

4.5 Conclusion

The trade balance is subject to various factors and there is no wonder that its correlation with output changes from country to country. There is, however, a noticeable gap between the developing and developed countries: the trade balance ratio in emerging countries is more responsive to output changes. The author of this paper argues that this is not a random phenomenon, and the driving factor behind it is the imperfections in international financial markets.

The author conjectures that the borrowing constraint, mainly for emerging countries, can cause the trade balance and output move more closely. The borrowing constraint here is simply modeled as an upper limit, which is a fraction of the output. With the borrowing constraint conditional on aggregate economic activity, the representative household has to save more by accumulating more foreign asset(or decreasing foreign debt) in "low" states to avoid the possibly of a binding constraint. This prudence in "low" states is compensated in "high" states when the borrowing constraint becomes less binding and the trade bal-

[10]As shown in Backus et al. (1992), the transmission of productivity shocks among countries is positive.

ance can move to consumption. By including this borrowing constraint into an otherwise standard small open economy real business cycle model, the paper finds that the borrowing constraint explains around 70 percent of the trade balance correlation difference.

In addition, the model with borrowing constraint outperforms the existing models, in particular, the "trend cycle" model and the "country premium" model in terms of matching with the excess volatility in consumption, the other stylized fact of emerging economies. The borrowing constraint model generates realistic trade balance ratio-output comovement, compared with "trend cycle" model. In comparison with the "country premium" model, it easily generates the excess volatility in consumption without using preference shocks. Successfully capturing the typical characteristics of emerging economies, this paper strongly suggests that the borrowing constraint may be an important factor in studying emerging economies.

Moreover, the model with the borrowing constraint may initiate new developments in small open economy models. In particular, it sheds light on most recent change in the business cycles of the developed economies. Some countries start displaying procyclical trade balance ratio. This new phenomenon in some developed economies can be explained by the larger adjustments in foreign asset positions, which is caused by the larger adjustment in the foreign debt positions, when the debt ceiling is imposed on the borrowing countries.

As the first paper to investigate the difference in the correlation between the trade balance and output across countries, this paper focused on the question of whether borrowing constraint can make a difference, and thus ignored some other aspects. For example, this paper does not take the "willingness-to-pay" into consideration, i.e., the voluntary default case. Also, the paper assumes that the borrowing constraint is one-sided: it only sets a maximum for foreign debt, not a minimum. This is of particular interest considering global trade imbalances, which corresponds to the phenomenon of persistent surplus for some countries. Adding these features and analyzing their quantitative effects on the trade balance correlation will be interesting for further research.

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