



Department of Economics

# **Three Essays in International Macroeconomics**

**Katrin Rabitsch**

Thesis submitted for assessment with a view to obtaining the degree of  
Doctor of Economics of the European University Institute

Florence  
May 2008

EUROPEAN UNIVERSITY INSTITUTE  
**Department of Economics**

# **Three Essays in International Macroeconomics**

**Katrin Rabitsch**

Thesis submitted for assessment with a view to obtaining the degree of  
Doctor of Economics of the European University Institute

**Examining Board:**

Prof. Giancarlo Corsetti, EUI, supervisor  
Prof. Philippe Martin, Université Paris 1 Panthéon Sorbonne  
Prof. Vincenzo Quadrini, University of Southern California  
Prof. Rick Van der Ploeg, EUI and University of Oxford

© 2008, Katrin Rabitsch  
No part of this thesis may be copied, reproduced or  
transmitted without prior permission of the author

# Acknowledgements

The support, comments and criticism of many people were indispensable for writing this thesis. Above all, I thank my supervisor Giancarlo Corsetti, for his guidance, numerous helpful discussions and constant support. I am also grateful to my second reader Rick van der Ploeg for his help and encouragement, to my advisor during my exchange at UC Berkeley Pierre-Olivier Gourinchas, to Morten O. Ravn for many useful comments, and to Omar Licandro. It was a pleasure to work with Elvira Prades on a joint paper which is chapter 3 of this thesis. My thanks also go to the members of my thesis committee, Vincenzo Quadrini and Philippe Martin.

I would also like to thank the administrative staff at the Economics department, in particular, Thomas Bourke, Marcia Gastaldo, Martin Legner, Jessica Spataro, and Lucia Vigna for their always prompt help with many issues.

Many friends and colleagues have helped and supported me during the time of this thesis. In particular, I thank Marta Arespa, Judith Ay, Irina Balteanu, Clara Barrabes, Zeno Enders, Lidia Farre, Alain Gabler, Liliane Karlinger, Christian Kascha, Tambiama Madiaga, Alessandro Maravalle, Mario Mariniello, Karel Mertens, Antonio Navas, Markus Poschke, Davide Sala, Claudia Trentini, and Sanne Zwart.

I am grateful to my parents for giving me the opportunity of becoming an independent thinker and for their full support on my chosen paths. To my brother, Kirsten, who has been and will remain one of the few role models in my life.

Finally, I would like to thank my partner, Kerstin Schilcher, for going with me through the entire years of my graduate studies and for always being there for me.

All errors, of course, are mine.

# Contents

<b>I</b>	<b>Introduction</b>	<b>1</b>
<b>II</b>	<b>Chapters</b>	<b>5</b>
<b>1</b>	<b>Wealth Effects of Exchange Rate Movements</b>	<b>7</b>
1.1	Introduction . . . . .	7
1.2	The Model . . . . .	9
1.2.1	Consumer Behavior . . . . .	10
1.2.2	Firms . . . . .	13
1.2.3	Additional Equilibrium Conditions . . . . .	16
1.2.4	Current Account and Net Foreign Assets . . . . .	18
1.3	Parameterization and Steady State . . . . .	20
1.4	Dynamic Behavior of the Model - Impulse Responses . . . . .	21
1.4.1	Productivity shock . . . . .	22
1.4.2	Government expenditure shock . . . . .	23
1.4.3	Monetary Shock . . . . .	23
1.5	Further avenues in accounting for exchange rate valuation effects . . . . .	24
1.6	Conclusions . . . . .	25
<b>2</b>	<b>International Pricing Puzzles</b>	<b>39</b>
2.1	Introduction . . . . .	39
2.1.1	<b>Stylized facts and related literature</b> . . . . .	41
2.2	The model . . . . .	45
2.2.1	Preferences . . . . .	45
2.2.2	Money . . . . .	48
2.2.3	Endowments . . . . .	49
2.2.4	<b>Consumer Optimization and Optimality conditions</b> . . . . .	49
2.3	Parameterization . . . . .	51
2.4	The mechanism . . . . .	52
2.5	Simulation . . . . .	57

2.6	Conclusion . . . . .	58
2.7	Appendix A . . . . .	59
2.8	Appendix B . . . . .	60
<b>3</b>	<b>Capital liberalization and global imbalances</b>	<b>75</b>
3.1	Introduction . . . . .	75
3.2	Endowment Economy . . . . .	79
3.2.1	The model . . . . .	79
3.3	Financial openness and capital liberalization in the model . . . . .	82
3.3.1	Model solution and parametrization . . . . .	85
3.3.2	Main results . . . . .	86
3.4	A model with production and capital accumulation . . . . .	90
3.4.1	Responses to financial account liberalization in the full model with capital . . . . .	92
3.5	Conclusions . . . . .	94
3.6	Appendix . . . . .	95

# Part I

## Introduction



# Introduction

This thesis deals with a number of different topics in the field of international macroeconomics. It proposes theoretical models of the open economy to think about and analyze questions such as the effects of financial globalization, countries' external adjustment mechanism, international relative prices, or the world's state of global imbalances. In the following, I will briefly describe each chapter in more detail.

Chapter 1 addresses an important aspect of the effects of financial globalization that has gained much attention in recent years. Increasing international financial integration has led to a big increase in gross foreign asset and liability positions of advanced, but also emerging market countries. As a result exchange rate and asset price fluctuation can create capital gains or losses on these positions of sizes no longer negligible, as the case of the U.S. economy seems to suggest in recent years. I use a U.S. versus the rest of the world scenario of a two country new open economy macro model that allows for non-zero long-run gross asset and liability positions and examine the workings of exchange rate induced valuation effects in such a framework. I contrast it to the standard symmetric country version of the model, in which countries do not hold any assets or liabilities at steady state. I find that, as expected, any shock that depreciates the exchange rate leads to a revaluation of foreign currency denominated assets and as a result transfers wealth from abroad to the U.S. The size of these valuation effects does not significantly alter the macroeconomic dynamics of the model. Exchange rate induced valuation effects in the model appear, unlike in the data, to be tiny. I claim that this finding might be due to the uncovered interest rate parity condition strictly holding in the model. I then proceed to introducing a risk-premium as a function of the aggregate asset position that temporarily breaks the uncovered interest rate parity relation. The effects of an exchange rate valuation effect are then shown to be much bigger under this setup.

In chapter 2 I address a number of puzzles on international relative prices in a theoretic model of the open economy, partly inspired by my findings in chapter 1. Large deviations from uncovered interest parity, high volatility of exchange rates and an apparent lack of risk sharing across countries are strong regularities in the data. I address these puzzling empirical facts on international relative prices in a simple two country model. The major departure from more standard models is the specification of preferences, which I borrow



from Campbell and Cochrane (1999) who add a slow-moving external habit to the standard power utility function. This specification gives a larger weight to endogenous fluctuations of marginal utility -which translates into higher exchange rate volatility and helps in lowering the consumption-real exchange rate correlation. It also gives a larger role to endogenous fluctuations of the conditional moments of the log stochastic discount factor -as a result the model is able to produce a time-varying risk premium on foreign exchange.

Chapter 3, which is joint work with Elvira Prades, looks at a widely debated topic: the state and the potential sources of world global imbalances. Differences in financial systems have been often named as prime candidates for being responsible for the current state of world global imbalances. This chapter argues that the process of capital liberalization and, in particular, the catching up of emerging market economies in terms of financial account openness can explain a substantial fraction of the current US external deficit. We assess this link in a simple two country one good model with an internationally traded bond. Capital controls are reflected in the presence of borrowing and lending constraints on that bond. A reduction in the foreign country's lending constraint, that is, a liberalization on outward capital flows in the rest of the world, enables the US to better insure against consumption risk and therefore decreases its motives for precautionary asset holdings relative to the rest of the world. As a result, the US runs a long run external deficit.

# Part II

## Chapters



## Chapter 1

# Wealth Effects of Exchange Rate Movements in the International Adjustment Mechanism

### 1.1 Introduction

In recent decades, gross foreign asset and liability positions of advanced economies have grown rapidly relative to GDP as a result of increased international financial integration. For most of the poorer economies, integration in world financial markets remains rather limited. The subset of 'emerging market' developing economies however, also displays increasingly deeper financial integration. Figure 1.1 plots the stocks of foreign assets and liabilities as a percent of GDP, for the industrialized world and emerging market countries, which have increased drastically in the period of 1970-2003<sup>1</sup>.

Recent empirical work suggests that this increase in financial integration can lead to sizeable wealth transfers between countries, since the value of net foreign assets depends on the exchange rate and asset prices, and fluctuations in these variables can create capital gains and losses on these positions. Even if countries' net asset positions have stayed roughly the same, valuation effects derive from the size of gross positions, which have been growing largely. For a given size of an exchange rate or asset price movement, the corresponding capital gains or losses are therefore much more significant today as compared to one or two decades ago. This constitutes, apart from the traditional channel of a change in competitiveness (on international trade), an additional channel through which exchange rate movements can impinge on a country's external wealth. In several recent papers Lane and Milesi-Ferretti (2002*a,b*, 2005), Gourinchas and Rey (2005), Tille (2003, 2005), Obstfeld (2004) stress that the valuation effects from exchange rate fluctuations can be sizeable and may require an

---

<sup>1</sup>The data are taken from the database of Lane and Milesi-Ferretti (2005).

explicit consideration when thinking of external adjustment. Studying these issues requires a model capable of accounting also for this additional channel of changes in net foreign asset positions.

Whether the valuation effects from currency (or price) movements improve or weaken a country's external position depends on the exchange rate exposure (exposure to asset price movements) of the gross assets and gross liabilities, which depend on the structure and composition of a country's net foreign asset position. For example a depreciation of a country's currency increases the value (in domestic currency) of assets and liabilities denominated in foreign currency but has no impact on the domestic-currency-value of assets and liabilities denominated in its own currency. If, as is the case for the U.S., foreign-currency-denominated securities account for a larger amount of a country's gross assets than of its gross liabilities, a depreciation will increase the value of these assets by more than it increases the value of liabilities, and the net international investment position will improve. In recent work Tille (2003, 2005) shows that because of a high leverage, exchange rate depreciations create big capital gains on the U.S. international position.

What is crucial to note is that while in general exchange rate fluctuations are not always favorable since they do not produce only capital gains but also losses, the U.S. is in a rather special position since valuation effects of exchange rate movements complement the more standard external adjustment process on the trade side. An exchange rate depreciation improves the U.S.' external position both over the trade side through stimulating net exports, but at the same time the revaluation of the assets held by the U.S. transfers wealth to the U.S. from abroad.

Unlike for the U.S., for many emerging market economies a currency depreciation affects their external wealth quite differently. While these countries typically hold their assets denominated in foreign currencies, they, in most cases, also find themselves unable to take on their liabilities in their own currency. The problems countries face, whose external debt is denominated in foreign currency as a result of their inability to borrow abroad in their own currency, have been well discussed in the 'Original Sin' literature Eichengreen, Hausmann and Panizza (2003, 2005). In addition almost all emerging market economies are (net) debtors. In such a case a real exchange rate depreciation, by reducing the purchasing power of domestic output over foreign claims, will make it more difficult to service that debt and could therefore be expected to hinder a country's external adjustment.

After Obstfeld and Rogoff's 'Redux' paper the role of net foreign assets and the current account has been deemphasized and many models in the branch of the literature of New Open Economy Macroeconomics made use of devices that left no role for net foreign assets and shut down the current account channel completely (e.g., through the assumption of complete markets, or through the assumption of unit intratemporal elasticity as in Cole and Obstfeld (1991) or Corsetti and Pesenti (2001)). Until recently most papers that analyze the

transmission mechanism of shocks in open economies build on the assumption of a symmetric steady state, that is, the model's dynamics are analyzed in the neighborhood of a steady state in which asset positions are set to zero.

Instead, here I will depart from this assumption, and allow for non-zero steady state asset holdings, including foreign asset and liability positions in the size we observe empirically in an otherwise standard model of the international macroeconomy. For the U.S. this means a gross external asset position denominated -to a large part- in foreign currency, that partially offsets its mainly dollar-denominated gross external liability position, resulting in a negative net asset position. When explicitly considering these positions, this extension allows the investigation of wealth effects on the international investment position. While at first the idea that countries can be debtors or creditors at steady state may seem surprising or at least unconventional, there is also no particular reason why countries should not be allowed to differ in terms of their asset holdings, since countries may also differ in terms of endowments, technology, preferences, etc. Empirical evidence by Lane and Milesi-Ferretti (2001) supports this assumption, i.e. they show that many countries have asset or liabilities holdings that are quite different from zero over very long time horizons.

Section 2 presents the canonical model, a relatively standard two-country open economy model in the style of the New Open Economy Macroeconomics, in which countries holdings of assets and liabilities are specifically taken into account. This allows us to make a first step towards analyzing wealth effects on asset holdings in the adjustment mechanism. Section 3 will discuss the parametrization of the model and steady state results, and section 4 will discuss our findings of the dynamics of our model economy when hit by a variety of shocks. In particular, I will consider a domestic productivity shock, a domestic government expenditure shock, as well as monetary shock. I find that exchange rate induced valuation effects affect macroeconomic dynamics very little and largely remain a challenge to the dynamic stochastic general equilibrium models used today. I suggest that a reason for this finding may be the strict holding of an uncovered interest rate parity condition in the model. A final experiment introduces a risk-premium that temporarily breaks the uncovered interest rate parity relation and shows that under such a scenario the macroeconomic dynamics of the 'valuation effect model' and the 'zero steady state assets model' can differ greatly.

## 1.2 The Model

The model world consists of two countries, Home and Foreign, each of which is specialized in the production of differentiated types of an intermediate good. Intermediate good producers are monopolistic competitors and set a price with some degree of market power under either flexible or sticky (Calvo) prices. Each country competitively produces a final good from

the domestic and foreign intermediates, that can be used for consumption, investment and government expenditures in that country. Home is populated over a continuum of  $[0, n)$ , while Foreign is populated over  $[n, 1]$ . Financial markets are incomplete, agents are only allowed to trade in two types of bonds, one denoted in domestic currency, the other in foreign currency. Finally, gross foreign asset and liability positions are allowed to be non-zero at steady state.

### 1.2.1 Consumer Behavior

Home agent  $j$  maximizes her expected lifetime utility:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left\{ U(C_t^j, (1 - N_t^j)) \right\} \quad (1.1)$$

The home consumer derives utility from consumption,  $C$ , and receives disutility from supplying labor,  $N$ . The functional form of utility is assumed to be additively separable and given by:

$$U(C_t^j, (1 - N_t^j)) = \frac{C_t^{j1-\sigma}}{1-\sigma} + \kappa \frac{(1 - N_t^j)^{1-\psi}}{1-\psi} \quad (1.2)$$

The Budget constraint of the Home and the Foreign consumer are given, respectively, by:

$$\begin{aligned} & \frac{\varepsilon_t B_{F,t}^j}{P_t} + \frac{B_{H,t}^j}{P_t} + C_t^j + I_t^j + \Psi \left( \frac{\varepsilon_t B_{F,t}^j}{P_t}, \frac{B_{H,t}^j}{P_t} \right) = \\ &= \frac{\varepsilon_t B_{F,t-1}^j}{P_t} (1 + i_{t-1}^*) + \frac{B_{H,t-1}^j}{P_t} (1 + i_{t-1}) + \frac{R_t K_{t-1}^j}{P_t} + \frac{W_t N_t^j}{P_t} + \int_0^n \frac{\phi_t(h, j) dh}{P_t} - \frac{TAX_t^j}{P_t} + \frac{TR_t^j}{P_t} \\ & \frac{B_{F,t}^{*j*}}{P_t^*} + \frac{B_{H,t}^{*j*}}{\varepsilon_t P_t^*} + C_t^{*j*} + I_t^{*j*} + \Psi^* \left( \frac{B_{F,t}^{*j*}}{P_t^*}, \frac{B_{H,t}^{*j*}}{\varepsilon_t P_t^*} \right) = \end{aligned} \quad (1.3)$$

$$\begin{aligned} & \frac{B_{F,t-1}^{*j*}}{P_t^*} (1 + i_{t-1}^*) + \frac{B_{H,t-1}^{*j*}}{\varepsilon_t P_t^*} (1 + i_{t-1}) + \frac{R_t^* K_{t-1}^{*j*}}{P_t^*} + \frac{W_t^* N_t^{*j*}}{P_t^*} + \int_n^1 \frac{\phi_t^*(f, j^*) df}{P_t^*} - \frac{TAX_t^{*j*}}{P_t^*} + \frac{TR_t^{*j*}}{P_t^*} \end{aligned}$$

where  $B_H$  denotes (the quantity of) Home-currency-bond holding of an agent from the Home country,  $B_F$  denotes Foreign-currency-bond holding of an agent from the Home country,

$B_F^*$  ( $B_H^*$ ) denotes Foreign-currency-bond (domestic-currency-bond) holdings of an agent from the Foreign country,  $I$  is investment,  $K$  the capital stock,  $R$  denotes the nominal rate of return on capital,  $W$  is the nominal wage rate.  $\phi(h, j)$  is the agent's share of profits of home firm  $h$ ,  $TAX$  denotes taxes and  $TR$  denotes transfers. The notation for foreign agents is similar, only that foreign variables are denoted with an asterisk.  $P$  ( $P^*$ ) is the domestic (foreign) CPI, which will be used as the numeraire.

Finally,  $\Phi(.,.)$  is a function that models portfolio adjustment costs. As is usual in an incomplete markets setup a stationarity problem arises under this market structure which would prevent a proper analysis of small deviations around a deterministic steady state. In particular, without further modification, such an incomplete markets structure implies a non-stationary distribution of wealth across countries, in which also temporary shocks lead to permanent wealth reallocations. Several modelling devices have been suggested in the literature to address that problem (for a summary see, Schmidt-Grohe and Uribe (2004)). Here I introduce a quadratic portfolio adjustment costs in holdings of both domestic and foreign nominal bonds. The portfolio adjustment cost for domestic agents reads<sup>2</sup>:

$$\Psi \left( \frac{\varepsilon_t B_{F,t}^j}{P_t}, \frac{B_{H,t}^j}{P_t} \right) = \frac{\psi_B}{2} \left( \frac{\varepsilon_t B_{F,t}^j}{P_t} - \frac{\overline{\varepsilon B_F}}{\overline{P}} \right)^2 + \frac{\psi_B}{2} \left( \frac{B_{H,t}^j}{P_t} - \frac{\overline{B_H}}{\overline{P}} \right)^2 \quad (1.6)$$

This not only induces stationarity, but will also allow to solve numerically for a steady state asset portfolio; there is a positive cost as long as the bond holdings deviate from their imposed steady state value (around which the cost is centered). Benigno (2001) imposes such a cost for engaging in the foreign asset market and rationalizes such a function as capturing a cost faced by domestic agents of taking a position in the foreign market<sup>3</sup>.

The asset market structure is modelled by allowing agents to take on two kinds of bonds, one denominated in Home currency, the other in Foreign currency. Steady state holdings of the domestic and foreign currency bonds that are non-zero will allow us to model the currency composition of U.S. gross assets and liabilities, which in turn makes it possible to examine valuation effects on these positions when the exchange rate moves. It is important

---

<sup>2</sup>Similarly, for the foreign agent:

$$\Psi^* \left( \frac{B_{F,t}^{*j}}{P_t^*}, \frac{B_{H,t}^{*j}}{\varepsilon_t P_t^*} \right) = \frac{\psi_B}{2} \left( \frac{B_{F,t}^{*j}}{P_t^*} - \frac{\overline{B_F^*}}{\overline{P^*}} \right)^2 + \frac{\psi_B}{2} \left( \frac{B_{H,t}^{*j}}{\varepsilon_t P_t^*} - \frac{\overline{B_H^*}}{\overline{\varepsilon P^*}} \right)^2 \quad (1.5)$$

<sup>3</sup>I impose the cost on the holdings of both bonds mainly for the following reason: the domestic agent's first order w.r.t. the domestic and foreign bond give rise to an equation relating the nominal interest rate differential to the expected rate of exchange rate depreciation. The foreign agent's first order condition w.r.t. the domestic and foreign bond give rise to a similar relationship. Once log-linearized these two expressions are exactly equal and as a result one cannot solve for  $\hat{B}_H$  and  $\hat{B}_F$  separately. In the log-linearized system one therefore has to either solve in terms of changes in the aggregate bond position, or, alternatively, specify a portfolio rule that pins down each of the bond holdings separately.



to note that size and currency composition of the international portfolio are assumed, taken as given<sup>4</sup>. The focus is therefore not on how these positions evolved, but on the consequences of their presence as of today. Also, the introduction of these non-zero asset positions could be justified by pointing to empirical evidence of large and persistent non-zero positions and by pointing out that portfolio theory does not require zero leverage in equilibrium. External debt does not need to be repaid as long as the outstanding debt is serviced.

The capital stock evolves according to the following law of motion, which includes quadratic capital adjustment costs:

$$K_t = (1 - \delta)K_{t-1} + I_t - \frac{\phi_K}{2} \left( \frac{K_t - K_{t-1}}{K_{t-1}} \right)^2 \quad (1.7)$$

The maximization of (1.1) subject to (1.3) yields the domestic consumer's optimality conditions: the labor supply condition (1.8), the Euler equations with respect to  $B_{H,t}^j$  (1.9) and  $B_{F,t}^j$  (1.10), and finally the Euler equation for capital, (1.11). In the following I drop the superscripts  $j$  ( $j^*$ ), since in equilibrium all households are equal, and the individual's optimality conditions hold also on aggregate.

$$-\frac{U_{N,t}}{U_{C,t}} = \frac{w_t}{P_t} \quad (1.8)$$

$$1 + \psi_B \left( \frac{\varepsilon_t B_{F,t}}{P_t} - \overline{\varepsilon B_F} \right) = \beta E_t \left\{ (1 + i_t) \frac{U_{C,t+1}}{U_{C,t}} \frac{P_t}{P_{t+1}} \right\} \quad (1.9)$$

$$1 + \psi_B \left( \frac{B_{H,t}}{P_t} - \overline{B_H} \right) = \beta E_t \left\{ (1 + i_t^*) \frac{U_{C,t+1}}{U_{C,t}} \frac{P_t}{P_{t+1}} \frac{\varepsilon_{t+1}}{\varepsilon_t} \right\} \quad (1.10)$$

$$1 + \frac{\phi_K}{K_{t-1}} \left( \frac{K_t}{K_{t-1}} - 1 \right) = \beta \left\{ \frac{U_{C,t+1}}{U_{C,t}} \left[ 1 - \delta + \frac{R_{t+1}}{P_{t+1}} - \frac{\phi_K}{K_t} \left( \frac{K_{t+1}}{K_t} - 1 \right) \frac{K_{t+1}}{K_t} \right] \right\} \quad (1.11)$$

The two Bond Euler equations (1.9) and (1.10) can be joined to give the (risk-adjusted) uncovered interest parity relation:

$$\frac{(1 + i_t)}{(1 + i_t^*)} = E_t \left\{ \frac{\varepsilon_{t+1}}{\varepsilon_t} \right\} \left[ 1 + \psi_B \left( \frac{B_{H,t} + \varepsilon_t B_{F,t}}{P_t} - \bar{b} \right) \right] \quad (1.12)$$

where  $\bar{b} = \frac{\overline{B_H + \varepsilon B_F}}{\bar{P}}$ . Foreign consumers' optimality conditions are similarly obtained.

---

<sup>4</sup>Developing an optimal portfolio model to explain how international portfolios evolve endogenously would be an important -and ambitious- extension.

Foreign's labor supply, Bond Euler equations and capital Euler equation are mirror images of equations (1.8), (1.9), (1.10) and (1.11).

### 1.2.2 Firms

#### Final Good Producers

Final goods are produced by competitive firms by combining intermediate domestically and foreign produced goods according to a CES aggregator:

$$Y_t^j = \left[ \gamma^{\frac{1}{\epsilon}} Y_{H,t}^{j \frac{\epsilon-1}{\epsilon}} + (1-\gamma)^{\frac{1}{\epsilon}} Y_{F,t}^{j \frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \quad (1.13)$$

where:

$$Y_{H,t}^j = \left[ \left( \frac{1}{n} \right)^{\frac{1}{\theta}} \int_0^n y_t(h, j)^{\frac{\theta-1}{\theta}} dh \right]^{\frac{\theta}{\theta-1}} \quad (1.14)$$

$$Y_{F,t}^j = \left[ \left( \frac{1}{1-n} \right)^{\frac{1}{\theta}} \int_n^1 y_t(f, j)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}} \quad (1.15)$$

The parameter  $\epsilon$  denotes the degree of substitutability between using Home and Foreign tradable goods in production, while  $\theta$  indicates the degree of substitutability between different varieties of the domestic (foreign) good<sup>5</sup>. Parameter  $\gamma$  allows introducing a home bias in production, i.e. domestic final good producers use domestic intermediate goods more intensively when  $\gamma > 0.5$ .

Final good producers solve the following static optimization problem:

$$\max P_t Y_t - \int_0^n p_t(h) y_t(h, j) - \int_n^1 p_t(f) y_t(f, j) \quad (1.16)$$

This optimization problem yields the following input demand functions for the home economy:

---

<sup>5</sup>Generally it is assumed that  $\theta > \epsilon > 1$ , which corresponds to the idea that each country is specializing in the production of a single type of good, and that the degree of substitutability between the same type of the good (between all Home goods or between all Foreign goods) will be higher than the degree of substitutability between different types of goods (ie, between Home and Foreign goods).

$$Y_{H,t}^j = \gamma \left( \frac{P_{H,t}}{P_t} \right)^{-\epsilon} Y_t^j \quad (1.17)$$

$$Y_{F,t}^j = (1 - \gamma) \left( \frac{P_{F,t}}{P_t} \right)^{-\epsilon} Y_t^j \quad (1.18)$$

$$y_t(h, j) = \frac{1}{n} \left( \frac{p_t(h)}{P_{H,t}} \right)^{-\theta} Y_{H,t}^j = \frac{\gamma}{n} \left( \frac{p_t(h)}{P_{H,t}} \right)^{-\theta} \left( \frac{P_{H,t}}{P_t} \right)^{-\epsilon} Y_t^j \quad (1.19)$$

$$y_t(f, j) = \frac{1}{1 - n} \left( \frac{p_t(f)}{P_{F,t}} \right)^{-\theta} Y_{F,t}^j = \frac{(1 - \gamma)}{1 - n} \left( \frac{p_t(f)}{P_{F,t}} \right)^{-\theta} \left( \frac{P_{F,t}}{P_t} \right)^{-\epsilon} Y_t^j \quad (1.20)$$

with the corresponding price indices:

$$\begin{aligned} P_{H,t} &= \left[ \frac{1}{n} \int_0^n p_t(h)^{1-\theta} dh \right]^{\frac{1}{1-\theta}} \\ P_{F,t} &= \left[ \frac{1}{1-n} \int_n^1 p_t(f)^{1-\theta} df \right]^{\frac{1}{1-\theta}} \\ P_t &= \left[ \gamma P_{H,t}^{1-\epsilon} + (1 - \gamma) P_{F,t}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \end{aligned} \quad (1.21)$$

Foreign final good producers face a symmetric problem.

### Intermediate Good Producers

The intermediate good producer's problem can be decomposed into a cost minimization problem and a profit maximization problem.

**Cost minimization problem** Firms in the intermediate goods sector produce intermediate goods as monopolistic competitors, using capital and labor services, according to a Cobb-Douglas production function, that is Home country's production technology is:

$$y_t(h) = Z_t K_{t-1}^\alpha (h) N_t^{1-\alpha} (h) \quad (1.22)$$

The intermediate goods producers aim to maximize their expected profits in the respective market. The marginal cost the firm in the intermediate good producing sector has to take into account in its profit maximization problem is obtained by the following minimization problem.

$$\{N_t^D(h), K_{t-1}^D(h)\} = \arg \min w_t N_t(h) + R_t K_{t-1}(h) + MC_t(h) [y_t(h) - Z_t K_{t-1}^\alpha(h) N_t^{1-\alpha}(h)]$$

which results in the following expressions for marginal costs and optimal capital-labor ratios:

$$MC_t(h) = \frac{1}{Z_t} \left[ \frac{W_t^{1-\alpha} R_t^\alpha}{(1-\alpha)^{(1-\alpha)} \alpha^\alpha} \right] \quad (1.23)$$

$$\frac{N_t(h)}{K_{t-1}(h)} = \frac{1-\alpha}{\alpha} \frac{R_t}{w_t} \quad (1.24)$$

**Profit maximization problem** I now turn to describing the firm's price setting problem. In my analysis I will consider both a setting of flexible prices as well as sticky prices. Since the case of flexible price setting can be obtained as a special case of the latter, I lay out only the sticky price setup. The intermediate firms' price setting behavior is modelled through a Calvo-type mechanism. Under the Calvo pricing assumption, each firm has the opportunity to adjust its price only when it receives a 'price-change signal' at stochastic intervals. In each period a firm can set a new price with (constant) probability,  $1 - \lambda$ , which is the same for all firms and is independent from the amount of time elapsed since it last changed price. Define  $Q_{t,t+k}$  as the households' stochastic discount factor from period  $t$  to period  $t+k$ <sup>6</sup>. When a Home-firm  $h$  has an opportunity to set a new price at period  $t$ , it does so in order to maximize the expected discounted value of its profits, i.e.:

$$\max_{p_t(h), p_t^*(h)} E_t \sum_{k=t}^{\infty} \lambda^k Q_{t,t+k} \left\{ \left[ \frac{p_t(h)}{P_{H,t+k}} - \frac{MC_{t+k}^{nom}(h)}{P_{H,t+k}} \right] y_{t+k}(h) + \left[ \frac{\varepsilon_{t+k} p_t^*(h)}{P_{H,t+k}^*} - \frac{MC_{t+k}^{nom}(h)}{P_{H,t+k}^*} \right] y_{t+k}^*(h) \right\} \quad (1.25)$$

subject to marginal costs as given by equation (1.23) and the demand functions for the domestic good given by equation (1.19) and its foreign counterpart.

Prices are assumed to be sticky in terms of the producer currency, that is, each firm chooses one price for both the domestic and the foreign market. This implies that the law of

---

<sup>6</sup>  $Q_{t,t+k} = \beta \frac{U_{C,t+k}}{U_{C,t}} \frac{P_t}{P_{t+k}}$ .

one price holds at the intermediate good level, and there is perfect exchange rate pass through to local prices in the foreign country<sup>7</sup>.

$$p_t^{opt}(h) = \frac{\theta}{(1-\theta)} \frac{\sum_{k=t}^{\infty} \lambda^k E_t \left\{ Q_{t,t+k} P_{H,t+k}^{1-\theta} Y_{H,t+k} MC_{t+k}^{nom} \right\}}{\sum_{k=t}^{\infty} \lambda^k E_t \left\{ Q_{t,t+k} P_{H,t+k}^{1-\theta} Y_{H,t+k} \right\}} \quad (1.26)$$

The optimal price is a markup over a weighted average of expected future nominal marginal costs.

The home country price index for domestic intermediate goods evolves according to:

$$P_{H,t}^{1-\theta} = \lambda P_{H,t-1}^{1-\theta} + (1-\lambda) p_t^{opt}(h) \quad (1.27)$$

When  $\lambda = 0$  firms are allowed to optimally reset their prices each period. The resulting optimality conditions under flexible prices are given by:

$$p_t(h) = \varepsilon_t p_t^*(h) = \frac{\theta}{\theta-1} MC_t(h) \quad (1.28)$$

### 1.2.3 Additional Equilibrium Conditions

#### Monetary Policy

The monetary authority is assumed to apply an interest-feedback rule. The interest rate targets inflation and the output gap according to a Taylor rule:

$$\frac{1+i_t}{1+\bar{i}} = \left[ \frac{1+i_{t-1}}{1+\bar{i}} \right]^{\rho_i} \left[ \left( \frac{\pi_t}{\bar{\pi}} \right)^{\rho_\pi} \left( \frac{Y_t}{\bar{Y}} \right)^{\rho_Y} \right]^{1-\rho_i} e^{\xi_{i,t}} \quad (1.29)$$

$$\frac{1+i_t^*}{1+\bar{i}^*} = \left[ \frac{1+i_{t-1}^*}{1+\bar{i}^*} \right]^{\rho_i} \left[ \left( \frac{\pi_t^*}{\bar{\pi}^*} \right)^{\rho_\pi} \left( \frac{Y_t^*}{\bar{Y}^*} \right)^{\rho_Y} \right]^{1-\rho_i} e^{\xi_{i,t}^*} \quad (1.30)$$

<sup>7</sup>If prices were sticky in terms of the local currency, each firm would choose a price for the Home market and a price for the Foreign market.

This would give another optimality condition similar to equation (1.26), given by:

$$p_t^{*opt}(h) = \frac{\theta}{(1-\theta)} \frac{\sum_{k=t}^{\infty} \lambda^k E_t \left\{ Q_{t,t+k} P_{H,t+k}^{*1-\theta} Y_{H,t+k}^* MC_{t+k}^{nom} \right\}}{\sum_{k=t}^{\infty} \lambda^k E_t \left\{ Q_{t,t+k} \varepsilon_{t+k} P_{H,t+k}^{*1-\theta} Y_{H,t+k}^* \right\}}$$

Under prices that are sticky in local currency exchange rate movements cause ex-post deviations from the law of one price. The automatic stabilizing property of exchange rates ('expenditure-switching') vanishes since there is no exchange-rate pass-through to local prices.

where the last terms in equation (1.29) and (1.30) denote an i.i.d. monetary policy shock (shock to the nominal interest rate).

### Fiscal Authority

The role of fiscal policy in the model is highly simplified. Government spending is assumed to be financed by lump-sum taxes. The government is not allowed to run budget deficits, and its budget constraint therefore is:

$$P_t G_t + TR_t = TAX_t \quad (1.31)$$

$$P_t^* G_t^* + TR_t^* = TAX_t^* \quad (1.32)$$

### Market Clearing Conditions

Bonds markets clear (zero net supply):

$$\int_0^n B_{F,t}(j) dj + \int_n^1 B_{F,t}^*(j^*) dj^* = 0 \quad \int_0^n B_{H,t}(j) dj + \int_n^1 B_{H,t}^*(j^*) dj^* = 0 \quad (1.33)$$

Labor markets clear:

$$\int_0^n N_t(h, j) dh = \int_0^n N_t(h, j) dj \quad \int_n^1 N_t^*(f, j^*) df = \int_n^1 N_t^*(f, j^*) dj^* \quad (1.34)$$

Capital markets clear:

$$\int_0^n K_t(h, j) dh = \int_0^n K_t(h, j) dj \quad \int_n^1 K_t^*(f, j^*) df = \int_n^1 K_t^*(f, j^*) dj^* \quad (1.35)$$

Goods markets clear:

$$\int_0^n Z_t K_{t-1}^\alpha(h) N_t^{1-\alpha}(h) dh = \int_0^n y_t(h, j) dj + \int_n^1 y_t^*(h, j^*) dj^* \quad (1.36)$$

$$\int_n^1 Z_t^* K_{t-1}^{*\alpha}(f) N_t^{*1-\alpha}(f) df = \int_0^n y_t(f, j) dj + \int_n^1 y_t^*(f, j^*) dj^* \quad (1.37)$$

$$Y_t = C_t + I_t + G_t \quad (1.38)$$

$$Y_t^* = C_t^* + I_t^* + G_t^* \quad (1.39)$$

### Exogenous Processes

Home and Foreign productivity and government expenditure evolve according to the following autoregressive processes:

$$\log(Z_t) = \rho_Z \log(Z_{t-1}) + \xi_{Z,t} \quad (1.40)$$

$$\log(Z_t^*) = \rho_Z^* \log(Z_{t-1}^*) + \xi_{Z,t}^* \quad (1.41)$$

$$\log(G_t) = \rho_G \log(G_{t-1}) + \xi_{G,t} \quad (1.42)$$

$$\log(G_t^*) = \rho_G^* \log(G_{t-1}^*) + \xi_{G,t}^* \quad (1.43)$$

#### 1.2.4 Current Account and Net Foreign Assets

Aggregating the Home individuals' budget constraint, taking into account the government budget constraint, the zero international bond holding condition and plugging in for profits gives Home's current account relation (where  $TB$  denotes the trade balance,  $TB_t = P_{H,t} Z_t K_{t-1}^\alpha N_t^{1-\alpha} - P_t C_t - P_t I_t$ ):

$$\varepsilon_t B_{F,t} + B_{H,t} = \varepsilon_t B_{F,t-1}(1 + i_{t-1}^*) + B_{H,t-1}(1 + i_{t-1}) + TB_t - \Psi\left(\frac{\varepsilon_t B_{F,t}}{P_t}, \frac{B_{H,t}}{P_t}\right) \quad (1.44)$$

The current account can be written in terms of international financial flows as:

$$\begin{aligned} CA_t &= (B_{H,t} - B_{H,t-1}) + \varepsilon_t (B_{F,t} - B_{F,t-1}) = \\ &= \varepsilon_t B_{F,t-1} i_{t-1}^* + B_{H,t-1} i_{t-1} - \Psi\left(\frac{\varepsilon_t B_{F,t}}{P_t}, \frac{B_{H,t}}{P_t}\right) + TB_t \end{aligned} \quad (1.45)$$

The change in the net foreign asset position on the other hand is given by:

$$NFA_{t+1} - NFA_t = CA_t + B_{F,t-1} (\varepsilon_t - \varepsilon_{t-1}) + \Psi\left(\frac{\varepsilon_t B_{F,t}}{P_t}, \frac{B_{H,t}}{P_t}\right) \quad (1.46)$$

Equation (1.46) states that a change in the net foreign asset position can occur either from the traditional channel of movements in the current account, or through capital gains or losses induced by movements in the exchange rate. Section 1 has discussed the U.S.' leveraged international portfolio, with gross debts mostly in dollars and assets largely in foreign currencies. By approximating the model economy around this initial pattern of international portfolio holdings, that is, with  $\overline{B_H} < 0$  and, in particular,  $\overline{B_F} > 0$  and eq. (1.46) shows that an exchange rate depreciation results in a positive wealth transfer to the Home country due to the now higher domestic currency value of the steady state asset position. Clearly, in the standard symmetric-country case with zero steady state asset and liability holdings none of these terms are captured.

This completes the description of the model's equilibrium relations. To obtain a solution to this system of non-linear equations, all domestic nominal variables are expressed in terms of the domestic final good price index, while all foreign variables are expressed relative to the foreign price index, e.g.  $\widetilde{W} = \frac{W}{P}$ ,  $\widetilde{R} = \frac{R}{P}$ ,  $\widetilde{P}_H = \frac{P_H}{P}$ ,  $\widetilde{P}_F = \frac{P_F}{P}$  etc., and  $\widetilde{W}, \widetilde{R}, \widetilde{P}_H, \widetilde{P}_F$ , etc. denote real variables. The rate of domestic (foreign) inflation is defined as  $\pi_t = \frac{P_t}{P_{t-1}}$  ( $\pi^* = \frac{P_t^*}{P_{t-1}^*}$ ), and the rate of nominal exchange rate depreciation is denoted by  $\Delta_t = \frac{\varepsilon_t}{\varepsilon_{t-1}}$ . The real exchange rate is given by  $RER_t = \frac{\varepsilon_t P_t^*}{P_t}$ , the terms of trade is  $TOT_t = \frac{P_{F,t}}{\varepsilon_t P_{H,t}^*}$ . The real version of the model is then log-linearized around a deterministic steady state (which is discussed in the next section) and solved using a standard algorithm<sup>8</sup>.

---

<sup>8</sup>I made use Schmidt-Grohe and Uribe (2004) files 'anal\_deriv.m' and 'num\_eval.m' to take and evaluate analytic derivatives and used Klein (2000) algorithm 'solab.m' to solve the system of linear difference equations.



### 1.3 Parameterization and Steady State

The models of the kind presented here, in general do not have closed form solutions even in the steady state. Such a solution can be derived however under the assumption that both countries are completely symmetric which indeed is the steady state that the large majority of papers in the literature consider. For the purpose of this paper, with non-zero asset positions we need to solve for the steady state numerically<sup>9</sup>.

Table 1 summarizes the parameterization of the model. The discount factor  $\beta$  is assumed to be 0.99, the coefficient of relative risk aversion of  $\sigma$  is set equal to 2, which are standard choices.  $\kappa$  is set such that households devote 30% of their time to market activities. The country size parameter  $n$  is set to 0.25 which approximately reflects the US population share in the OECD.

Turning to the production technology parameters, the capital share parameter in the Cobb-Douglas function  $\alpha$  is set to  $\frac{1}{3}$ , the quarterly depreciation rate is equal to  $\delta = 0.021$ . In order to avoid excessive responses in capital accumulation and investment in response to shocks, quadratic capital adjustment costs are introduced, and its parameter  $\psi_K$  is set to 8 as in ?. The elasticity of substitution between varieties of the domestic good and between varieties of the foreign good is set to  $\theta = 10$ , which implies a markup of about 11%.

The parameter that controls the amount of home bias in final good production,  $\gamma$ , is set to 0.85, approximately reflecting the U.S. import share in a U.S. vs. rest-of-the-world scenario. The intratemporal elasticity between Home and Foreign intermediate goods is chosen to be  $\epsilon = 1.5$ , i.e. Home and Foreign intermediate goods are substitutes in the production of final goods. Wide ranges have been used in the literature for the choice of this elasticity parameter<sup>10</sup>. The substitution elasticities are crucial parameters: a lower intratemporal substitution elasticity implies that sharper price changes are needed to accommodate a given change in quantities consumed, resulting in greater the terms of trade and real exchange rate responses. Also, the lower the intertemporal elasticity (the higher the relative risk aversion) the more responsive international relative prices. When considering the sticky price scenario, the parameter that governs the degree of price stickiness,  $\lambda$ , is set to 0.75, which implies an average price stickiness of about 2 1/2 quarters. The parameters that describe the monetary policy feedback rule are taken as estimated in Lubik and Schorfheide (2005), that is,  $\rho_i = 0.72$ ,  $\rho_\pi = 1.67$ , and  $\rho_Y = 0.04$ .

Parameter  $\psi_B$ , describing the portfolio adjustment costs, which governs the speed of convergence back to steady state of bond holdings, is set to 0.0001, such that the costs of

<sup>9</sup>An analytical solution could be also obtained if *gross* asset and liability positions are positions of exactly the same size and offsetting as in Tille (2005).

<sup>10</sup>International real business cycle models commonly use elasticities around 1.5 or even lower (See for example, Backus, Kehoe and Kydland (1994) or Heathcote and Perri (2005)). In contrast, Yi (2003) shows that applied general equilibrium models need large, up to values of 12 or 13 to generate the large growth in trade found in the data.

engaging in the bond markets are very small.

For the exogenous processes, we consider shocks with autoregressive parameters of 0.9 throughout.

Finally, I turn to describing the steady state values of asset and liability holdings. I want to allow for a role of valuation effects that, given the U.S.' leveraged international portfolio, with gross debts mostly in dollars and assets largely in foreign currencies, a dollar depreciation has on these positions. As of 2003, the U.S.' net foreign asset position as a percent of GDP was about -25%. The stock of U.S. foreign liabilities is at around 95.6% of GDP and these liabilities are primarily denoted in domestic currency. The dollar-value of the stock of U.S. foreign assets is at around 71.5% of GDP, of which about 2/3 is denoted in foreign currency<sup>11</sup>. To incorporate these facts of the U.S. asset and liability positions into the model we impose the Home country's steady state holdings of  $\frac{RERB_F}{\bar{Y}} \approx 0.5$  (roughly reflecting the foreign currency part of U.S. external assets) and  $\frac{\bar{B}_H}{\bar{Y}} \approx -0.75$  (roughly reflecting the dollar denominated external liabilities net of dollar denominated assets). The portfolio adjustment cost function ensures that the value of foreign bond holdings converges to its steady state value, i.e. I choose  $\frac{\bar{B}_H}{\bar{Y}}$  and  $\frac{RERB_F}{\bar{Y}}$  as parameters.

Table 2 presents the solution for the steady state. The second column presents the steady state under the above parametrization, while the first column provides a comparison case with zero steady state asset positions but otherwise identical parametrization. As can be seen, when the Foreign economy is a creditor in steady state, it can permanently afford higher consumption levels than Home from the income flows from its international investment position. Also the real exchange rate in the case where Home is a net debtor (second column) shows a more depreciated steady state real exchange rate relative to the case of a zero international investment position. This is in line with the empirical evidence by Lane and Milesi-Ferretti (2004) and reflects that in the long run countries with net external liabilities need to run trade surpluses in order to service their outstanding debt, which in turn requires a more depreciated level of the real exchange rate<sup>12</sup>.

## 1.4 Dynamic Behavior of the Model - Impulse Responses

The model is now used to extract impulse responses to a variety of shocks, summarized in 1.2 to 1.4. The shocks analyzed are a productivity shock, a government expenditure shock, and an expansionary monetary shock, under flexible and sticky prices, in the domestic economy.

<sup>11</sup>see e.g. Tille (2005), Lane and Milesi-Ferretti (2004), Obstfeld and Rogoff (2005).

<sup>12</sup>The short run comovement between net foreign assets and the real exchange rate however depends the type of underlying shock and can clearly be very different from this long run relationship.

For each of the shocks analyzed I contrast two versions of the model economy. I compare the standard case of symmetric countries with a zero international investment position, when no assets or liabilities are held at steady state, with our case of interest -the model that incorporates non-zero steady state asset and liability positions that allow for valuation effects.

In all figures, the blue solid line corresponds to the economy with the zero international investment position, while the dashed pink line represents the case of interest when asset positions are included. For all variables apart from the current account and net foreign assets, the plotted impulse response are percentage deviations from steady state. The current account and the net foreign asset position, is expressed in percent deviations from steady state output, since, at least in the case of the zero international investment position, these variables are zero at steady state, and the percentage deviation can be used. The first two rows of each of the figures present panels that summarize variables important for understanding the effect of including U.S. gross asset positions in the model: the valuation effect<sup>13</sup>, the net foreign asset position,  $\widehat{NFA}_t$ , the current account to GDP ratio,  $\widehat{CA}_t$ , the rate of nominal depreciation,  $\widehat{\Delta}_t$ , the real exchange rate,  $\widehat{REER}_t$ , and the nominal interest rate differential,  $\widehat{i}_t - \widehat{i}_t^*$ . The lower two rows of each figure present panels that report the responses for other important variables in the domestic and foreign economy, in particular, consumption, (final) output, hours worked, and the capital stock.

### 1.4.1 Productivity shock

Figure 1.2 depicts the response to a 1 percent positive domestic productivity shock. The increase in production in the domestic intermediate good translates into higher output of the final good, in the domestic economy, and to a much smaller degree also abroad. It also leads to a drop in domestic marginal costs, and thus the price for the domestic intermediate good which lead to a worsening in the terms of trade and a depreciation of the real exchange rate. The nominal exchange rate depreciates on impact<sup>14</sup>. The response on the net foreign asset position in the first couple of periods is slightly negative since domestic agents borrow abroad to increase the capital stock, but soon turns positive. Since agents care about smooth consumption over time, they save away some of their extra income for later periods. As a result, the current account drops slightly into negative on impact and is positive thereafter until it converges back to steady state.

I now want to turn to the comparison of the case of zero steady state asset positions with our case of interest. As explained before, the exchange rate depreciation causes a valuation

<sup>13</sup>The valuation effect in loglinear terms is given by  $\frac{\bar{\varepsilon}\bar{B}_F}{\bar{P}}\widehat{\Delta}_t$ .

<sup>14</sup>The responses of bond holding, the trade balance and the current account are in percentage points of output since their steady state values are 0 in the symmetric case of no steady state asset holdings (and small or close to 0 in the second case).

effect of the foreign currency asset position (depicted in panel 1). This transfers wealth from the foreign to the home country, allowing domestic consumers to consume more and work less relative to the standard symmetric zero steady state assets model - the domestic consumption response for the 'valuation effect model' (dashed line) lies above the response in the 'zero asset positions model', and for (domestic) hours worked it lies below. For the case of the productivity shock, however, it does not appear that the presence of valuation effects would fundamentally change any of the macroeconomic dynamics. The responses of all variables depicted, including the current account and the net foreign asset position, do appear to be very similar.

### 1.4.2 Government expenditure shock

We next consider a government expenditure shock (one percent) in the domestic economy, which is shown in figure 1.3. The increase in government consumption increases demand for the final good and increases output, but crowds out investment and private consumption. The increased demand in the home economy also leads to an appreciation of both the exchange rate and a drop in the net foreign asset position/ a current account deficit. In the model version that includes the gross asset and liability positions the nominal exchange rate appreciation leads to a valuation effect that now works against the home country. As a result domestic consumers can consume slightly less and work slightly more in the non-zero asset case, compared to the standard symmetric country case with zero asset postings.

### 1.4.3 Monetary Shock

Figures 1.4 and 1.5 present impulse responses to a domestic expansionary monetary shock under the case of either flexible (figure 1.4) or sticky prices (figure 1.5). The shock is taken to be a 10 basis point drop in the domestic interest rate. Not surprisingly, under flexible prices and in the standard case with zero asset positions at steady state, a monetary shock does not have any effect on the real variables of the model, and only the rate of nominal exchange rate depreciation shows a response. The case is different, however, in the model case with non-zero international investment position. The responses in the case with non-zero assets can therefore entirely attributed to the effect of the revaluation of foreign currency assets.

Figure 1.5 plots the case of sticky prices, under which the expansionary monetary shock now has real effects. As can be seen, the domestic expansionary monetary shock increases home consumption and investment, and, to a lesser degree, through expenditure switching effects, also foreign consumption and investment. Due to a deterioration in the terms of trade,

the exchange rate depreciates. The wealth effect from the revaluation of foreign currency assets is somewhat more visible in the impact on the accumulation of net foreign assets. We also observe that the valuation effect of the exchange rate depreciation lead to a slightly higher surplus on the net foreign asset position relative to the standard case. This is in line with the observation that for the U.S. structure and composition of its asset and liability positions valuation may facilitate the U.S. external adjustment. An exchange rate depreciation does affect the current account positively not only through the traditional 'trade channel' of an improvement in competitiveness, but also through the valuation effect. Again, however, exchange rate induced valuation effects appear to be only of minor importance in the model.

## 1.5 Further avenues in accounting for exchange rate valuation effects

The analysis above has shown us that the inclusion of domestic currency liability and foreign currency asset positions can account for the presence of valuation effects. An exchange rate depreciation creates a positive valuation effect that redistributes wealth from the foreign country to the domestic country. However, the differences between the model with a zero international investment position and the case of interest, that is the magnitude of the valuation effects in the model seems to be rather small. Empirically, several recent papers have emphasized that valuation effects for the U.S. are quite sizable. Gourinchas and Rey (2005) find that historically about a third of payments on U.S. net foreign debt has historically been financed by valuation effects.

I propose some explanations for why the valuation effects in the model are found to be of rather small magnitude. One reason might be that the amount of exchange rate depreciation produced by the shocks in the model is not very high, while in the data exchange rates appear to be much more volatile.

Another explanation for why the model's valuation effects are small are the shortcomings of the analytical model to account for the very strong empirical fact of large deviations from the uncovered interest rate parity (UIP) condition, which states that the return earned on domestic or foreign bonds, measured in the same currency, are expected to always be equal. In the model any change in the exchange rate immediately translates into an offsetting change in the relative returns on domestic versus foreign currency denominated assets, and most of the wealth transferred from one country to another from the exchange rate valuation effect is flowing back in terms of higher interest on liabilities or lower income on assets (everything beyond the impact effect). To explore this avenue I experimented with suspending the uncovered interest rate parity condition by making the risk premium in equation (1.12), which is a function of the aggregate bond holdings, very large. In particular, this is done by

setting the portfolio adjustment cost parameter  $\psi_B$  to a very large number, which I set equal to 1. I then repeat the experiments of the productivity shock, the government expenditure shock, and the monetary policy shock. The resulting dynamic responses are shown in figures 1.6 to 1.9. As can be seen, the difference between the case of a zero international investment position and the model that allows for valuation effects is now much more substantial, and, in a number of cases, even changes the sign of macroeconomic transmission.

## 1.6 Conclusions

This paper has emphasized that because of the process of increased financial integration and the large gross foreign assets and liability positions that have resulted from this process, valuation effects on these positions may be sizeable. Therefore, an otherwise standard two-country model of the international macroeconomy has been suggested in which non-zero foreign assets and liabilities have been specifically incorporated, the domestic country reflecting the U.S., the foreign country being the 'rest-of-the-world'. This model has been compared with and contrasted to the standard symmetric-country model in which neither country holds any asset or liabilities (in steady state), for a variety of shocks.

The inclusion of non-zero asset positions added some insights on the workings of valuation effect in the dynamic behavior of the macroeconomy. In general a real exchange rate depreciation leads, in addition to its usual effect on the trade side, to a positive revaluation of U.S. assets, i.e. it leads to a wealth transfer from abroad to the domestic country, which leads to higher consumption and lower hours worked in the domestic economy. However, the model suggests that valuation effects are of minor magnitude, unless the uncovered interest rate parity condition is suspended.

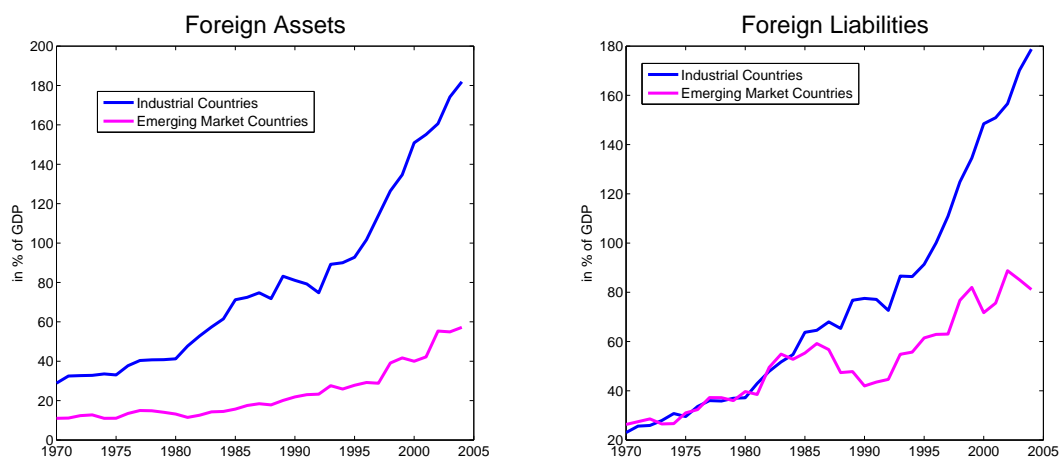
Table 1: Specification of Parameters

$\beta$	Discount factor	0.99
$\sigma$	Coefficient of relative risk aversion	2
$\psi$	inverse labor supply elasticity	2
$\overline{N}, \overline{N}^*$	Hours worked	0.3
$\alpha$	Capital share in CD-prod. fct. in both T and N sector	0.3
$\delta$	Quarterly rate of depreciation	0.021
$\theta$	Elast. among varieties	10
$\phi_K$	Capital adjustment cost	8
$\psi_B$	Portfolio adjustment cost	0.0001 / 1
$\epsilon$	Elast. of subst. between H and F goods	1.5
$\gamma, \gamma^*$	Weight of own country's good in final good prod.	0.85
$\lambda$	parameter of price stickiness in Calvo pricing	0 / 0.75
$n$	Country size	0.5
$\rho_Z, \rho_{Z^*}$	persistence of technology shocks	0.9
$\rho_G, \rho_{G^*}$	persistence of government expenditure shocks	0.9
$n$	Country size	0.5
$\rho_i, \rho_i^*$	weight on past interest rate in Taylor rule	0.72
$\rho_\pi, \rho_\pi^*$	weight on inflation in Taylor rule	1.67
$\rho_Y, \rho_Y^*$	weight on output in Taylor rule	0.04
$\frac{\overline{G}}{\overline{Y}}, \frac{\overline{G}^*}{\overline{Y}^*}$	ratio of government expenditures to output	0.20
$\frac{RER \overline{B}_F}{\overline{Y}}$	foreign currency denominated assets to output	0.50
$\frac{\overline{B}_H}{\overline{Y}}$	domestic currency denominated assets to output	-0.75
$\frac{\overline{b}}{\overline{Y}}$	net foreign assets to output	-0.25

Table 2: Steady State Results

	Zero international investment position	Non-Zero st.st. asset positions
$Y$	0.78500	0.78204
$Y^*$	0.65283	0.65454
$C$	0.48156	0.47937
$C^*$	0.40048	0.40174
$I$	0.14645	0.14626
$I^*$	0.12179	0.12189
$K$	5.85782	5.85044
$K^*$	4.87151	4.87579
$RER$	0.74141	0.74396
$TOT$	0.65164	0.65486
$\overline{RER}\tilde{B}_F$	0.00000	0.52559
$\tilde{B}_H$	0.00000	-0.58653
$\bar{b}$	0.00000	-0.19551





**Figure 1.1:** Foreign Assets and Foreign Liabilities in Industrialized and Emerging Market Countries.  
Source: Lane and Milesi-Ferretti database (Lane and Milesi-Ferretti (2005))

## Domestic Productivity Shock

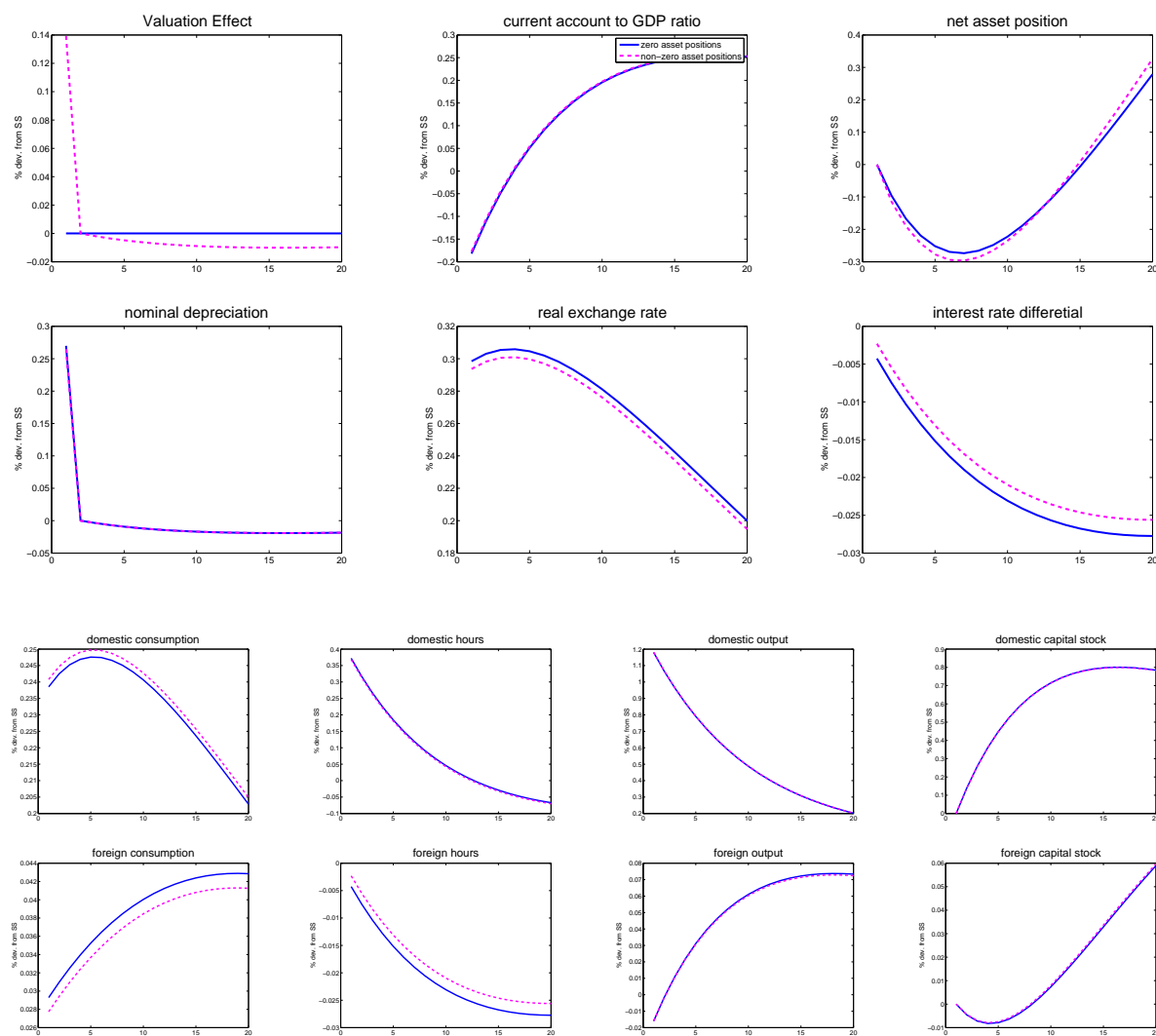
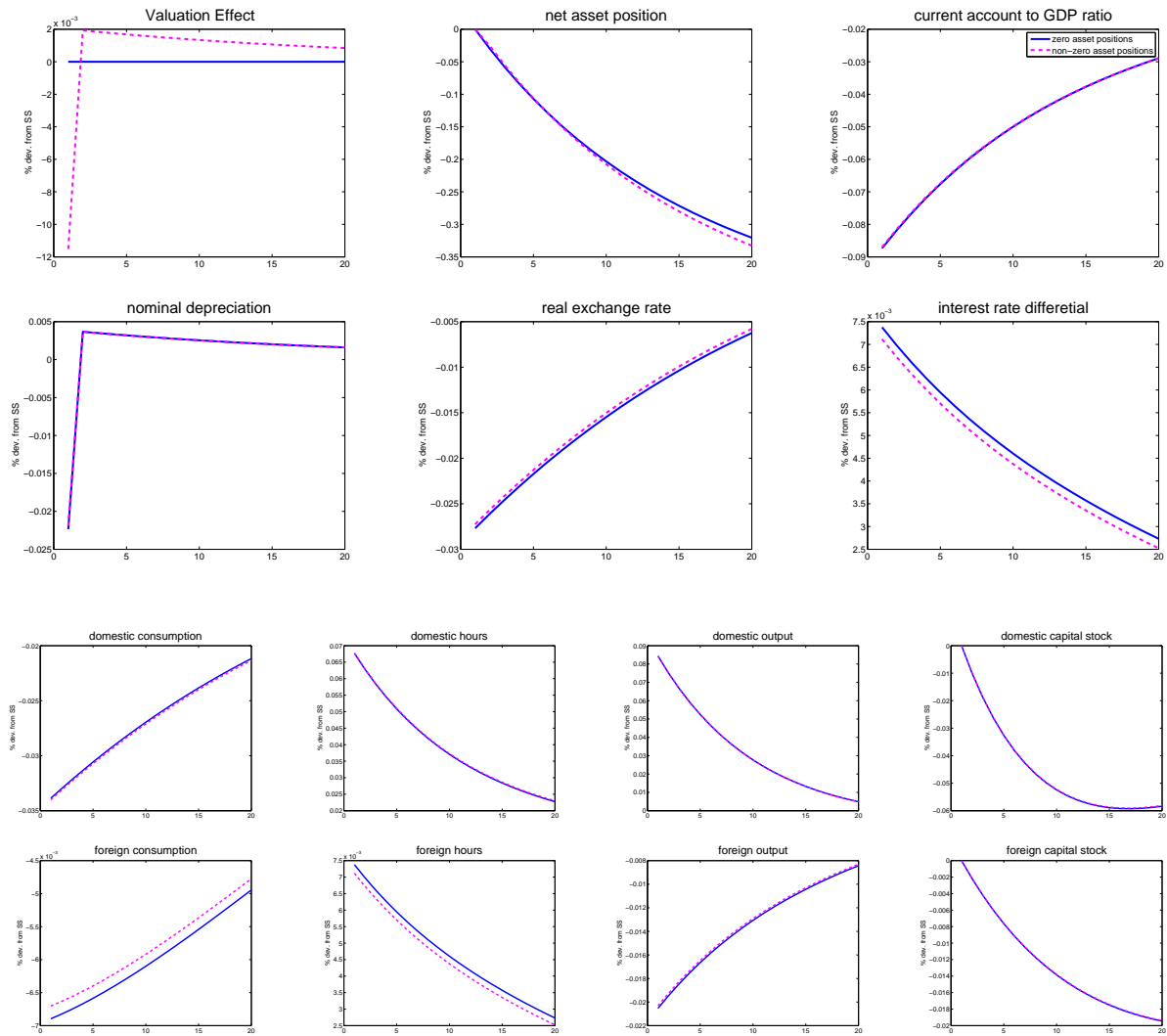


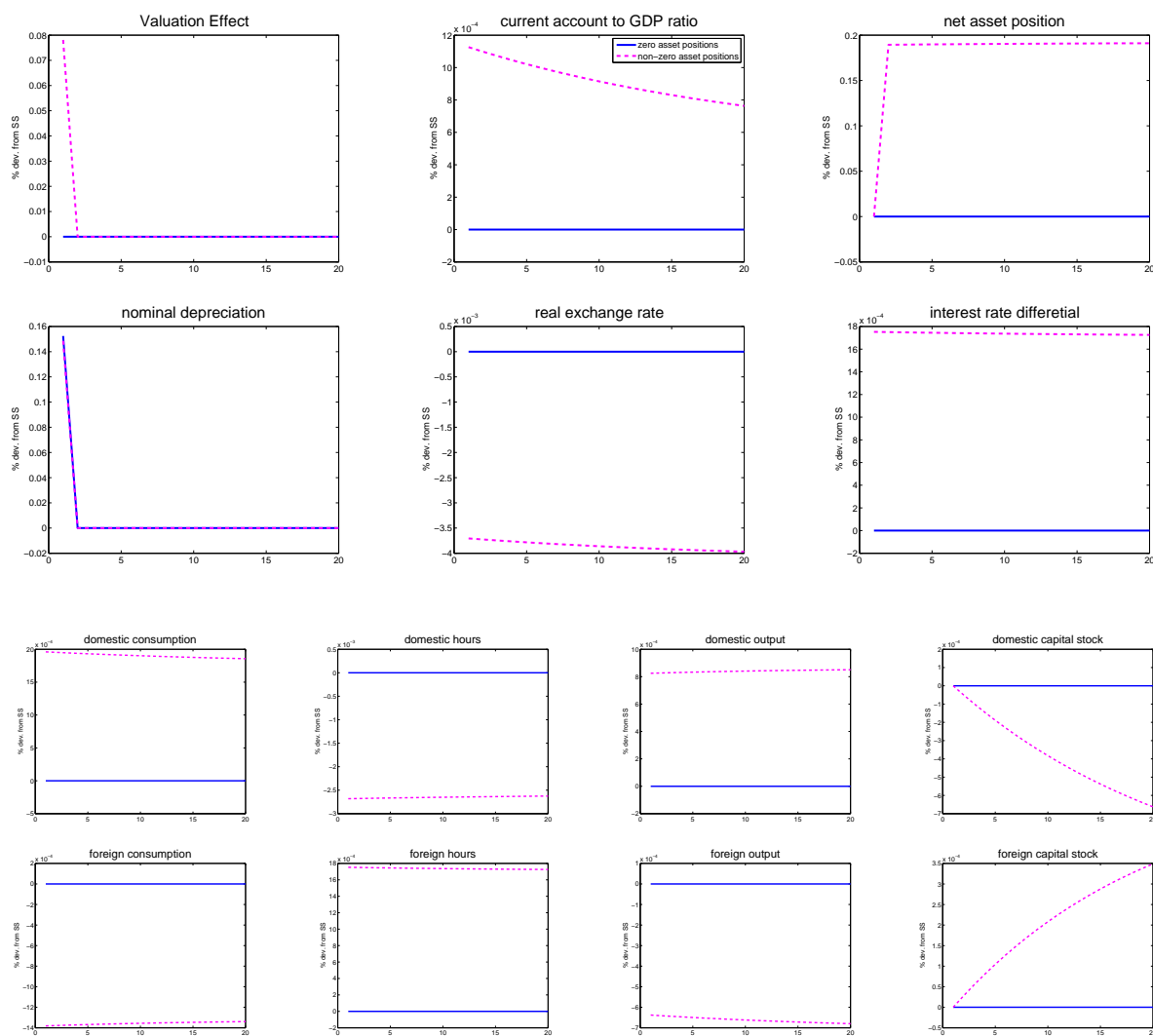
Figure 1.2: Impulse response to a 1 percent domestic productivity shock

## Government Expenditure Shock



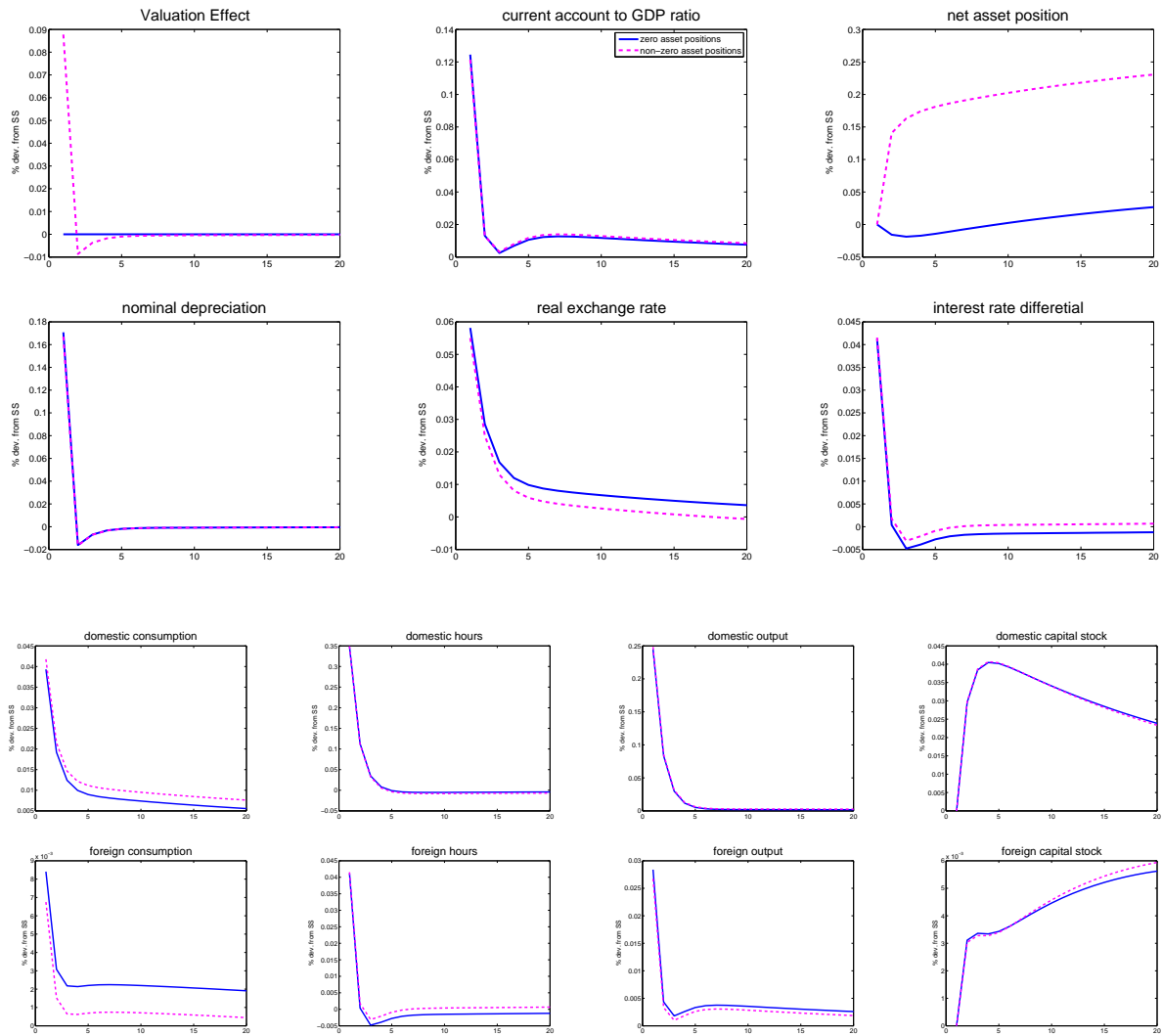
**Figure 1.3:** Impulse response to a 1 percent increase in domestic government expenditure

## Expansionary Monetary Shock, flexible prices



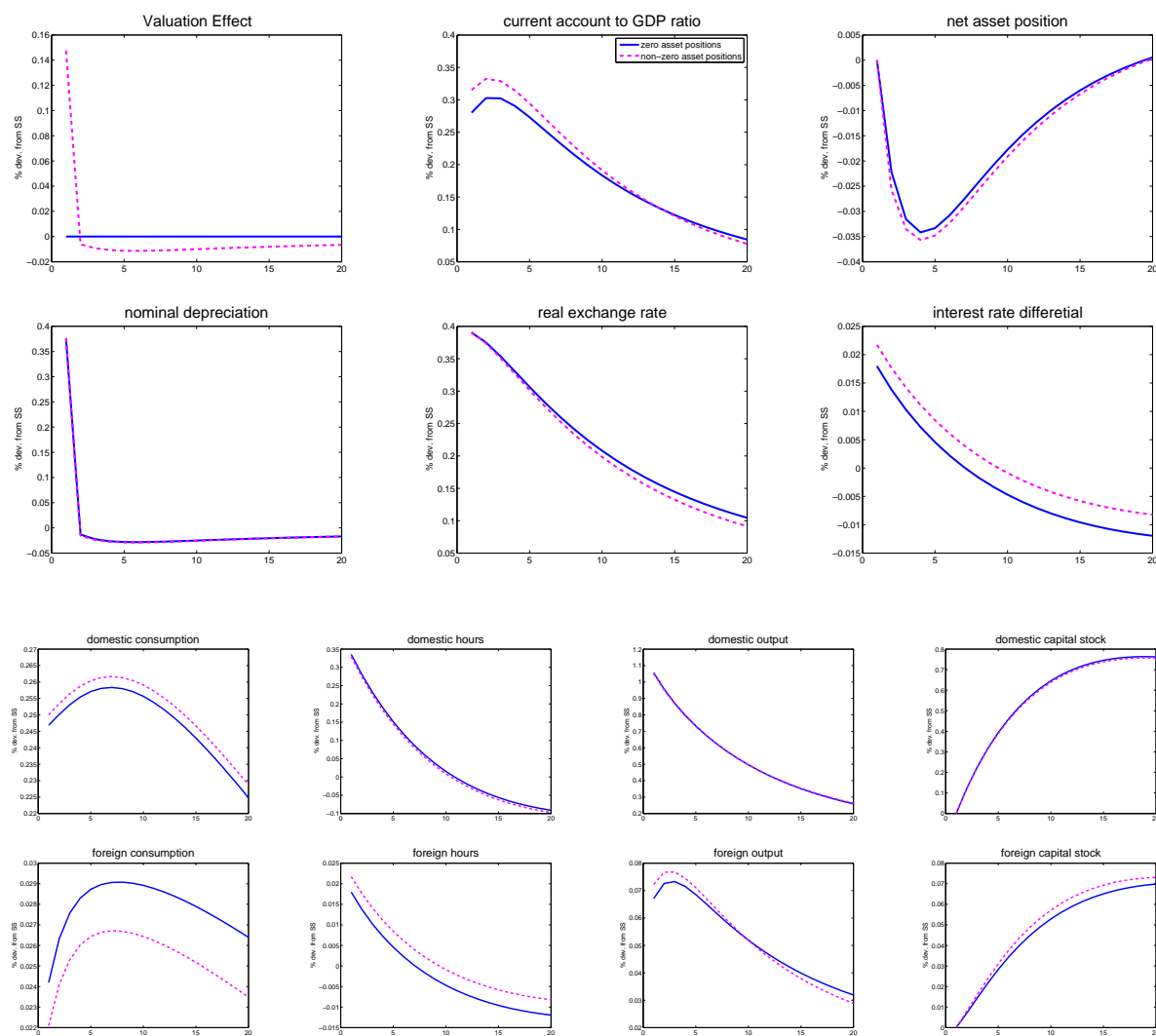
**Figure 1.4:** Impulse response to a 10 basis point drop in the domestic nominal interest rate under flexible prices

## Expansionary Monetary Shock, sticky prices



**Figure 1.5:** Impulse response to a 10 basis point drop in the domestic nominal interest rate under sticky prices

## Domestic Productivity Shock with UIP suspended

**Figure 1.6:** Impulse response to a 1 percent domestic productivity shock

## Government Expenditure Shock with UIP suspended

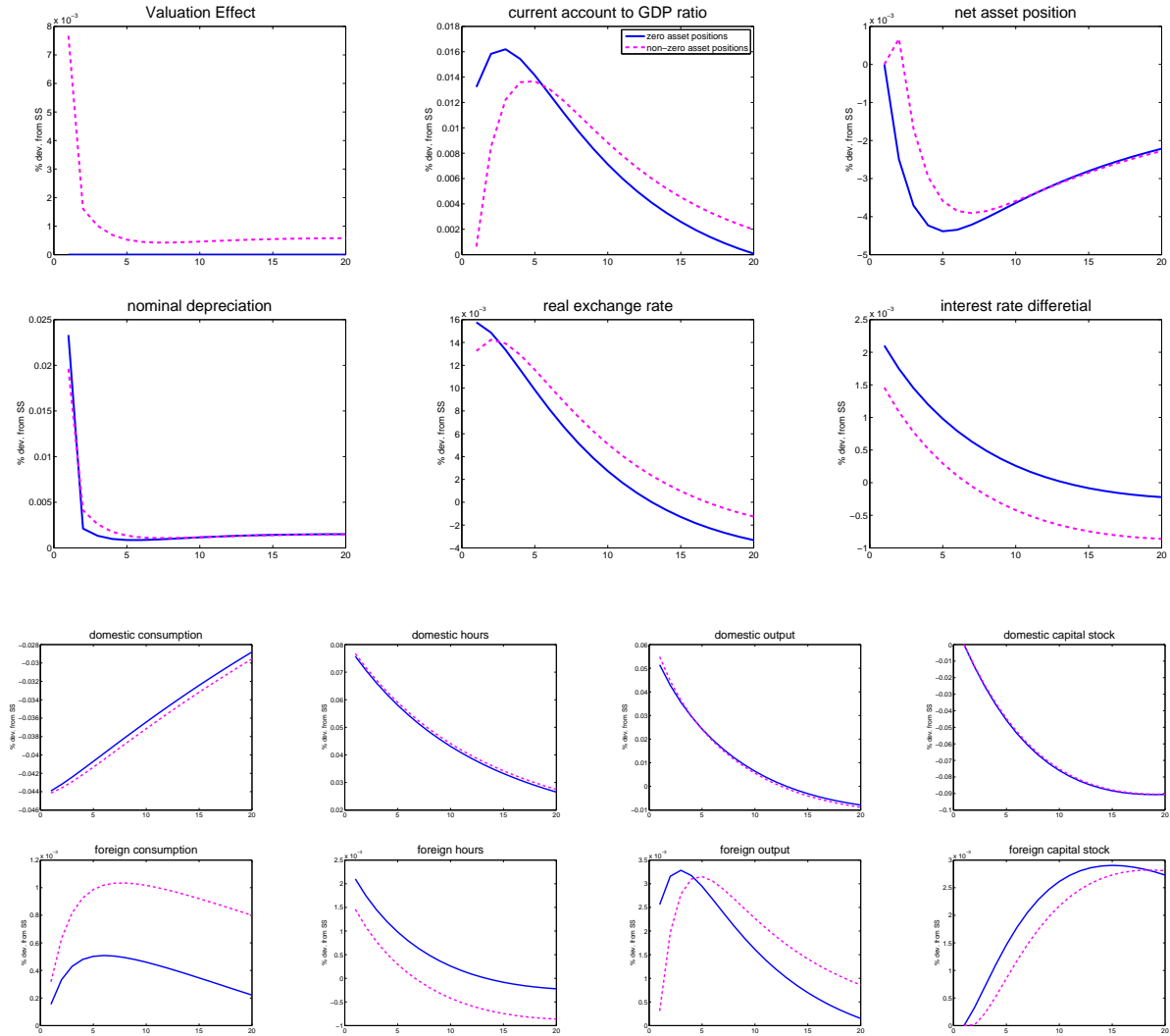
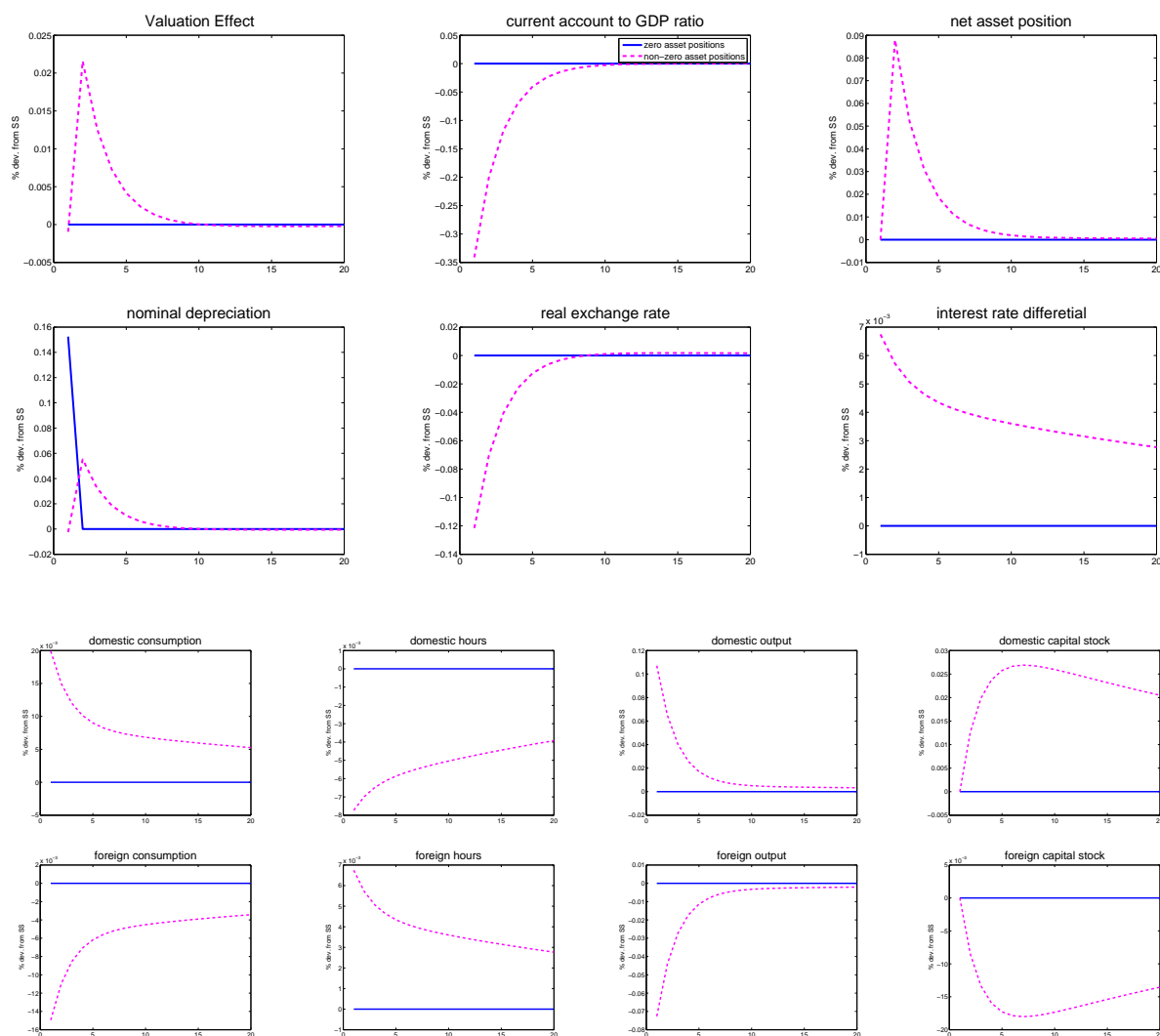


Figure 1.7: Impulse response to a 1 percent increase in domestic government expenditure

---

 Expansionary Monetary Shock, flexible prices, with UIP suspended
 

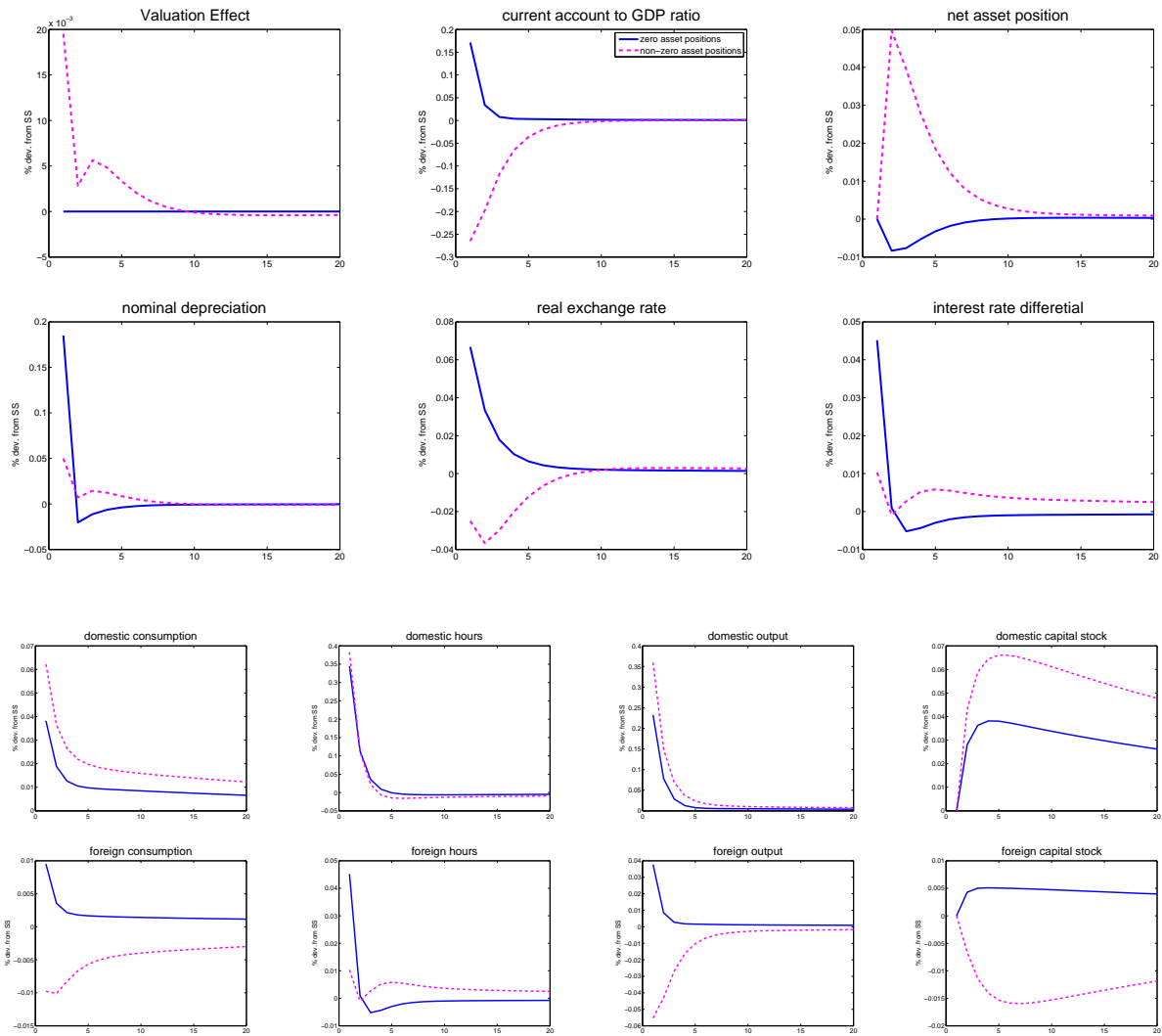
---



**Figure 1.8:** Impulse response to a 10 basis point drop in the domestic nominal interest rate under flexible prices



## Expansionary Monetary Shock, sticky prices, with UIP suspended



**Figure 1.9:** Impulse response to a 10 basis point drop in the domestic nominal interest rate under sticky prices

# Bibliography

- Backus, D. K., Kehoe, P. J. and Kydland, F. E. (1994), ‘Dynamics of the trade balance and the terms of trade: The j-curve?’, *American Economic Review* **84**, 84–103.
- Benigno, P. (2001), ‘Price stability with imperfect financial integration’, *CEPR Discussion Paper Series* (2854).
- Cole, H. L. and Obstfeld, M. (1991), ‘Commodity trade and international risk sharing: How much do financial markets matter?’, *Journal of Monetary Economics* (28), 3–24.
- Corsetti, G. and Pesenti, P. (2001), ‘Welfare and macroeconomic interdependence’, *Quarterly Journal of Economics* (116), 421–446.
- Eichengreen, B., Hausmann, R. and Panizza, U. (2003), ‘Currency mismatches, debt intolerance, and original sin: Why they are not the same and why it matters’, *NBER Working Paper* (10036).
- Eichengreen, B., Hausmann, R. and Panizza, U. (2005), ‘The pain of original sin’.
- Gourinchas, P.-O. and Rey, H. (2005), ‘International financial adjustment’, *NBER Working Papers* (11155).
- Heathcote, J. and Perri, F. (2005), ‘Financial autarky and international business cycles’, *Journal of Monetary Economics* **49**(3), 601–627.
- Klein, P. (2000), ‘Using the generalized schur form to solve a multivariate linear rational expectations model’, *Journal of Economic Dynamics and Control* (24), 1405–1423.
- Lane, P. and Milesi-Ferretti, G. M. (2001), ‘The external wealth of nations - measures of foreign assets and liabilities for industrial and developing countries’, *Journal of International Economics* (55), 263–94.
- Lane, P. and Milesi-Ferretti, G. M. (2002*a*), ‘External wealth, the trade balance, and the real exchange rate’, *IMF Working Paper* (51).
- Lane, P. and Milesi-Ferretti, G. M. (2002*b*), ‘Long term capital movements’, pp. 73–116.

- Lane, P. and Milesi-Ferretti, G. M. (2004), 'The transfer problem revisited: Net foreign assets and real exchange rates', *Review of Economics and Statistics* **86**(4), 841–57.
- Lane, P. and Milesi-Ferretti, G. M. (2005), 'The external wealth of nations mark ii: Revised and extended estimates of foreign assets and liabilities, 1970-2003', *unpublished* .
- Lubik, T. and Schorfheide, F. (2005), 'A bayesian look at new open economy macroeconomics', *NBER Macroeconomics Annual 2005* .
- Obstfeld, M. (2004), 'External adjustment', *Center for International and Development Economics Research Paper* (C04-136).
- Obstfeld, M. and Rogoff, K. (2005), 'The unsustainable us current account position revisited', *NBER Working Paper* (10869).
- Schmidt-Grohe, S. and Uribe, M. (2004), 'Solving dynamic general equilibrium models using a second-order approximation to the policy function', *Journal of Economic Dynamics and Control* **28**, 755–775.
- Tille, C. (2003), 'The impact of exchange rate movements on us foreign debt', *Current Issues in Economics and Finance, Federal Reserve Bank of New York* **9**(1), 755–775.
- Tille, C. (2005), 'Financial integration and the wealth effect of exchange rate fluctuations', *Federal Reserve Bank of New York Staff Report* 226 .
- Yi, K.-M. (2003), 'Can vertical specialization explain the growth of world trade?', *Journal of Political Economy* **111**(1), 52–102.

## Chapter 2

# Can we explain international pricing puzzles 'by force of habit'?

### 2.1 Introduction

The behavior of exchange rates gives rise to several major puzzles in international macroeconomics. Standard open economy models are challenged in accounting for a multitude of features observed in the data. Among these are, first, the negative correlation of the forward premium with the subsequent change in the nominal exchange rate, that is, the violation of the uncovered interest rate parity condition. Second, the volatility of both nominal and real exchange rates. And third, the lack of -or even negative- comovement of relative consumption with the real exchange rate.

A possible explanation for the difficulties that theoretical models face in accounting for these observed regularities might be due to the use of preferences. The choice of preferences determines the measure of marginal utility of wealth, and therefore the stochastic discount factor, which is crucial for the price of trading consumption intertemporally, and, in open economies, intratemporally. Standard preferences, like the widely used constant relative risk aversion preferences, may give a too simple view of what matters for agents' utility by linking it only to the level of current consumption <sup>1</sup>. The key to addressing the above mentioned puzzles may lie in considering a utility function that allows for a richer description of the preference based stochastic discount factor. In this paper I show that a less standard set of preferences, namely habit preferences à la Campbell and Cochrane (1999), hereafter CC,

---

<sup>1</sup>And maybe leisure, for preferences nonseparable in consumption and leisure.

can go a long way in addressing some of these puzzles in an otherwise simple model of the open economy. Their setup gives an expression of the marginal utility of wealth with several desirable properties for explaining exchange rate puzzles: it displays high variability; it depends not only on the level of current consumption, but also on what agents have grown used to -the habit; and it provides a stochastic discount factor (or pricing kernel) that stresses the importance of not only intertemporal substitution effects but also precautionary savings effects on interest rates. In addition, relative risk aversion varies over the cycle -agents are more risk averse when times are bad, and less so when times are good.

The paper succeeds in giving a rationale to deviations from uncovered interest rate parity (UIP) since Campbell and Cochrane preferences are able to produce a time-varying risk premium on foreign exchange. The mechanism is as following: If interest rates behave procyclically, because precautionary savings motives dominate the effect of intertemporal substitution on interest rates, then at times when domestic agents face, say, bad times relative to foreign agents, the domestic interest rate is lower than the foreign interest rate. Since at bad times domestic agents are relatively more risk averse they need to be compensated by a premium in order for them to hold the other country's assets, since these assets contain exchange rate risk from the perspective of the domestic agent. The interpretation of a foreign exchange risk premium evolves nicely. Because the resulting risk premium is time-varying and in particular negatively correlated with expected exchange rate changes, the model is capable of producing the 'right' negative UIP regression coefficient, as found in the data.

Utility is obtained from the difference of consumption over the habit level, or, as Campbell and Cochrane restate it, from the level of consumption and the consumption surplus ratio, that is, by how many percent consumption lies above the habit reference level. Because surplus consumption is volatile and the exchange rate, which is tied to the ratio of marginal utilities, depends on relative surplus consumption Campbell and Cochrane preferences can help in matching the exchange rate volatility observed in the data. Therefore, under the setup of the present paper any exchange rate movements that arrive from exogenous shocks to fundamentals are much more amplified. In addition to exchange rate volatility the model also matches the volatility of other relative prices, that are usually considered in the open macro literature, such as the terms of trade, the ratio of consumer price indices across countries, as well as the relative price of nontradables.

The dependence of relative marginal utilities on surplus consumption in the risk sharing condition can be interpreted as the presence of preference shocks. Since consumption is less than perfectly correlated with surplus consumption it disturbs the perfect relationship between the real exchange rate and relative consumption and can therefore help to lower the Backus-Smith correlation closer to the levels observed in the data, even under complete risk sharing.

The model I set up, presents, apart from the habit specification, a relatively standard way in open economy macroeconomics to think about movements in international relative prices. I adopt a structure with tradable and nontradable goods, over which agents' consumption bundle is defined as a constant elasticity of substitution index. This will allow a realistic parameterization of countries' consumption baskets, which in reality display a large fraction of nontradable consumption and a heavy bias towards the country's own goods in tradable consumption. This setup allows a structured way to think about the behavior of the exchange rates: endogenous movements in the real exchange rate arrive from either movements in the terms of trade or through fluctuations in the relative price of nontraded (to traded) goods across countries. For nominal exchange rates, variations in money growth are another source of fluctuations. A role for money is specified -in particular, money is needed in order to buy goods- since deviations from uncovered interest rate parity are concerned with nominal variables.

The paper is organized as follows. Section 2 presents some stylized facts on each of the puzzles and discusses related literature. Section 3 introduces the model, the parameterization of which is discussed in section 4. Section 5 explains the mechanism used to address the three puzzles and shows some impulse responses. Section 6 presents results of a simulation of the model economy and section 7 concludes.

### 2.1.1 Stylized facts and related literature

This section devotes some time to discuss stylized facts on each of the puzzles addressed in this paper. It gives an overview of the empirical findings of the relevant literature and discusses some of the approaches and mechanisms that have been used to address the puzzles

in theoretical models.

Uncovered interest rate parity, which states that the nominal interest rate differential should be equated to the expected change in the exchange rate, is a central feature of virtually all general equilibrium open economy models. While it would appear logical that investors would demand higher interest rates on currencies that are expected to fall in value, empirical evidence for advanced economies suggests that currency prices for high interest rates tend, instead, to appreciate. This departure from uncovered interest rate parity, also known as the forward premium anomaly, has been extensively documented. Ever since Fama (1984) seminal paper an enormous amount of research has been dedicated to addressing the puzzle. One strand of the literature argues that the behavior of forward and spot exchange rates can be attributed to a time-varying risk premium on foreign exchange<sup>2</sup>. Empirically, the violation of the uncovered interest rate parity condition is usually tested by a simple regression of (actual) exchange rate variations on the nominal interest rate differential. Under the assumption of rational expectations and risk neutral agents, the forward exchange rate is an unbiased estimator of the future spot exchange rate and therefore, since covered interest rate parity holds, the UIP regression should theoretically deliver a regression coefficient of 1. This is severely violated in the data, where, for advanced economies, the UIP coefficient is generally found to be much lower than 1, typically even negative. Following the first strand of the literature, that is, assuming that the true explanation for the behavior of forward and spot exchange rates and for the violation of UIP can be attributed to the existence of a time-varying risk premium, Fama has shown that this implied foreign exchange risk premium would need to satisfy two conditions to match empirical observations. First, the implied risk premium on a currency must be negatively correlated with the expected rate of exchange rate depreciation, and, second, needs to have greater variance than the latter.

The literature dedicated to the uncovered interest rate parity puzzle is enormous and cannot possibly be covered here. Engel (1996) survey provides a good overview of the literature until then. Engel (1999) examines the properties of the foreign exchange risk premium in general equilibrium models with sticky nominal prices. He shows that such models are capable of producing large enough risk premia to match the data; endogenous risk premia arise since

---

<sup>2</sup>Other explanations include the 'peso problem' (i.e. that agents need to learn about structural changes of the economy over time and that during this transitional learning period, market participants make systematic prediction errors) or 'noise trading' (i.e. that agents are actually irrational because they believe the value of an asset depends on information else than economic fundamentals).

under sticky prices monetary shocks do lead to a covariation of consumption and exchange rates. However, the implied risk premium from his models is constant<sup>3</sup>, and therefore does not help explain the negative correlation between the interest rate differential and exchange rate changes. More recently, Alvarez, Atkeson and Kehoe (2006) stress the importance of time-varying risk premia resulting from endogenous market segmentation, Bacchetta and van Wincoop (2006) hold the cost of actively managing foreign exchange portfolios responsible for the failure of UIP, and Burnside, Eichenbaum and Rebelo (2006a) suggest a microstructure approach in addressing the puzzle.

The model I present in this paper is not the first to employ habit preferences in order to address price puzzles in the international economy. Recently, Verdelhan (2006) has made use of Campbell and Cochrane's habit preferences and their ability to produce a time-varying risk premium and has shown the potential of these preferences for models of the open economy. He addresses the forward premium anomaly in a two country one good model. Verdelhan's model economy however is purely in real terms, thus the model cannot strictly speaking address the uncovered interest rate parity puzzle, which is concerned with the behavior of the nominal interest rate differential and nominal spot return. Another recent paper is Moore and Roche (2006) who also employ CC preferences and look at a monetary economy. In their model agents have additive preferences over the difference of a domestic and a foreign country specific good over a good specific habit level. However, under the setup of their model, what they refer to as the real exchange rate is actually the relative price of the foreign to domestic good, that is, the terms of trade, that is linked to the ratio of marginal utilities. Since this ratio is -under CC preferences- highly volatile, it implies a too high volatility of the terms of trade, while the real exchange rate in their model actually is always equal to one.

Another noticeable feature about international relative prices is the empirical evidence on high exchange rate volatility. Both nominal exchange rates as well as real exchange rates are several times as volatile as output. Chari, Kehoe and McGrattan (2002), hereafter CKM, report standard deviations relative to GDP of 4.67 and 4.36 for the quarterly US-European nominal and real exchange rates respectively<sup>4</sup>. Corsetti, Dedola and Leduc (2004) report the real exchange rate to be 3.90 times as volatile as GDP for the U.S. vis-a-vis the rest of the

---

<sup>3</sup>As long as the process for money supply has a constant variance.

<sup>4</sup>The measures of the nominal and real exchange rates in CKM are based on the US versus a European aggregate, which consists of France, Italy, the U.K., and West Germany, and covers the period 1973:1-1994:4.



OECD for annual data <sup>5</sup>. The terms of trade and the relative price of nontradables are much less volatile, 1.68 and 0.86 times the standard deviation of GDP. In addition to being highly volatile nominal and real exchange rates appear to be closely correlated. The volatility of exchange rates is puzzling since consumption paths are found to be very smooth. To match the observed volatility found in the data, two core mechanisms have been put forward as to how to generate large swings of the exchange rate in response to shocks to fundamentals. Backus, Kehoe and Kydland (1995) evoked the first mechanism to generate high exchange rate volatility by choosing a relatively low price elasticity of imports (low intratemporal elasticity of substitution between domestic and foreign goods). CKM on the other hand choose a very high risk aversion that, by exploiting the positive and strict link between the ratio of marginal utilities of consumption and the real exchange rate, in combination with high nominal rigidities has been able to generate large exchange rate volatility<sup>6</sup>.

Finally, exchange rate data display a negative correlation with cross-country consumption ratios. This apparent lack of efficient risk sharing constitutes another puzzle. While it would appear natural that countries should consume more when their consumption basket is relatively cheap compared to the other country, Backus and Smith (1993) have first shown that this is clearly at odds with the data. Corsetti et al. (2004) report the real exchange rate and relative consumption correlation for a variety of countries. Relative to US (the OECD), they find a median correlation of -0.30 (-0.27) in levels and -0.27 (-0.21) for the correlation in first differences. Under standard constant relative risk aversion preferences and complete markets the link between the real exchange rate and relative consumption is one to one. CKM have shown that also under incomplete markets this correlation remains very close to 1. Recent contributions emphasize the importance of nontradables, elasticities of substitution and persistence of the underlying technology processes in addressing the correlation puzzle.

---

<sup>5</sup>The annual data from OECD's Outlook database cover the period 1970-2001.

<sup>6</sup>Corsetti, Dedola and Leduc (2006) show that while CKM also use nominal rigidities, their mechanism also works quite well under flexible prices, as long as national economies are sufficiently insulated from one another by the presence of nontraded goods.

## 2.2 The model

The world consists of two economies, denoted Home and Foreign both of which receive endowments of a nontradable and a tradable good that arrive stochastically every period. The consumption basket in both countries therefore consists of nontradables and domestic and foreign tradables. Consumers have preferences over the difference of the consumption bundle over an external habit reference level. In addition, to buy goods agents face cash-in-advance constraints. Financial markets are complete, in the sense that there exists a complete set of assets that pay a unit of domestic or foreign currency in each possible state.

### 2.2.1 Preferences

Utility is time-inseparable because of the presence of habit persistence. The representative domestic agent maximizes the utility function<sup>7</sup>:

$$E_t \sum_{t=0}^{\infty} \beta^t \frac{(C_t - X_t)^{1-\sigma} - 1}{1-\sigma} \quad (2.1)$$

Where  $X_t$  is the habit level and  $C_t$  is a CES consumption index over tradable and nontradable goods, i.e.

$$C_t = \left[ \omega^{\frac{1}{\mu}} C_{T,t}^{\frac{\mu-1}{\mu}} + (1-\omega)^{\frac{1}{\mu}} C_{N,t}^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}} \quad (2.2)$$

$$C_t^* = \left[ \omega^{*\frac{1}{\mu}} C_{T,t}^{*\frac{\mu-1}{\mu}} + (1-\omega^*)^{\frac{1}{\mu}} C_{N,t}^{*\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}} \quad (2.3)$$

and where tradable good consumption consists of domestic and foreign tradables, bundled together as:

$$C_{T,t} = \left[ \gamma^{\frac{1}{\epsilon}} C_{H,t}^{\frac{\epsilon-1}{\epsilon}} + (1-\gamma)^{\frac{1}{\epsilon}} C_{F,t}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \quad (2.4)$$

$$C_{T,t}^* = \left[ \gamma^{*\frac{1}{\epsilon}} C_{H,t}^{*\frac{\epsilon-1}{\epsilon}} + (1-\gamma^*)^{\frac{1}{\epsilon}} C_{F,t}^{*\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \quad (2.5)$$

---

<sup>7</sup>The problem for the foreign representative agent is equivalent.

Parameters  $\mu$  (and  $\gamma$ ) express the weight of consumption of tradables in overall consumption (of consumption of domestic tradables in tradable consumption). In particular,  $\gamma > 0$  ( $\gamma^* < 0$ ) expresses a home bias in consumption of tradables.

The relation between consumption and habit can be captured by the *surplus consumption ratio*:

$$S_t = \frac{C_t - X_t}{C_t} \quad (2.6)$$

The surplus consumption ratio increases with consumption.  $S_t = 0$  corresponds to an extremely bad state in which consumption is equal to the habit;  $S_t$  approaches 1 as consumption rises relative to habit. Relative risk aversion, or the local curvature of the utility function, denoted  $\eta_t$ , is state dependent and is related to the surplus consumption ratio by:

$$\eta_t = -\frac{U_{CC}C}{U_C} = \frac{\sigma}{S_t} \quad (2.7)$$

Therefore, in bad times, when consumption is close relative to habit or when surplus consumption is low, risk aversion is high, that is, the local curvature of the utility function is high.

Finally, we need to specify how habit level  $X_t$  evolves. The habit acts as a trend line for consumption, utility is derived by how much consumption lies above the trend. This proxies the idea that people may get used to an accustomed standard of living, so a fall in consumption hurts after a few years of good times, even though the same level of consumption might have seemed very pleasant if it arrived after years of bad times. The easiest specification to model the habit level would be as an autoregressive process that moves slowly in response to consumption<sup>8</sup>.

I closely follow Campbell and Cochrane in specifying instead an exogenous process for how the (log) surplus consumption evolves. The habit specification is *external*, in that agents take the habit level as given and each individual's habit  $X_t$  responds to the history of aggregate consumption  $C^a$ . Campbell and Cochrane's process for  $\log S_t^a = \frac{C_t^a - X_t}{C_t^a}$  implies that habit adapts nonlinearly to the history of consumption and makes sure that habit is always below

---

<sup>8</sup>e.g.  $X_t = (1 - \delta) X_{t-1} + \lambda C_t$ , where  $X$  is the habit level,  $\delta$  governs the rate of depreciation of the stock of habit, and the parameter  $\lambda$  measures the sensitivity of the stock of habit to current consumption.

consumption and that therefore marginal utility is always kept finite and positive<sup>9</sup>. Using lower-case letters to denote logs of corresponding upper-case letters,  $s_t^a$  evolves according to:

$$s_{t+1}^a = (1 - \phi) \bar{s} + \phi s_t^a + \lambda(s_t^a) [c_{t+1}^a - c_t^a - g] \quad (2.8)$$

Equation (2.8) shows that (log) surplus consumption behaves as an autoregressive process with parameter  $\phi$ , however, also unexpected news about consumption growth affect how  $s_{t+1}$  evolves<sup>10</sup>.  $\lambda(s_t^a)$  is the *sensitivity function* of how the surplus consumption is influenced by (simultaneous) deviations of consumption growth from the average growth rate of the economy,  $g$ . The nonlinear process in equation (2.8) not only prevents consumption from falling below habit which would result in infinite or negative marginal utility, but also avoids another problem. A linear specification for habit typically implies interest rates that vary a great deal over time. Allowing a non-constant sensitivity function  $\lambda(s_t)$  allows to control interest rate variation and is essential to generate time-varying risk premia.

The functional form of  $\lambda(s_t)$ , again following Campbell and Cochrane (1999), is chosen in order to satisfy three conditions: 1) the risk-free interest rate is constant, if parameter  $B = 0$  in eq. (2.10)<sup>11</sup>. 2) Habit is pre-determined at the steady state  $s_t = \bar{s}$ . 3) Habit is predetermined near steady state, or equivalently, habit moves non-negatively with consumption everywhere. These three considerations lead to the following steady state surplus consumption ratio  $\bar{S}$  and specification of the sensitivity function:

$$\lambda(s_t) = \frac{1}{\bar{S}} \sqrt{1 - 2(s_t - \bar{s})} - 1 \quad \text{when } s_t \leq s_{\max}, \text{ and } 0 \text{ elsewhere} \quad (2.9)$$

$$\bar{S} = \sigma_c \sqrt{\frac{\sigma}{1 - \phi - \frac{B}{\sigma}}} \quad (2.10)$$

---

<sup>9</sup>Note that, as CC point out, a first order approximation of equation (2.8) near the steady state implies that log habit  $x_t$  is approximately a standard linear specification in which (log) habit responds slowly to consumption. Eq. (2.8), approximated at the steady state gives:

$$x_{t+1} = [(1 - \phi)(\bar{x} - \bar{c}) + g] + \phi x_t + (1 - \phi) c_t$$

<sup>10</sup>In equilibrium, identical individuals choose the same level of consumption, so  $C_t = C_t^a$  and  $S_t = S_t^a$ . Therefore, from now on the superscripts will be dropped.

<sup>11</sup>Under CC's additional assumptions that consumption is given exogenously and consumption growth is a random walk with i.i.d. shocks. I will show that in the present model this is approximately so.

$$s_{\max} = \bar{s} + \frac{(1 - \bar{S}^2)}{2} \quad (2.11)$$

Appendix C reproduces proofs of conditions 1) to 3) given by CC and plots the  $\lambda$  function as well as the responsiveness of (log) habit with respect to (log) consumption for various levels of surplus consumption for the parameterization of the model in the present paper as described in section 4.

### 2.2.2 Money

Households face cash-in-advance constraints. In order to buy goods they need to acquire currency. Consumers acquire the cash they need for period  $t$  by first visiting asset markets at the beginning of period  $t$  (after period  $t$  shocks have been observed)<sup>12</sup>. I will assume that home residents must buy all goods with home currency, and foreign agents must buy all goods with foreign currency. Therefore, the domestic and foreign agent's cash-in-advance constraints in period  $t$  are given by:

$$M_t \geq P_t C_t \quad M_t^* \geq P_t^* C_t^* \quad (2.12)$$

Money supply is given by a simple money growth rule:

$$\log \left( \frac{M_{t+1}}{M_t} \right) = \pi_{t+1} = (1 - \rho_\pi) \bar{\pi} + \rho_\pi \pi_t + u_{\pi,t+1} \quad u_{\pi,t+1} \sim N(0, \sigma_{u_\pi}) \quad (2.13)$$

$$\log \left( \frac{M_{t+1}^*}{M_t^*} \right) = \pi_{t+1}^* = (1 - \rho_\pi) \bar{\pi}^* + \rho_\pi \pi_t^* + u_{\pi,t+1}^* \quad u_{\pi,t+1}^* \sim N(0, \sigma_{u_\pi}^*) \quad (2.14)$$

Since there are flexible prices we assume that the law of one price holds so that:

$$P_{H,t} = \varepsilon_t P_{H,t}^* \quad (2.15)$$

---

<sup>12</sup>In a production economy that would mean that producers have to hold the cash until next period, and that inflation therefore would act like a 'tax' on production. In an endowment economy however, since output growth is unaffected by unexpected money growth, so is consumption growth.

$$P_{F,t} = \varepsilon_t P_{F,t}^* \quad (2.16)$$

### 2.2.3 Endowments

The rest of the model is as follows: The output endowment vector can be described as  $\mathbf{y}_t = g\mathbf{1} + \tilde{\mathbf{y}}_t$ , where  $\mathbf{1}$  is a 4x1 vector of ones and  $\mathbf{y}_t = [y_{N,t}, y_{T,t}, y_{N,t}^*, y_{T,t}^*]'$ . Output therefore grows at rate  $g$  each period. I assume that random disturbances of output endowments arrive every period and follow a lognormal AR(1) process.

$$\tilde{\mathbf{y}}_{t+1} = \Omega \tilde{\mathbf{y}}_t + \mathbf{u}_{t+1} \quad \mathbf{u}_{t+1} \sim N(0, V(\mathbf{u})) \quad (2.17)$$

where  $\mathbf{u} = [u_N, u_T, u_N^*, u_T^*]'$  has variance-covariance matrix  $V(\mathbf{u})$  and  $\Omega$  is a 4x4 matrix of coefficients describing the autocorrelation properties of the shocks.

Resource constraints are given by:

$$Y_{T,t} = C_{H,t} + C_{H,t}^* \quad (2.18)$$

$$Y_{T,t}^* = C_{F,t} + C_{F,t}^* \quad (2.19)$$

$$Y_{N,t} = C_{N,t} \quad (2.20)$$

$$Y_{N,t}^* = C_{N,t}^* \quad (2.21)$$

### 2.2.4 Consumer Optimization and Optimality conditions

The home representative agent maximizes utility equation, eq. (2.1), subject to cash-in-advance constraints, eq. (2.12), and subject to the budget constraint under complete markets,

eq. (2.22). There exists a complete set of Arrow-Debreu securities paying one unit of currency if state  $s$  occurs. Let  $Q(s^{t+1} | s^t)$  denote the price in state  $s$  in period  $t$  of an Arrow-Debreu security that delivers one unit of domestic currency in state  $s'$  at time  $t + 1$ . Similarly,  $Q^*(s^{t+1} | s^t)$  is the price of an Arrow-Debreu security that pays one unit of foreign currency if state  $s'$  at time  $t + 1$  occurs. In addition the representative agent chooses a forward position in foreign exchange,  $x_{t+1}$ . The forward rate  $F_t$  (defined here as the home currency cost of buying a unit of foreign exchange one period forward) is known at the time the forward contract is entered into, prior to the realization of shocks.

$$\sum_{s^{t+1}} Q(s^{t+1} | s^t) B(s^{t+1}) + \varepsilon_t \sum_{s^{t+1}} Q^*(s^{t+1} | s^t) B^*(s^{t+1}) + M_t - M_{t-1} = \quad (2.22)$$

$$B_t + \varepsilon_t B_t^* + x_t (F_{t-1} - \varepsilon_t) + P_{H,t} Y_{H,t} + P_{N,t} Y_{N,t} - P_{H,t} C_{H,t} - P_{F,t} C_{F,t} - P_{N,t} C_{N,t}$$

which results in the following first order conditions<sup>13</sup>:

$$C_{H,t} = \gamma \omega \left( \frac{P_{H,t}}{P_{T,t}} \right)^{-\epsilon} \left( \frac{P_{T,t}}{P_t} \right)^{-\mu} C_t \quad (2.23)$$

$$C_{F,t} = (1 - \gamma) \omega \left( \frac{P_{F,t}}{P_{T,t}} \right)^{-\epsilon} \left( \frac{P_{T,t}}{P_t} \right)^{-\mu} C_t \quad (2.24)$$

$$C_{N,t} = (1 - \omega) \left( \frac{P_{N,t}}{P_t} \right)^{-\mu} C_t \quad (2.25)$$

$$1 = E_t \left\{ \beta \left( \frac{S_{t+1}}{S_t} \right)^{-\sigma} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} (1 + i_t) \right\} \quad (2.26)$$

$$1 = E_t \left\{ \beta \left( \frac{S_{t+1}}{S_t} \right)^{-\sigma} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{\varepsilon_{t+1}}{\varepsilon_t} \frac{P_t}{P_{t+1}} (1 + i_t^*) \right\} \quad (2.27)$$

<sup>13</sup>having plugged in for the Lagrange multiplier on the budget constraint,  $\lambda_t = S_t^{-\sigma} C_t^{-\sigma} P_t^{-1}$ , and where  $(1 + i_t) = \frac{1}{Q_t}$  is the interest rate on domestic currency Arrow-Debreu securities and  $(1 + i_t^*)$  is the foreign nominal interest rate.

$$0 = E_t \left\{ \beta (S_{t+1} C_{t+1})^{-\sigma} P_{t+1}^{-1} (F_t - \varepsilon_{t+1}) \right\} \quad (2.28)$$

$$M_t = P_t C_t \quad (2.29)$$

Similar first order conditions can be derived from the foreign representative agent's problem. Combining Home's and Foreign's Euler equations (with respect to same currency denominated AD securities) and iterating back to 0 delivers the following familiar expression for the exchange rate under complete markets:

$$\varepsilon_t = \left( \frac{S_t^* C_t^*}{S_t C_t} \right)^{-\sigma} \frac{P_t}{P_t^*} \quad (2.30)$$

This is the risk sharing condition. An internationally efficient allocation implies that the marginal utility of consumption, weighted by the real exchange rate,  $RER_t = \frac{\varepsilon_t P_t^*}{P_t}$ , should be equalized across countries.

Combining equation (2.28) with (2.26) and (2.27) gives the covered interest rate parity condition, i.e. the forward premium expressed by the interest rate differential:

$$\frac{F_t}{\varepsilon_t} = \frac{(1 + i_t)}{(1 + i_t^*)} \quad (2.31)$$

Finally, the relative price of exports to imports, the terms of trade is defined as  $TOT_t = \frac{P_{F,t}}{P_{H,t}}$ .

Equations (2.23)-(2.30) and (2.8)-(2.11) and their foreign counterparts, together with resource constraints (2.18)-(2.21) and exogenous processes, equations (2.13)-(2.14) and (2.17) complete the description of the economy.

## 2.3 Parameterization

Table 1 presents the baseline parameterization of the model. For the specification of the consumption basket there is a large literature, with a broad range for the values of intratemporal elasticities (both between nontradables and tradables as well as between domestic and foreign



tradable goods). I follow Stockman and Tesar in their parameter choice on the weight of non-tradable consumption and the elasticity between tradables and nontradables. The parameter for the trade elasticity,  $\epsilon$ , is taken from Backus et al. (1994) and is equal to 1.5, and a home bias is specified,  $\theta = 0.75$ .

The curvature parameter of the utility function  $\sigma$  is set to 2 a value similar to the one chosen by CC. Recall however, that the coefficient of relative risk aversion is equal to  $\frac{\sigma}{S_t}$  and therefore much higher. The subjective discount factor  $\beta$  is set equal to .986, which, together with the economy's growth rate,  $g$ , of 0.47 percent and the value of  $\sigma$  imply a quarterly real interest rate of 0.55 percent. Persistence of the process how the log habit evolves is set to 0.985. Parameter  $B$  is essential for obtaining the 'right' negative coefficient in the uncovered interest rate parity regressions. In particular, with  $B$  negative the precautionary savings effect on interest rates outweighs the intertemporal substitution effect and interest rates behave procyclically. The steady state level of surplus consumption implied by this parameterization is 4.8 % and the implied  $s_{\max}$  lies at 7.8%. As for the endowment processes, I choose to look at temporary output shocks around the growth path, unlike CC or Verdelhan (2006) who consider random walk consumption processes. Because sectoral data is difficult to obtain at the quarterly level, I specify a rather simple process for the output endowments. First, shocks are assumed to be persistent, with an autocorrelation of 0.95. Second, the standard deviation of the innovations is set to 0.007 and their correlation across countries to 0.25, while the correlation across sectors is set to zero. Finally, we assume that there are no spillovers across countries and sectors. The parameters of the money growth processes are taken from Moore and Roche (2006) who estimate an AR(1) process for base money (M1) from U.S. data from the Federal Reserve Bank of St.Louis. Finally, the model is symmetrically specified, the same set of parameters holding for the foreign economy.

## 2.4 The mechanism

This section lays out the mechanism of how the present model is able address the uncovered interest rate parity puzzle, high exchange rate volatility and the consumption-real exchange rate correlation. It first discusses some of the properties of CC preferences and in how they

give expressions of the marginal utility of consumption and the conditional moments of the growth of the marginal utility of consumption that are desirable for addressing international price puzzles. Later, I plot some impulse responses to illustrate the mechanism at work.

Purely consumption-based models in the open economy face very much the same kind of problems as in closed economies, where relatively smooth consumption would seem to imply counterfactually low equity premia, or, equivalently, high equity premia would seem to imply counterfactually high consumption volatility. In the open economy smooth consumption paths would suggest to imply relatively little volatile exchange rates, if preferences are based on the level of consumption only.

Like in the closed economy the way to resolve these problems may be to find 'new utility functions' which better describe the marginal utility of wealth and which give a rationale to both smooth consumption paths and volatile exchange rates. The marginal utility of wealth is also what determines the preference based stochastic discount factor<sup>14</sup>, and therefore interest rates.

Table 2 contrasts the expressions of marginal utility, the stochastic discount factor and the coefficient of relative risk aversion of standard constant relative risk aversion preferences with those implied by Campbell and Cochrane habit preferences. Under the latter, marginal utility of consumption today depends on variables other than consumption today, because of inseparability across time. If good times lead people to acquire 'taste for the good life', higher consumption in the past might *raise* rather than lower the marginal utility of consumption today. Also, the conditional moments of the (log) stochastic discount factor do not only depend on consumption growth, but in addition, also on the growth in surplus consumption.

From equation (2.30), making use of eq. (2.29) and taking logarithms, the log real and nominal exchange rate under complete markets can be expressed as:

$$rer_t = -\sigma(c_t^* - c_t) - \sigma(s_t^* - s_t) \quad (2.32)$$

---

<sup>14</sup>That is, the intertemporal marginal rate of substitution, as it is generally referred to in macroeconomics. Lettau and Uhlig (1997) however stress that expression in fact summarizes both attitudes towards intertemporal substitution as well as attitudes towards risk aversion of an agent that faces the problem of substituting one unit of consumption at time  $t$  versus a bundle of consumption at date  $t+1$ , that is one unit for each contingency. Since especially for CC preferences both attitudes matter, I prefer to call it the stochastic discount factor throughout the paper.

$$e_t = -(\sigma - 1)(c_t^* - c_t) - \sigma(s_t^* - s_t) - (m_t^* - m_t) \quad (2.33)$$

Inspecting these expressions it becomes clear that exchange rates, both real and nominal, can vary a great deal even when consumption is relatively smooth since it depends on (relative) surplus consumption, which is very volatile.

Eq. (2.32) also shows that the tight link between relative consumption and the behavior of the real exchange rate can be broken as long as surplus consumption is not perfectly correlated with consumption. Because of the nonlinear process for how the habit evolves, surplus consumption moves very closely with consumption only when the economy is close to the steady state. They move together rather little when consumption is temporarily very high or very low relative to its long run values<sup>15</sup>. Since the behavior of exchange rates is mostly determined by movements in surplus consumption this breaks the tight link between relative consumption and the real exchange rate.

From taking logs of eq. (2.26) and by making use of the lognormality of the model the log real and nominal interest rate can be written as minus the conditional expectation of the log stochastic discount factor minus half its conditional variance:

$$\begin{aligned} r_t = & -E_t \{ \ln(\beta) - \sigma(s_{t+1} - s_t) - \sigma(c_{t+1} - c_t) \} \\ & - \frac{1}{2} \text{Var}_t \{ -\sigma(s_{t+1} - s_t) - \sigma(c_{t+1} - c_t) \} \end{aligned} \quad (2.34)$$

$$\begin{aligned} i_t = & -E_t \{ \ln(\beta) - \sigma(s_{t+1} - s_t) - (\sigma - 1)(c_{t+1} - c_t) - (m_t^* - m_t) \} \\ & - \frac{1}{2} \text{Var}_t \{ -\sigma(s_{t+1} - s_t) - (\sigma - 1)(c_{t+1} - c_t) - (m_t^* - m_t) \} \end{aligned} \quad (2.35)$$

Appendix B derives expressions for the log real and nominal interest rate<sup>16</sup>. In this

<sup>15</sup>This can be seen clearly from 2.5 in the appendix.

<sup>16</sup>Although this is mostly straightforward, it involves one difficulty. In order to derive expressions for the conditional expectation and variance of the growth in surplus consumption and money, one just needs to plug in from the exogenous processes. The difficulty however lies in deriving expressions for the conditional expectation and variance of consumption growth, which is an endogenous variable depending nonlinearly on the underlying output processes and relative prices. To get an approximate expression for consumption growth I solve a loglinearized version of the model (around the nonstochastic steady state). Since this solution describes

derivation, the real interest rate -and, abstracting from monetary factors for now, the nominal interest rate- is determined by two factors, one negatively linked to deviations of surplus consumption over its long run value, one positively linked. The first of these terms is the effect of *intertemporal substitution*, which is related to the conditional expectation of the log stochastic discount factor. In bad times, when the (log-) surplus consumption ratio is below its steady state value, the agent wants to borrow in order to smooth consumption, which tends to increase the interest rate. But there is also a second effect, that, unlike under more standard CRRA preferences, is not of minor magnitude: the *precautionary savings effect*, which comes from the conditional variance of the log stochastic discount factor<sup>17</sup>. Now, in bad times, when the (log-) surplus consumption ratio is below its steady state value, people are more risk averse (recall that the coefficient of relative risk aversion is given by  $\frac{\sigma}{S_t}$ ), so want to save less, which tends to decrease the real interest rate.

While Campbell and Cochrane (1999) choose a parameterization in which the intertemporal substitution and the precautionary savings effect exactly offset each other such that the real interest rate is constant, they show that it is essentially a matter of parameterization which effect dominates, and, as a result, whether the interest rate behaves countercyclical or procyclical. Given the parameterization of section 4, in the present model, the precautionary savings effect on interest rates dominates, and as a result, interest rates behave procyclical.

At this point it is useful to recall Fama (1984) decomposition of the forward discount and his conclusions on how to rationalize deviations from UIP. In particular, he decomposes the forward discount, which by covered interest rate parity eq. (2.31) is given by the nominal interest rate differential, into the sum of expected spot return and the risk premium:

$$\begin{aligned}
 i_t - i_t^* &= \\
 f_t - e_t &= \underbrace{E_t[e_{t+1} - e_t]}_{q_t} + \underbrace{[f_t - E_t(e_{t+1})]}_{p_t} \quad (2.36) \\
 &= q_t + p_t
 \end{aligned}$$

---

endogenous variables as linear functions of the state variables, it is then easy to take the conditional expectation and variance and of approximate consumption growth. Appendix A provides further details.

<sup>17</sup>Under standard CRRA preferences the precautionary savings effect, that is the variance effect of the log stochastic discount factor is relatively small (and, as long as the lognormal forcing process is homoscedastic, constant). CRRA preferences therefore cannot account for a large (or time-varying) risk premium.

From this decomposition it is then clear that in a regression of actual changes in the (log) exchange rate on the interest rate rate differential,  $(e_{t+1} - e_t) = \alpha + \beta(i_t - i_t^*) + u_{t+1}$ , the sign and size of the regression coefficient  $\hat{\beta}$  depends on the variance and covariance of the variables in the above equation. In particular, to replicate the negative UIP coefficient  $\hat{\beta} = \frac{Cov\{q, q+p\}}{Var(q+p)} = \frac{Cov(q, p) + Var(q)}{Var(q+p)}$ ,  $p$  and  $q$  need to have a negative covariance, and  $p$  needs to have greater variance than  $q$ . With the assumption that interest rates behave procyclically, the two conditions Fama outlines are satisfied.

To illustrate, consider the workings of a shock to domestic nontradable output. Figure 2.2, which plots the impulse responses to that shock, shows that this increases aggregate output by half a percent. Domestic consumption of nontradables goes up one by one with the increase in domestic nontradable output, which drives up domestic aggregate consumption. The higher abundance of domestic nontradables also decreases the relative price of nontradable goods to tradable goods at home which depreciates the exchange rate. Note that because of the presence of surplus consumption in expression (2.30), which is very volatile, the exchange rate depreciation is substantial, more than 4 times as large as the increase in output. As figure 2.2 shows, surplus consumption goes up by almost 4% at home and 3% at foreign, driven by increases in consumption. This addresses the volatility puzzle. Now, with procyclical interest rates the forward discount, which by equation (2.31) is equal to the nominal interest rate differential, is positive at a time when the expected rate of change in the exchange rate is appreciating (back to its steady state value, after a (unexpected) depreciation on impact of the arrival of the shock).

Appendix B derives expressions for the forward discount, expected spot return and the risk premium. As can be seen from the last panel in figure 2.2, in response to a shock in nontradable output, Fama's conditions for obtaining a negative coefficient in the UIP regression, are satisfied, since the risk premium is both negatively correlated with the expected change in the exchange rate and has higher variance. The negative relationship that gives rise to a negative UIP coefficient can also be seen from the second to last panel, which plots the interest rate differential on the actual change in the exchange rate.

One thing about figure 2.2 deserves mention. While it plots the nominal interest rate differential and nominal expected and actual exchange rate depreciation, these are the responses

to a real shock. Therefore, it should be clear that the nominal interest rates increase because the real interest rates go up. As will be shown in the next section, when undertaking a simulation of the model economy, the presence of money will generally make nominal interest rates less procyclical than real interest rates, and will in general result in a less negative coefficient of a regression of nominal spot return on the nominal interest rate differential, than if we were to run the same regression on real variables.

Figure 2.4 shows impulse responses to a 1% shock to output of tradables. As a result, because of deviations of the law of one price for traded goods across countries due to the assumption of home bias in tradables consumption, the terms of trade and the exchange rate depreciate. Therefore the benefits of the positive domestic output shock are shared and consumption in both countries increases, again slightly more so in the domestic country. With procyclical interest rates, the forward discount, the expected change in the exchange rate and the risk premium again respond in a way satisfying Fama's conditions.

## 2.5 Simulation

This section proceeds with presenting results on the simulation of the model economy. Artificial data is been generated over 5000 periods. I draw i.i.d. shocks for the endowment and money processes and compute all other variables using the equilibrium conditions outlined in section 3 by solving the system with a nonlinear equations solver each period. To derive major second moments, which are summarized in Table 3, the constructed data is then HP-filtered with  $\lambda = 1600$  for U.S. quarterly data.

In the data, the finding of a negative estimate of  $\beta$  in the UIP regression is a robust finding, that among industrial countries also has not changed in recent years. Table 4 presents the results from a regression of the nominal interest rate differential on the subsequent change in the nominal exchange rate from the simulated data (t-values are in parentheses) and compares it to the recent empirical findings of Burnside, Eichenbaum, Kleshchelski and Rebelo (2006a) based on a 3-months regression for a sample of nine industrial countries, covering the period 1976-2005. The coefficients produced by the model are well in the region found in the data.

## 2.6 Conclusion

Using habit preferences a la Campbell and Cochrane (1999), which have been successful in addressing the equity premium puzzle in a closed economy, this paper shows that they are successful also in addressing exchange rate puzzles in an open economy. In modern open macroeconomic models the uncovered interest rate parity condition is a central optimality condition, though empirical findings show large deviations from UIP. The paper succeeds in giving a rationale. A time-varying foreign exchange risk premium evolves from this preferences. At times when domestic investors are very risk averse relative to foreign investors they need to be compensated by a risk premium in order for them to hold foreign currency assets, since these assets contain exchange rate risk from the perspective of the domestic agent. In the model, the risk premium moves negatively with expected exchange rate depreciation and displays a higher variance than the latter, thus the model is able to produce a negative UIP regression coefficient, as found in the data. Campbell and Cochrane preferences can also explain exchange rate volatility. Exchange rates are equated to the relative marginal utilities of consumption, which in turn depend on an additional factor under these preferences, surplus consumption, which are very volatile and persistent, therefore helping in explaining real and nominal exchange rate volatility and persistence found in the data. Finally, a third puzzle, even though the model could not entirely explain and match the data on the Backus Smith correlation, it could contribute to a substantial reduction in the consumption real exchange rate correlation. Here, the mechanism is again through the dependence of the ratio of marginal utilities on relative surplus consumption. This acts as a preference shock and disturbs the otherwise perfect correlation, even under complete markets.

## 2.7 Appendix A

In order to derive expressions for interest rates, the expected real exchange depreciation and expected spot return we need to take expectations of log consumption growth. This involves a difficulty. While it is easy to find an expression for the conditional expectation of the growth in surplus consumption (one just needs to substitute in from the specified processes), we also need to take expectations over domestic and foreign consumption growth. Unfortunately however, unlike in Campbell and Cochrane (1999) or Verdelhan (2006), consumption growth is not given by an exogenous lognormal process, but instead is a nonlinear -constant elasticity of substitution- function over the lognormal endowment processes  $y_i$  where  $i = N, N^*, H, F^*$ . In order to get an approximate expression for the conditional expectation (and variance) of consumption growth I make use of the loglinear-lognormal approximation method first proposed by Jermann (1998). He notes that the model solution from the loglinearized (around the nonstochastic steady state) system of equations describes endogenous variables as linear functions of the state variables. In particular one can make use of the equilibrium law of motion, i.e. the model solution of the log-linearized model, which is given by:

$$\begin{aligned}\hat{\mathbf{y}}_t &= \mathbf{g}\mathbf{x} \hat{\mathbf{x}}_t \\ \hat{\mathbf{x}}_{t+1} &= \mathbf{h}\mathbf{x} \hat{\mathbf{x}}_t + \varepsilon_{t+1}\end{aligned}$$

where  $\hat{\mathbf{x}}_t$  is the vector of state variables, i.e.  $\hat{\mathbf{x}}_t = [\hat{s}_{t-1}, \hat{s}_{t-1}^*, \hat{c}_{t-1}, \hat{c}_{t-1}^*, \hat{y}_{N,t}, \hat{y}_{N,t}^*, \hat{y}_{T,t}, \hat{y}_{T,t}^*, \hat{\pi}_t, \hat{\pi}_t^*]'$  and  $\hat{\mathbf{y}}_t$  is the vector of control variables, i.e.  $\hat{\mathbf{y}}_t = [\hat{c}_t, \hat{c}_t^*, \hat{c}_{H,t}, \hat{c}_{F,t}, \hat{c}_{H,t}^*, \hat{c}_{F,t}^*, \dots]$ . Using the the equilibrium law of motion from the log-linear solution, consumption growth can be (approximately) written as:

$$c_{t+1} - c_t = \left[ \mathbf{g}\mathbf{x}^{(c)}\mathbf{h}\mathbf{x} - \mathbf{g}\mathbf{x}^{(c)} \right] \hat{\mathbf{x}}_t + \mathbf{g}\mathbf{x}^{(c)}\varepsilon_{t+1}$$

Denote  $\mathbf{W} \equiv [\mathbf{g}\mathbf{x}^{(c)}\mathbf{h}\mathbf{x} - \mathbf{g}\mathbf{x}^{(c)}]$  and  $u_{c,t+1} = \mathbf{g}\mathbf{x}^{(c)}\varepsilon_{t+1}$ . The (approximate) conditional expectation and variance of consumption growth are therefore given by:

$$E_t(c_{t+1} - c_t) = \left[ \mathbf{g}\mathbf{x}^{(c)}\mathbf{h}\mathbf{x} - \mathbf{g}\mathbf{x}^{(c)} \right] \hat{\mathbf{x}}_t \equiv \mathbf{W} \hat{\mathbf{x}}_t$$



$$\text{Var}_t(c_{t+1} - c_t) = \text{Var}_t(u_{c,t+1}) = \mathbf{g}\mathbf{x}^{(c)}\boldsymbol{\Sigma}_\varepsilon\boldsymbol{\Sigma}_\varepsilon'\mathbf{g}\mathbf{x}^{(c)'} \equiv \widehat{\sigma}_C^2$$

Note that I use this procedure only in order to derive expressions for the conditional expectation and variance of consumption growth, not to approximate the whole intertemporal optimality condition (which also depends on surplus consumption). Therefore, my procedure preserves the effects of intertemporal substitution and precautionary savings on interest rates that comes in through the highly nonlinear process of surplus consumption.

## 2.8 Appendix B

In the following derivations I will assume  $g = g^*$ ,  $\bar{\pi} = \bar{\pi}^*$ ,  $\sigma_{u_N}^* = \sigma_{u_N} = \sigma_{u_H} = \sigma_{u_F}^* = \sigma_u$ ,  $\bar{S} = \bar{S}^*$ ,  $\sigma_\pi = \sigma_\pi^*$ .

Restating eq. (2.30) from the text we can derive expressions for the change in the real and nominal exchange rate by taking logs and differences of  $t+1$  and  $t$ .

$$\varepsilon_t = \left( \frac{S_t^* C_t^*}{S_t C_t} \right)^{-\sigma} \frac{P_t}{P_t^*} \quad (\text{B.1})$$

*Real and nominal exchange rate depreciation:*

$$\text{rer}_{t+1} - \text{rer}_t = -\sigma [(s_{t+1}^* - s_t^*) - (s_{t+1} - s_t)] - \sigma [(c_{t+1}^* - c_t^*) - (c_{t+1} - c_t)] \quad (\text{B.2})$$

Spot return, or nominal exchange rate depreciation is derived by plugging in CIA constraints  $M_t = P_t C_t$  and  $M_t^* = P_t^* C_t^*$  into expression (B.1). Then, taking logs and first differences, gives:

*Expected real and nominal exchange rate depreciation:*

Taking expectations of equations (B.2) and (??) involves the difficulty of taking expectations of (domestic and foreign) consumption growth which are nonlinear functions of the

fundamental lognormal shock processes. I derive approximate expressions for expected log consumption growth as outlined in Appendix A.

Taking expectations of equations (B.2) and (??) and plugging in for (approximated) expected consumption growth and from the exogenous processes for surplus consumption gives the expected real exchange rate depreciation and the expected spot return, respectively:

$$E_t(rer_{t+1} - rer_t) = \sigma(1 - \phi)(s_t^* - s_t) - \sigma(\mathbf{W}^* - \mathbf{W}) \hat{\mathbf{x}}_t \quad (\text{B.4})$$

$$E_t(e_{t+1} - e_t) = \sigma(1 - \phi)(s_t^* - s_t) - \rho_\pi(\pi_t^* - \pi_t) + (1 - \sigma)(\mathbf{W}^* - \mathbf{W}) \hat{\mathbf{x}}_t \quad (\text{B.5})$$

*Real and Nominal interest rates:*

The real interest rate is the reciprocal of the conditionally expected stochastic discount factor, given by eq. (2.26).

Taking logarithms of (2.26) and making use of the lognormality of the forcing processes, the log risk-free interest rate can be written as:

$$\begin{aligned} r_t = & -E_t\{\ln(\beta) - \sigma(s_{t+1} - s_t) - \sigma(c_{t+1} - c_t)\} \\ & - \frac{1}{2}Var_t\{\ln(\beta) - \sigma(s_{t+1} - s_t) - \sigma(c_{t+1} - c_t)\} \end{aligned} \quad (\text{2.37})$$

Substituting in for consumption growth from the recursive equilibrium law of motion from the solution to the log-linearized model,  $c_{t+1} - c_t = \mathbf{W} \hat{\mathbf{x}}_t + u_{C,t+1}$ . Also, we plug in for  $s_{t+1} - s_t$  from eq. (2.8), for sensitivity function  $\lambda(s_t)$  from eq. (2.9). This gives the following expression for the domestic real interest rate:

$$r_t = \bar{r} + \sigma \mathbf{W} \hat{\mathbf{x}}_t - \left[ \sigma(1 - \phi) - \frac{\sigma^2 \hat{\sigma}_c^2}{\bar{S}^2} \right] (s_t - \bar{s}) \quad (\text{B.6})$$

where  $\bar{r} = -\ln(\beta) + \sigma g - \frac{\sigma^2 \hat{\sigma}_c^2}{2\bar{S}^2}$ . If  $\hat{\sigma}_c = \sigma_c$  then, if parameter  $B > 0$  the intertemporal substitution effect outweighs the precautionary savings effect on the interest rate and the real

interest rate is countercyclical, if  $B < 0$  the precautionary savings effect dominates and the real interest rate behaves procyclically.

Similarly for the foreign real interest rate:

$$r_t^* = \bar{r}^* + \sigma \mathbf{W}^* \hat{x}_t - \left[ \sigma (1 - \phi) - \frac{\sigma^2 \hat{\sigma}_c^{*2}}{\bar{S}^{*2}} \right] (s_t^* - \bar{s}^*) \quad (\text{B.7})$$

Undergoing similar steps to for nominal interest rates:

$$i_t = r_t - [g + \mathbf{W} \hat{x}_t] + [(1 - \rho_\pi) \bar{\pi} + \rho_\pi \pi_t] - \left[ \frac{1}{2} - \frac{\sigma}{\bar{S}} \sqrt{1 - 2(s_t - \bar{s})} \right] \hat{\sigma}_c^2 - \frac{1}{2} \sigma_\pi^2 \quad (\text{B.8})$$

similarly:

$$i_t^* = r_t^* - [g^* + \mathbf{W}^* \hat{x}_t] + [(1 - \rho_\pi) \bar{\pi}^* + \rho_\pi \pi_t^*] - \left[ \frac{1}{2} - \frac{\sigma}{\bar{S}^*} \sqrt{1 - 2(s_t^* - \bar{s}^*)} \right] \hat{\sigma}_c^{*2} - \frac{1}{2} \sigma_\pi^{*2} \quad (\text{B.9})$$

*Real interest rate differential and Forward discount/ premium:*

$$(r_t - r_t^*) = - \left[ \sigma (1 - \phi) - \frac{\sigma^2 \hat{\sigma}_c^2}{2\bar{S}^2} \right] (s_t - s_t^*) + \sigma (\mathbf{W}^* - \mathbf{W}) \hat{\mathbf{x}}_t \quad (\text{B.10})$$

taking logs of (2.31) gives

$$(f_t - \varepsilon_t) = (i_t - i_t^*) = (r_t - r_t^*) + \rho_\pi (\pi_t - \pi_t^*) - (\mathbf{W}^* - \mathbf{W}) \hat{\mathbf{x}}_t + \frac{\sigma \hat{\sigma}_c^2}{\bar{S}} \left( \sqrt{1 - 2(s_t - \bar{s})} - \sqrt{1 - 2(s_t^* - \bar{s}^*)} \right) \quad (\text{B.11})$$

*Expected excess return and risk premium:*

Backus, Foresi and Telmer (2001) show that under complete markets the expected excess return is the difference of half the conditional variance of the stochastic discount factors, i.e.:

$$rp_t = -E_t(rx_{t+1}) \quad (\text{B.12})$$

It is easy to verify that this expression for the risk premium coincides with computing the risk premium as:

$$rp_t = (f_t - \varepsilon_t) - E_t(\varepsilon_{t+1} - \varepsilon_t) = (i_t - i_t^*) - E_t(\varepsilon_{t+1} - \varepsilon_t)$$

Table 1

Baseline parameters values		
Weight of H in tradables cons.	$\gamma$	0.75
Weight of T in overall cons.	$\omega$	0.5
Elasticity of subst. betw. H and F	$\epsilon$	1.5
Elasticity of subst. betw. T and N	$\mu$	0.44
Curvature parameter	$\sigma$	2
Growth rate of endowments (T and NT)	$g$	0.0047
AR(1) parameter for process $s_t$	$\phi$	0.985
Importance of ISE vs. PSE	$B$	-0.01
Discount factor	$\beta$	0.986
Money growth rate	$\pi$	0.0136
AR(1) coefficient on money growth	$\rho_\pi$	0.1
Std. of money growth	$\sigma_\pi$	0.00946
Sectoral autocorrelation matrix	$\Omega$	$\begin{bmatrix} 0.95 & 0 \\ 0 & 0.95 \end{bmatrix}$
Sectoral variance-covariance matrix (in %)	$V(\mathbf{u})$	$\begin{bmatrix} 0.7^2 & 0.25 * 0.7 \\ 0.25 * 0.7 & 0.7^2 \end{bmatrix}$

Table 2

		CRRA pref.	CC habit pref.
Marg. utility	$U_{C,t}$	$(C_t)^{-\sigma}$	$(S_t C_t)^{-\sigma}$
Stoch. disc. factor	$SDF_t = \beta E_t \frac{U_{C,t+1}}{U_{C,t}}$	$\beta E_t \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma}$	$\beta E_t \left( \frac{S_{t+1}}{S_t} \frac{C_{t+1}}{C_t} \right)^{-\sigma}$
Coeff. RRA	$-\frac{U_{C_t, C_t} C_t}{U_{C,t}}$	$\sigma$	$\frac{\sigma}{S_t}$

Table 3<sup>18</sup>

Major second moments from model and data				
<i>Variable i</i>				
	Model		Data	
<i>Volatility</i>	$\sigma_i$	$\frac{\sigma_i}{\sigma_y}$	$\sigma_i$	$\frac{\sigma_i}{\sigma_y}$
Output	0.82	1.00	-	-
Consumption	0.60	0.73		-
Surplus Consumption	8.13	9.95		-
Nom. Exchange Rate	3.72	4.56	7.95 <sup>b</sup>	3.26 <sup>a</sup>
Real Exchange Rate	3.69	4.52	7.52 <sup>b</sup>	3.04 <sup>a</sup>
CPI Price Ratio	0.98	1.20	1.18 <sup>b</sup>	
Terms of Trade	1.52	1.86		1.71 <sup>a</sup>
<i>Correlations</i>				
Real Exch. Rate, Rel. Cons. in levels	0.47		-0.30 <sup>c</sup>	
Real Exch. Rate, Rel. Cons. in first differences	0.46		-0.27 <sup>c</sup>	

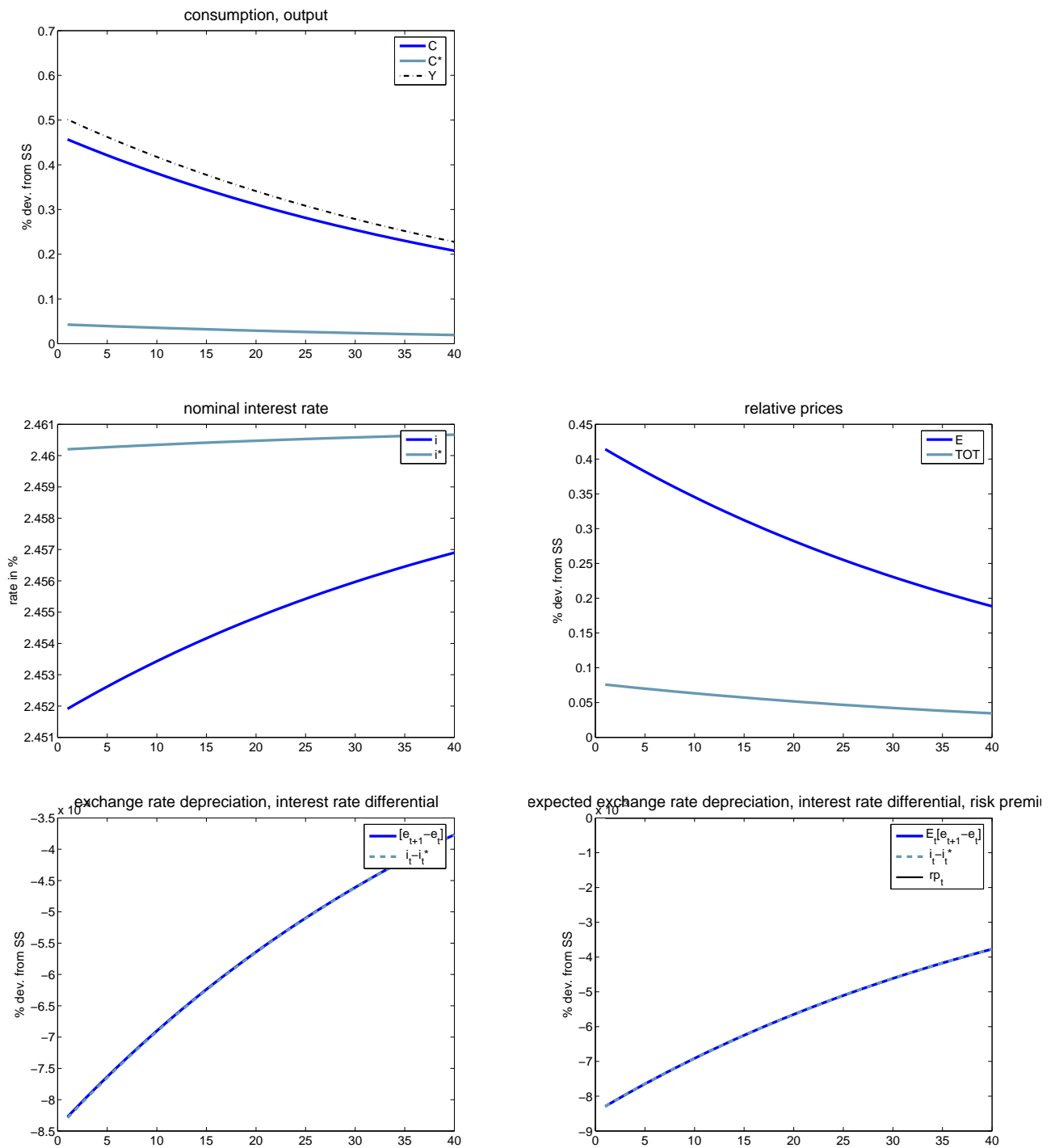
<sup>18a</sup> Corsetti et al. (2006), quarterly data.; <sup>b</sup> Chari, Kehoe, McGrattan (2001), Europe rel. to US, 1973:1-1994:4; <sup>c</sup> Corsetti et al. (2004).

Table 4<sup>19</sup>

Forward Premium Regression		
$(e_{t+1} - e_t) = \alpha + \beta (i_t - i_t^*) + u_{t+1}$		
	Model	Data <sup>a</sup> (range)
$\hat{\alpha}$	0.0002 (0.49234)	(-0.063, 0.001)
$\hat{\beta}$	-1.2087 (-2.94139)	(-0.061, -4.482)

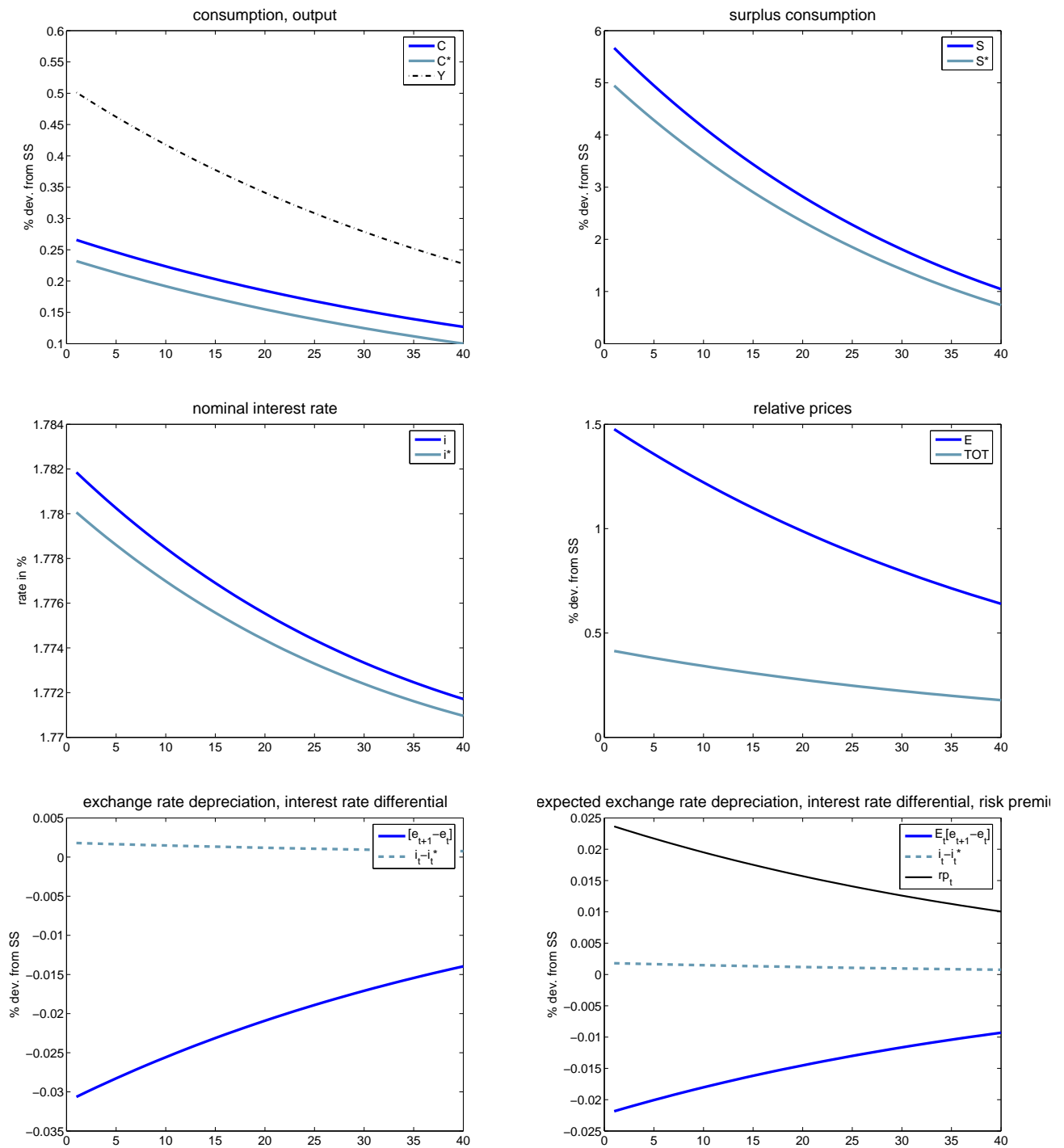
<sup>19a</sup> Burnside et al. (2006a), based on a 3-months regression covering the period 1976-2005 for a sample of nine industrial countries; The countries they consider are Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Switzerland and the USA.

## Shock to Nontradables under CRRA Preferences

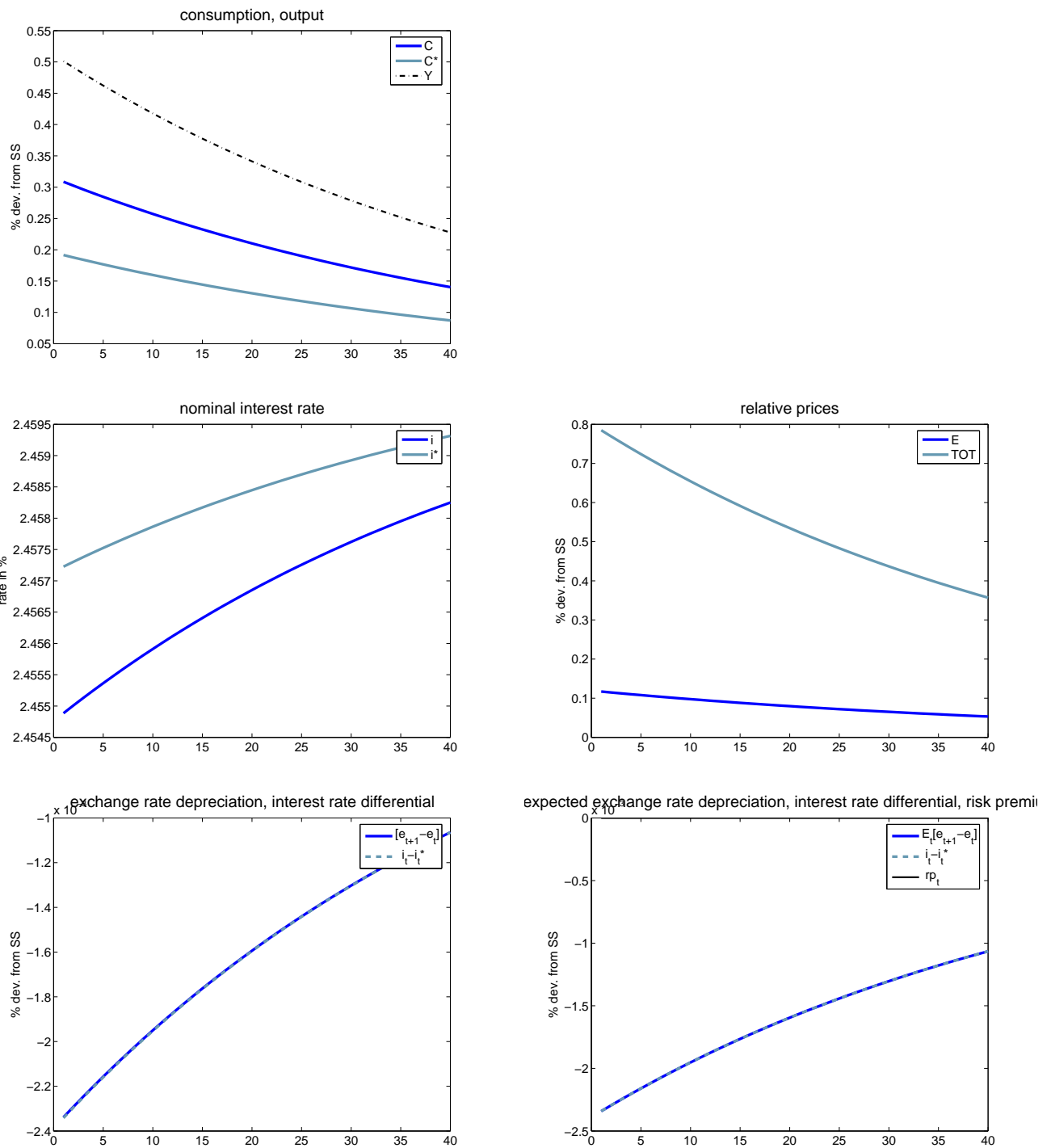
**Figure 2.1:** Impulse response to a 1% shock in domestic nontradables output



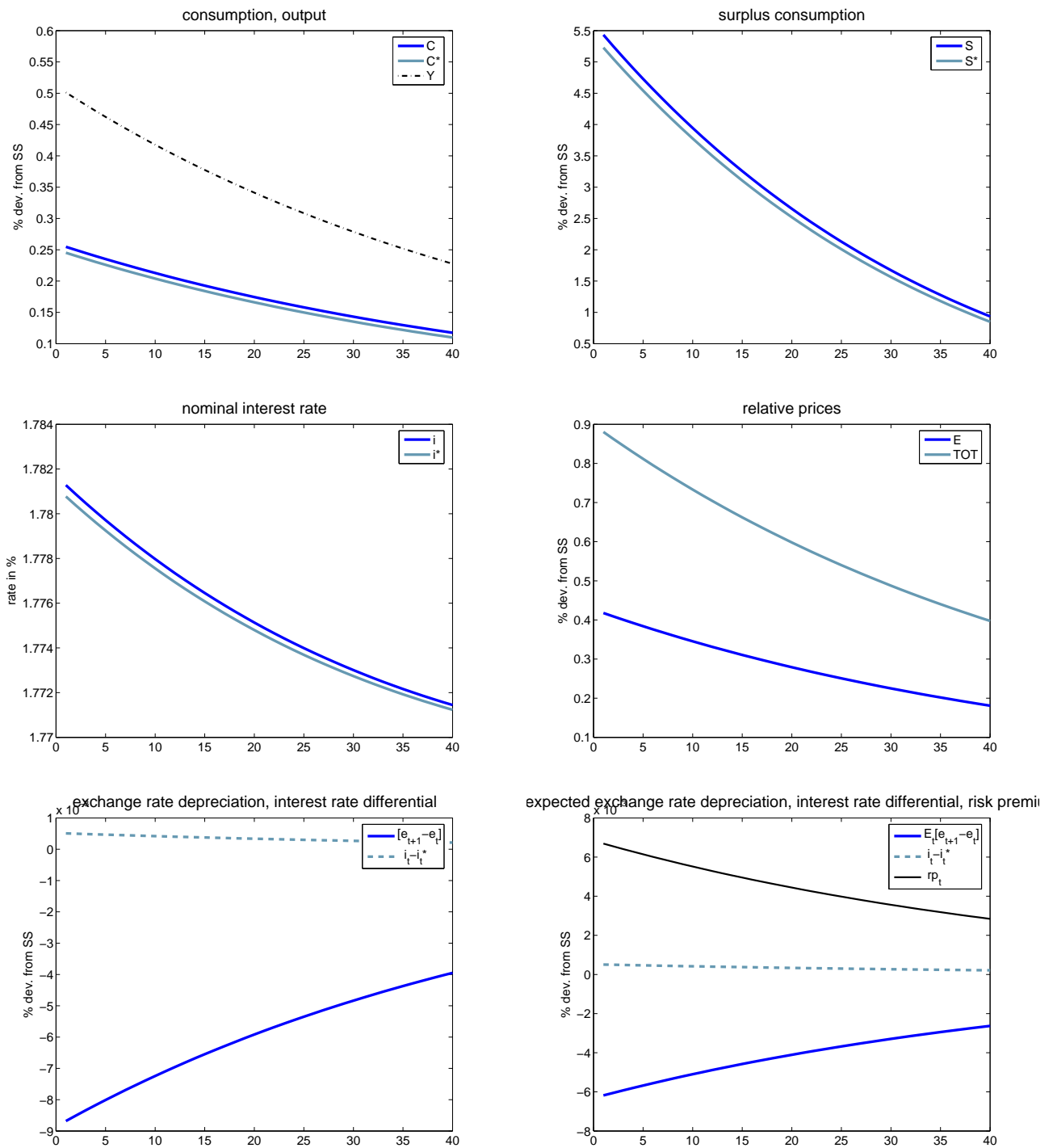
## Shock to Nontradables under Campbell and Cochrane Habit Preferences

**Figure 2.2:** Impulse response to a 1% shock in domestic nontradables output

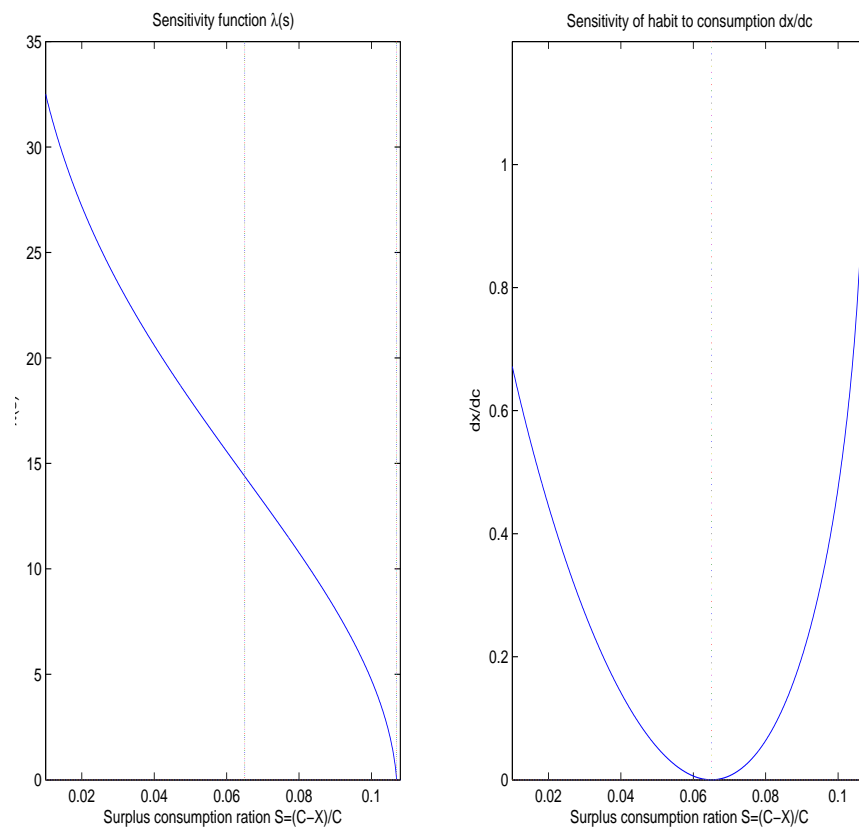
## Shock to Tradables under CRRA Preferences

**Figure 2.3:** Impulse response to a 1% shock in domestic tradables output

## Shock to Tradables under Campbell and Cochrane Habit Preferences



**Figure 2.4:** Impulse response to a 1% shock in domestic tradables output



**Figure 2.5:** Sensitivity function  $\lambda(s)$  and implied sensitivity of (log) habit  $x$  to contemporaneous consumption



# Bibliography

- Alvarez, F., Atkeson, A. and Kehoe, P. J. (2006), ‘Time-varying risk, interest rates, and exchange rates in general equilibrium’, *mimeo*, *Federal Reserve Bank of Minneapolis* .
- Bacchetta, P. and van Wincoop, E. (2006), ‘Incomplete information processing: A solution to the forward discount puzzle’, *mimeo*, *Study Center Gerzensee* .
- Backus, D. K., Foresi, S. and Telmer, C. I. (2001), ‘Affine term structure models and the forward premium anomaly’, *Journal of Finance* *LVI* pp. 279–304.
- Backus, D. K., Kehoe, P. J. and Kydland, F. E. (1994), ‘Dynamics of the trade balance and the terms of trade: The j-curve?’, *American Economic Review* **84**, 84–103.
- Backus, D. K., Kehoe, P. J. and Kydland, F. E. (1995), ‘International business cycles: Theory and evidence’, in *Thomas F. Cooley (ed.) Frontiers of Business Cycle Research*, *Princeton University Press, Princeton*, pp. 331–56.
- Backus, D. K. and Smith, G. W. (1993), ‘Consumption and real exchange rates in dynamic economies with non-traded goods’, *Journal of International Economics* **35**, 297–316.
- Burnside, C., Eichenbaum, M., Kleshchelski, I. and Rebelo, S. (2006a), ‘The returns to currency speculation’, *mimeo* .
- Burnside, C., Eichenbaum, M. and Rebelo, S. (2006a), ‘Understanding the forward premium puzzle: A microstructure approach’, *mimeo*, *Northwestern University* .
- Campbell, J. Y. and Cochrane, J. H. (1999), ‘A consumption-based explanation of aggregate stock market behavior’, *Journal of Political Economy* **107**(2), 205–251.

- Chari, V., Kehoe, P. J. and McGrattan, E. R. (2002), ‘Can sticky price models generate volatile and persistent real exchange rates?’, *Federal Reserve Bank of Minneapolis, Staff Report* (277).
- Corsetti, G., Dedola, L. and Leduc, S. (2004), ‘International risk sharing and the transmission of productivity shocks’, *European Central Bank Working Paper* (308).
- Corsetti, G., Dedola, L. and Leduc, S. (2006), ‘Dsge models with high exchange rate volatility and low pass-through’, *CEPR Discussion Papers* (5377).
- Engel, C. (1996), ‘The forward discount anomaly and the risk premium: A survey of recent evidence’, *Journal of Empirical Finance, Elsevier* **3**(2), 123–192.
- Engel, C. (1999), ‘On the foreign-exchange risk premium in sticky-price general equilibrium models’, *NBER Working Papers* (7067).
- Fama, E. (1984), ‘Forward and spot exchange rates’, *Journal of Monetary Economics* (14), 319–338.
- Jermann, U. J. (1998), ‘Asset prices in production economies’, *Journal of Monetary Economics, Elsevier* **41**(2), 257–275.
- Lettau, M. and Uhlig, H. (1997), ‘Preferences, consumption smoothing, and risk premia’, *CEPR Discussion Papers* (1678).
- Moore, M. J. and Roche, M. J. (2006), ‘Solving exchange rate puzzles without sticky prices nor trade costs’, *mimeo* .
- Verdelhan, A. (2006), ‘A habit-based explanation of the exchange rate risk premium’, *mimeo* .

## Chapter 3

# Capital liberalization and the U.S. external imbalance

Jointly written with Elvira Prades

### 3.1 Introduction

Among the most debated topics in international macroeconomics in recent years is the US current account deficit over the past years and the ongoing accumulation of US' net foreign debt since the mid eighties. At the end of 2006 the US net foreign asset position is standing at about minus 25% of its GDP, the current account deficit in 2006 stands at above 6% of GDP after being in the red for most of the last 25 years. The size and persistence of the US net external positions are challenging to the conventional wisdom of the standard theory of the current account and has led to a large debate -among academics and policy makers alike. Contents of this debate are the sustainability of these imbalances, whether and when adjustment needs to take place or how painful it is going to be for the world economy. A number of authors have argued that the current imbalances might create major financial turbulence, or at least that major policy actions need to be taken to avoid a painful worldwide rebalancing process (e.g. Obstfeld and Rogoff (2004), Roubini and Setser (2005), Blanchard, Giavazzi and Sa (2005)). On the other hand, a number of papers have emphasized that before policy advice can be given as to how adjustment of the current global imbalance should take place, it is important to understand how these imbalances have arrived in the first place. Recently, attention has been put on cross-country differences in financial factors as a potential driving force behind the imbalances (Mendoza, Quadrini and Rios-Rull (2006), Caballero, Farhi and



Gourinchas (2006)). We propose a mechanism that is related to this view, yet different. While we also stress the importance of financial factors, we focus less on the financial development within a country, but instead more on the role of differences in financial openness across countries. Arguably, the US is the economy that has had the most liberalized financial account already in the 1980s. We suggest that the catching up of other advanced and emerging market economies in terms of financial account openness may be partly responsible for the current global imbalances.

Figure 3.1 presents an index of financial openness developed by Chinn and Ito (n.d.) that is based on measures such as a country's controls on capital and current account transactions, the presence of multiple exchange rates within that country or requirements for the surrender of export proceeds. As it can be seen from this index, the US has always been financially open over the last three decades, and most other regions have been liberalizing gradually since the beginning of the 1980s. We can observe that the index for Asian countries starts picking up in the late 1970s or early 1980s, for the group of Latin American emerging markets it increases in the early 1990s. The index for European countries shows a first increase in the early 1980s but picks up substantially also only in the early 1990s. Figure 3.2 plots the development of the US current account and its net foreign asset position. As can be seen the gradual decline in the US net external position begins somewhere in the mid 1980s, and was actually positive before.

A basic function of world capital markets is to allow countries with imperfectly correlated income risks to trade them. If world financial markets were complete, countries would be able to largely reduce the cross-sectional variability in their per capital consumption levels. The empirical stylized facts just presented, indicate that a quarter century ago, for most regions of the world other than the US the degree of financial openness was rather limited. At that time, because of controls on inflows and especially on outflows of capital in most emerging market countries as well as in many industrial countries world capital markets were far from complete. With international capital markets being only a limited means for involving in consumption smoothing in response to country specific shocks, a country's agents have an incentive to have some buffer asset holdings to insure against bad times in which consumption would be very low otherwise - there is a precautionary savings motive. We argue that while

the US has had a very liberalized financial account already in the mid 1980s, long before the rest of the world (RoW), it nevertheless could not access world financial markets unrestrictedly, because the RoW had high controls on capital outflows. Effectively, this ‘constrained’ the US in its ability to borrow in international financial markets in order to insure against any risk of fluctuations in their consumption. When capital controls in the rest of the world started to be dismantled, this allowed the US to effectively borrow more easily at any point and decreased the importance for them to have precautionary asset holdings. It is the drop in the relative importance of precautionary savings that links the accumulation of US net foreign debt to the process of capital liberalization.

We address this question in a two country one good model and consider two cases: 1) an endowment economy, where outputs arrive stochastically each period, and, 2) a model with production and capital accumulation similar to Backus, Kehoe and Kydland (1992), which is the standard workhorse model of international macroeconomics. The simple model is developed mainly to build intuition, whereas the model with capital accumulation allows for a more realistic description of actual economies. We assume that the representative agent in each country can trade a non-contingent bond to smooth consumption in response to country specific shocks, but that she cannot do so unrestrictedly. In particular, in each country agents have limited access to borrow and lend in international financial markets; there are limits beyond which they cannot borrow or lend. We think of the presence of capital controls as being reflected in the tightness of these borrowing and lending constraints. When the limits are set to zero, such that the bond holdings are not only constrained but cannot be used at all, the economies are in financial autarky. As the constraints get more and more relaxed, it becomes increasingly easier to achieve smoother consumption. The presence of the borrowing and lending constraints creates a role for a precautionary savings. The catching up of the rest of the world’s (RoW) financial openness, that is, the financial account liberalization in the RoW is modeled as a one-time permanent relaxation of the upper limit of capital outflows of the foreign economy. Effectively, this improves also the domestic -US- ability to borrow. For any given level of risk it faces it can now better use the international bond for consumption smoothing purposes, and the implied drop in consumption volatility means that it has less of a motive to hold assets as a buffer for times of low consumption. It is this drop of the

(relative) importance of the precautionary savings motive that endogenously makes the U.S. hold long run negative net foreign assets as it transitions to a new implied steady state.

There are several contributions in the literature that our paper connects to. As mentioned before, in recent work Mendoza et al. (2006) also refer to differences in financial factors as a potential explanation for the U.S. external imbalances. They emphasize the heterogeneity of financial systems within countries such as a country's credit markets and differences in the ability to borrow from collateral.<sup>1</sup> They propose a model in which agents face idiosyncratic risk from both endowments and investment technology, which has to be managed differently. In such a setup, differences in financial development between countries matter when economies open up to trade in international financial markets. The accompanied process of factor equalization -less developed economies face an increase in the interest rate relative to its autarky interest rate, therefore an incentive to save- leads to capital flows from less developed financial markets into the US economy. Contrary to Mendoza et al. (2006) we focus on the effects of capital liberalization on cross-country risk sharing, and show that even in a model with aggregate risk only the implied imbalances of a change in financial openness can be substantial.

Caballero et al. (2006) argue that for emerging market economies, among them most prominently China, the development of local financial markets has not kept pace with the growth experiences of their economies. They argue, that for these countries, this has led to an inability to supply high quality financial assets. The high demand for quality assets on world financial markets, together with the process of capital liberalization has allowed emerging market economies to hold their savings in U.S. assets, or equivalently has allowed the U.S. to more easily hold foreign debt.

The explanation for what is driving the US external deficit that is suggested here, that is, the decrease in the US precautionary savings motive relative to the rest of the world is similar to the mechanism proposed by Fogli and Perri (2006). They claim that the 'great

---

<sup>1</sup>Their paper also provides empirical evidence of a negative relationship between the state of development of a country's credit markets and its current account. The ratio of Private Credit to Domestic Sector as percentage of GDP from the World Development Indicators shows that the US is (and has been) world leader in terms of credit market development.

moderation' in business cycle volatility in the US (compared to the rest of the world) has led to a decrease in consumption volatility which is what is driving the US external imbalance. In our model it is the opening up of countries' financial accounts which allows the US to better smooth its consumption and which endogenously leads to the external deficit.

The paper is organized as follows. In section 3.2 we present the model framework, a simple two country endowment model that allows for constraints on capital in- and outflows. Section 3.3 explains in detail how financial openness and capital liberalization is modeled. Subsection 3.3.1 briefly describes the solution technique and discusses parametrization. In subsection 3.3.2 we present the results of the quantitative exercise for the simple model together with some sensitivity analysis. Section 3.4 proceeds with the discussion and results of the model with capital that can be calibrated. Section 3.5 concludes.

## 3.2 Endowment Economy

### 3.2.1 The model

The world economy consists of two countries, Home and Foreign, each inhabited by a large number of infinitely lived agents with mass  $n$  and  $(1 - n)$  respectively. We will assume that all idiosyncratic risk is perfectly insured among residents of a country, i.e. within-country financial markets are complete. We can therefore think of a representative consumer in each country that maximizes the expected sum of future discounted utilities from consumption  $c_t$

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t) \quad (3.1)$$

where  $\beta$  is the rate of time preference. The utility function  $u(c)$  is assumed to be constant relative risk aversion  $u(c) = (1/(1 - \sigma)) [c^{1-\sigma} - 1]$ , where  $\sigma$  is the coefficient of relative risk aversion. The foreign representative agent faces an equivalent problem, where foreign variables are denoted with an asterisk. Agents of each country receive an exogenous endowment  $y_t$  or  $y_t^*$  respectively in every period  $t$ . Exogenous outputs are assumed to follow a bivariate

autoregressive process of order 1:

$$\begin{pmatrix} \ln(y_t) - \ln(\bar{y}) \\ \ln(y_t^*) - \ln(\bar{y}^*) \end{pmatrix} = A \begin{pmatrix} \ln(y_{t-1}) - \ln(\bar{y}) \\ \ln(y_{t-1}^*) - \ln(\bar{y}^*) \end{pmatrix} + \begin{pmatrix} \varepsilon_t \\ \varepsilon_t^* \end{pmatrix} \quad (3.2)$$

where  $\bar{y}$  is mean income,  $A$  is a 2x2 matrix of coefficients describing the autocorrelation properties of the process, and  $\mathbf{e} = (\varepsilon_t \ \varepsilon_t^*)'$  is a vector of shocks from a bivariate normal distribution with mean zero and variance-covariance matrix  $V(\mathbf{e})$ , i.e.  $\mathbf{e}_t \sim N(0, V(\mathbf{e}))$ .

Asset markets are incomplete in the sense that countries are only allowed to trade in a one-period risk free bond  $b_t$  which promises one unit of consumption the next period and trades at price  $\frac{1}{r_t}$ , where  $r$  is the gross real interest rate. We can then write the domestic country's budget constraint as:

$$\frac{b_{t+1}}{r_t} = b_t + y_t - c_t \quad \text{with } b_0 \text{ given} \quad (3.3)$$

Even though agents are assumed to be able to trade a risk free bond in order to smooth their consumption, they cannot do so unrestrictedly. In particular, we assume that the domestic country's debt level cannot exceed some fraction  $\underline{B}$  of the level of its current output:<sup>2</sup>

$$\frac{b_{t+1}}{y_t} \geq -\underline{B} \quad (3.4)$$

Due to capital controls international asset holdings are also limited by an upper bound.

$$\frac{b_{t+1}}{y_t} \leq \overline{B} \quad (3.5)$$

The foreign country's budget constraint and the borrowing and lending constraints are equivalent versions of equations (3.3) and (3.4), replacing all variables with starred ones. The borrowing limit for the foreign country therefore is  $\frac{b_{t+1}^*}{y_t^*} \geq -\underline{B}^*$  and the lending limit is

---

<sup>2</sup>In addition, there is a 'natural debt' limit as in Ayagari (1994) in which both countries will not borrow more than the minimum value that the endowment can take at period  $t+1$  discounted to period  $t$  prices, but on top of that countries face more restrictive debt limits. To compute the natural debt limit in a two country model, where the interest rate is endogenous, is more difficult than in a partial equilibrium model where the interest rate is exogenous. In addition if one of the constraint binds for one of the economies the interest rate differs for each agent, for a detailed discussion see Anagnostopoulos (2006). However, the debt limits we impose are generally stricter than the natural debt limit.

$$\frac{b_{t+1}^*}{y_t^*} \leq \bar{B}^*.$$

Due to symmetry and the fact that bond holdings must be in zero net supply, only two of the four constraints on borrowing and lending effectively matter. More precisely, the limit that is imposed on up to how much one country can borrow is determined by either its own borrowing constraint or by the other country's lending constraint - whichever of the two is stricter. Formally, the range over which the international bond can effectively be traded is given by the interval  $[\mathbf{B}, \mathbf{B}^*]$ , where  $\mathbf{B} = \max(-\underline{B}y_t, -\bar{B}^*y_t^*)$  denotes the domestic country's *effective* borrowing constraint. Similarly,  $\mathbf{B}^* = \min(\bar{B}y_t, \underline{B}^*y_t^*)$  denotes the foreign country's *effective* borrowing constraint.

The equilibrium of this economy is defined as a path of interest rates  $r = \{r_t\}_{t=0}^\infty$  together with consumption plans  $c = \{c_t\}_{t=0}^\infty$  and  $c^* = \{c_t^*\}_{t=0}^\infty$  and debt plans  $b = \{b_t\}_{t=0}^\infty$  and  $b^* = \{b_t^*\}_{t=0}^\infty$  such that:

1.  $c_t$  and  $b_{t+1}$  maximize (3.1) subject to (3.3)-(3.4)-(3.5)
2.  $c_t^*$  and  $b_{t+1}^*$  maximize the foreign version of (3.1) s.t. the foreign versions of (3.3)-(3.4)-(3.5)
3. the real interest rate clears the bond market,  $b_t + b_t^* = 0$ , for all  $t$
4. the goods market also clears (due to Walras' Law),  $c_t + c_t^* = y_t + y_t^*$ , for all  $t$ .

The equilibrium conditions can then be summarized as:<sup>4</sup>

$$c_t^{-\sigma} - r_t \lambda_t^{\underline{B}} + r_t \lambda_t^{\bar{B}} = \beta r_t E_t [c_{t+1}^{-\sigma}] \quad (3.6)$$

$$c_t^{*- \sigma} - r_t \lambda_t^{\underline{B}^*} + r_t \lambda_t^{\bar{B}^*} = \beta r_t E_t [c_{t+1}^{*- \sigma}] \quad (3.7)$$

$$\frac{b_{t+1}}{r_t} = b_t + y_t - c_t \quad (3.8)$$

<sup>3</sup>In equilibrium, since bonds are held in zero net supply, the foreign country's borrowing constraint reads  $\frac{b_{t+1}}{y_t^*} < \bar{B}^*$  and the lending constraint reads  $\frac{b_{t+1}}{y_t} \geq -\bar{B}^*$ .

<sup>4</sup>Where we have used the bond market clearing condition to substitute out  $b_t^*$ .

$$-\frac{b_{t+1}}{r_t} = -b_t + y_t^* - c_t^* \quad (3.9)$$

$$\lambda_t^{\underline{B}} \left[ \frac{b_{t+1}}{y_t} + \underline{B} \right] = 0 \quad (3.10)$$

$$\lambda_t^{\underline{B}^*} \left[ -\frac{b_{t+1}}{y_t^*} + \underline{B}^* \right] = 0 \quad (3.11)$$

$$\lambda_t^{\bar{B}} \left[ \bar{B} - \frac{b_{t+1}}{y_t} \right] = 0 \quad (3.12)$$

$$\lambda_t^{\bar{B}^*} \left[ \bar{B}^* + \frac{b_{t+1}}{y_t^*} \right] = 0 \quad (3.13)$$

We can distinguish five cases that are summarized by equilibrium conditions (3.6)-(3.13):

1. The case where no borrowing or lending constraint is binding for either country. In this case the lagrange multipliers associated to the borrowing and lending limits are equal to zero, i.e.  $\lambda_t^{\underline{B}} = \lambda_t^{\underline{B}^*} = 0$  and  $\lambda_t^{\bar{B}} = \lambda_t^{\bar{B}^*} = 0$ , and the Euler equations (3.6)-(3.7) reduce to their standard expressions.
2. The borrowing constraint binds for the domestic country, i.e.  $\frac{b_{t+1}}{y_t} = -\underline{B}$ . The Lagrange multiplier of the domestic borrowing constraint,  $\lambda_t^{\underline{B}}$ , which reflects the shadow value of relaxing the constraint marginally, is therefore positive.
3. The lending constraint binds for the domestic country, that is  $\frac{b_{t+1}}{y_t} = \bar{B}$ , and  $\lambda_t^{\bar{B}^*} > 0$ .
4. The borrowing constraint binds for the foreign country,  $\frac{b_{t+1}}{y_t^*} = \bar{B}^*$  and  $\lambda_t^{\bar{B}} > 0$ .
5. The lending constraint binds for the foreign economy,  $\frac{b_{t+1}}{y_t^*} = -\bar{B}^*$ , and  $\lambda_t^{\bar{B}^*} > 0$ .

### 3.3 Financial openness and capital liberalization in the model

In the framework of the model we think of financial market openness as being reflected in the tightness of the respective borrowing and lending constraints the countries are facing.

Therefore, a relaxation of a country's lending or borrowing constraints can be interpreted as a reduction of capital controls on that country's capital outflows or inflows. Before we discuss the choice of these constraints in our model, let us first consider two special cases that are nested in our model setup and correspond to the more standard cases, known as the 'financial autarky' case and as the incomplete markets 'bond economy' case.

First, if  $\bar{B} = \bar{B}^* = \underline{B} = \underline{B}^* = 0$  then the world is in financial autarky. In this case there is no international consumption risk sharing - the bond cannot be used at all to insure against country idiosyncratic consumption risk.<sup>5</sup>

The second special case is the scenario in which the bond can be freely traded across countries, that is  $\bar{B}$ ,  $\bar{B}^*$ ,  $\underline{B}$  and  $\underline{B}^*$  are sufficiently high, such that none of the constraints ever binds.<sup>6</sup> This case coincides with the standard case of what is known as the incomplete markets 'bond economy' case. It is well known that under this case, even though markets are incomplete, the outcome is very close to the perfect risk sharing case under complete markets, where consumption in both economies perfectly co-moves (see Baxter and Crucini (1995)).

We interpret intermediate cases between financial autarky and no limits in borrowing and lending as reflecting intermediate stages of financial account openness, with the state of liberalization being more advanced as  $\bar{B}$  and  $\bar{B}^*$ , and  $\underline{B}$  and  $\underline{B}^*$  increase. The presence of limits in bond holdings in these intermediate cases makes it hard for the countries' economic agents to perfectly insure against country specific shocks. Since agents dislike the possibility of being left without any consumption at any point in time, they have an incentive to build up a buffer stock of savings to facilitate consumption smoothing, that is they have precautionary savings motives. This will be the crucial mechanism with which we are able to generate large imbalances with our model. As long as borrowing constraints are not 'too' relaxed, such that consumption smoothing is not too close to perfect risk sharing, precautionary savings motives have a significant impact on the equilibrium policy functions.<sup>7</sup>

<sup>5</sup>In the endowment case therefore volatility of the endowment directly translates into the volatility of consumption. In the model with capital, the domestic country can even under financial autarky engage in at least some consumption smoothing through increasing or running down its capital stock.

<sup>6</sup>However, there still is a 'natural debt limit' and a 'No Ponzi' condition that needs to be satisfied.

<sup>7</sup>As shown by Anagnostopoulos (2006) a global solution when there are relatively restrictive borrowing



The experiment we undertake is the following. The initial borrowing constraints, denoted  $\underline{B}^{BL}$  and  $\underline{B}^{*BL}$  ( $BL$  stands for ‘before liberalization’) for the domestic and foreign country respectively and capital outflow limits,  $\overline{B}^{BL}$  and  $\overline{B}^{*BL}$ , are initially set to some constant fraction of steady state world output, i.e.  $\underline{B} = \frac{b}{y}$  and  $\underline{B}^* = \frac{b^*}{y^*}$  and similarly for the capital outflow limit,  $\overline{B} = \frac{b}{y}$  and  $\overline{B}^* = \frac{b^*}{y^*}$ . We model the RoW’s reduction of controls on capital outflows as a relaxation of the lending constraint to a new level  $\overline{B}^{*AL}$  (‘after liberalization’), with  $\overline{B}^{*AL} > \overline{B}^{*BL}$ . Rather than modeling the process of liberalization as something that took place gradually over time, we make the simplifying assumption that liberalization occurs at once. That is, we consider a one-time permanent relaxation in the RoW’s lending constraint, which the representative agents of both countries learn about instantly. If the capital outflow constraints for the RoW initially are tighter than the US borrowing constraint,  $\overline{B}^{*BL} < \underline{B}^{BL}$ , this implies that the US economy can achieve lower consumption volatility. It should be noted that, clearly, also the RoW is able to better smooth its consumption in response to the relaxation. The drop in US consumption volatility is bigger, however, since agents are more risk averse when consumption is rather low.<sup>8</sup> Accordingly, the US motive to hold precautionary assets decreases by more than the RoW’s motive for buffer assets.

The modeling of financial markets, that is, the assumption that there only exists one internationally traded bond, is clearly overly simplistic. In particular, it cannot address questions of portfolio choice or give any rationale to why gross asset and liability positions have risen drastically. We however also see the simplicity of our model and the fact that the standard workhorse international macro-model is nested in our setup as an advantage. We show that even in a simple setup and with only aggregate (country specific) risk we can explain a sizable portion of the US net external deficits through effects of capital liberalization.

---

limits instead of a local approximation solution avoids the well-known problem of non-stationarity of bonds in the model.

<sup>8</sup>That is, utility is concave.

### 3.3.1 Model solution and parametrization

**Solution method** To address the question we are interested in, local approximation techniques like log-linearization around the non-stochastic steady state cannot be used. Instead, we need to use a global solution technique that can explicitly account for the influence of second moments on agent's policy functions and that also allows treatment of occasionally binding inequality constraints.

We use time iteration techniques as described by Coleman (1990) and increased its speed by using the endogenous grid points method developed by Carroll (2006) which reduces the number of non-linear equations the algorithm needs to solve. Time iteration has several advantages as compared to standard dynamic programming as it preserves the continuous nature of the state space since it relies on interpolation techniques, and it easily allows to take into account inequality constraints. In particular, we make guesses on the policy rules as functions of the economy's state variables. In the endowment economy we obtain policy rules for bond holdings and the interest rate as functions of last period bond holdings and the two endowment processes,  $b''(b'; y', y^*)$  and  $r'(b'; y', y^*)$ . Further details about the solution technique are provided in the appendix.

**Parameters values** Table 3.1 presents our baseline parameter values for the quantitative experiments of our model economy, chosen such as to match U.S. quarterly data versus the rest of the world. Most parameter choices are relatively standard in the literature, which we briefly outline first. We then discuss the choice of the borrowing and lending constraints, for which there is no previous (nor obvious) choice.

The coefficient of risk aversion  $\sigma$  is set to 2, a very standard choice in macroeconomics. The discount factor  $\beta$  is set as to match a 4% annual interest rate in the non-stochastic steady state. The exogenous process follows a bivariate AR(1) with a coefficient of autocorrelation  $\rho$  of 0.98 (and no cross-correlation) and standard deviation of the exogenous process  $\sigma_\varepsilon$  set to 0.0075 as estimated by Fogli and Perri (2006) for the US economy.

The analysis of the endowment economy model is quite useful to build intuition we can show how borrowing and lending constraints and their relaxation matter for the equilibrium net foreign asset position. It is convenient to start with a completely symmetric initial parametrization. The two economies are equal in terms of country size (set to one-half), long term output levels ( $\bar{y} = \bar{y}^* = 1$ ), as well as their initial borrowing and lending constraints,  $\bar{B}^{BL} = \bar{B}^{*BL} = \underline{B}^{BL} = \underline{B}^{*BL} = .5$ .

### 3.3.2 Main results

We now turn to the quantitative predictions of our model economy when we relax the effective borrowing constraint faced by the US. To build intuition we start from an initial setting where both economies are symmetric. Before discussing the experiment of the relaxation in the domestic country's borrowing constraint we want to comment on the general effect of borrowing constraints in a stochastic environment. The presence of borrowing constraints give households of both countries an incentive to engage in precautionary saving, to store away some extra assets in the 'good' states of nature for the 'bad' states in which the constraint may bind and in which they may not be able to borrow as much as they would desire in world markets. In our endowment economy the only asset available to be used as a buffer is the bond. Since both economies are initially symmetric and the bond must be held in zero net supply, this means that none of two countries can actually have positive holdings of the international bond. As first observed by Ayagari (1994), as a result of motives to hold precautionary buffer assets, when the (gross) real interest rate would be at their certainty equivalent level  $\frac{1}{\beta}$  there would be an excess demand for savings. Under uncertainty, therefore, the asset price needs to be higher relative to its non-stochastic level to clear the bond market, or, equivalently, the real interest rate needs to be lower than in a non-stochastic world.

For displaying the mechanism of the model it does not matter whether the domestic country's ability to borrow is restricted because of its own actual constraints on borrowing,  $b_{t+1} \geq -\underline{B}y_t$ , or whether it is constrained because the foreign economy is restricted from holding the domestic country's financial assets, i.e.  $b_{t+1} \geq \bar{B}^*y_t^*$ . Since what matters is the domestic country's effective borrowing constraint,  $\mathbf{B} = \max\left(-\underline{B}y_t, -\bar{B}^*y_t^*\right)$ , we will conduct

our experiment in terms of a relaxation of this effective constraint. We model the increase in financial openness of capital outflows for the ROW as a one-time permanent relaxation of the effective US' borrowing constraint from 50% of its current output level to 100% of its output. This means that before capital liberalization the effective borrowing constraints are  $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 0.5$ , and are equal to  $\mathbf{B}^{*AL} = 0.5$  and  $\mathbf{B}^{AL} = 1.0$  after liberalization. We assume that the RoW economy still faces the same borrowing limit as before, as in practice the ability of obtaining external finance for many emerging market countries is still limited. Two reasons are behind this fact, first, these economies are financially less developed. Second, after the recurrent crises that some of the emerging markets have faced during the end of the 90's, they suffered limitations in their ability to borrow internationally. With this parametrization we capture the asymmetry in borrowing in financial markets and therefore the differences in the ability to manage consumption uncertainty. We choose the mid 1980 as the date for the experiment which coincides with the start of the decline in the U.S. net foreign asset position.

Figure 3.3 shows the response of main macroeconomic variables in the face of the U.S. increased ability to borrow in international markets in comparison to RoW. Since the foreign household's motive to engage in precautionary savings has remained unchanged and it therefore now has, relative to the US, a stronger desire for precautionary savings we observe (in panel 2 of figure 3.3) a U.S. current account deficit and a gradual decline in the U.S. net foreign asset position as the economy transitions to a new steady state.<sup>9</sup> After the relaxation of the domestic country's borrowing constraint, its desire to hold assets for precautionary savings drops because the borrowing constraint has softened, and therefore the probability that the constraint binds at any moment in time has decreased and the desire to hold assets as a buffer to avoid these eventualities decreases; the bond can now be used more freely in response to random output shocks and can achieve better consumption smoothing and therefore a lower consumption volatility for any given risk.

---

<sup>9</sup>In principle the responses shown in figure 3.3 need to be derived from averages over a large number of simulations, such that the stochastic behavior of the economy can be 'aggregated away' and only the deterministic change in the policy functions -that reflects the change in the importance of precautionary savings- is left over. To save computational time we instead feed  $\sigma_\varepsilon = 0$  in the 'simulation' (however, the policy functions themselves have, of course, been obtained from a stochastic setting with  $\sigma_\varepsilon$  as indicated in section 3.3.1).

The decrease in the importance of U.S.' precautionary savings lowers its demand for the asset and, as a consequence, pushes up the interest rate (panel 4 of figure 3.3) which gives the RoW a motive to forgo consumption today. As interest rates increase the RoW finds it optimal to save and enjoy some higher consumption in the future. The consumption responses in panel 3 of figure 3.3 show that domestic consumers become relatively more impatient. The drop in the precautionary savings motive leads them to consume more relative early on at the expense of consumption in future periods, such that the long run value of U.S. consumption at the new steady state is at a lower level permanently.

It is important to note that figure 3.3 does not plot the responses to a particular shock, nor did we assume that the mean or variance of the endowment processes has changed at any point in time. The response in figure 3.3 is entirely due to the decrease in the importance of the precautionary savings motive for the U.S. economy, that stems from the domestic country's improved ability to smooth consumption, and plots the expected path as the economy transitions to the new implied steady state.

**Sensitivity Analysis** Figure 3.4 presents some sensitivity analysis. The first column presents the equilibrium response of our baseline parametrization for values of the coefficient of relative risk aversion  $\sigma$  equal to 1, 2 (baseline) and 5, respectively. As can be seen, the higher is the degree of risk aversion, the smaller is the reduction of the importance of US' precautionary motives and therefore, the smaller is the accumulation of net foreign debt.

Given the difficulty to parameterize the borrowing limits, we consider it especially important to do sensitivity analysis on different values of the effective borrowing constraints. The quantitative response of net foreign assets to a relaxation depends on two things: one, the degree to which the constraints were initially restricting asset trade, and two, the amount by which the effective constraints are relaxed. The panels in the second and third columns therefore show variations in the assumptions on these constraints either before or after capital liberalization.

We plot the first set of sensitivity experiments with respect to the borrowing constraints in column 2 of figure 3.4 under varying degrees of 'initial financial market openness' and show the responses of the economic variables for three different parameterizations. The first assumes that initially international financial markets were very closed (the constraints change from  $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 0.01$  to  $\mathbf{B}^{*AL} = 0.01$  and  $\mathbf{B}^{AL} = 0.5$ ), the second set of responses repeat the baseline case, and the third starts out in a situation where international financial markets were (relatively) open to begin with (from  $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 1.0$  to  $\mathbf{B}^{*AL} = 1.0$  and  $\mathbf{B}^{AL} = 1.5$ ). Since precautionary motives are highest when financial markets can hardly be accessed as a means to engage in consumption smoothing, the drop in the net foreign asset position is strongest in the case where international financial markets are initially very closed.

The third column of figure 3.4 shows different cases for 'the extent of liberalization', that is, for different assumptions on by how much the effective borrowing constraint is relaxed. We show the baseline case, and the changes in the constraints from  $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 0.5$  to  $\mathbf{B}^{*AL} = 0.5$  and  $\mathbf{B}^{AL} = 1.5$ , and from  $\mathbf{B}^{BL} = \mathbf{B}^{*BL} = 0.5$  to  $\mathbf{B}^{*AL} = 0.5$  and  $\mathbf{B}^{AL} = 2.5$ . Not surprisingly, the decline in the net foreign asset position is more pronounced the higher the extent of the relaxation.

We summarize the new stochastic steady states obtained 20 years after financial account liberalization in table 3.2. Taking in to account that the current level of US net foreign assets has achieved almost -25% of GDP the results obtained under our experiments are quite significant. In 2006 our baseline experiment for the endowment economy accounts for a net foreign debt of about 15 percent of domestic output. The new steady state level of net foreign assets of approximately -23% is reached at around 80 years later.

In order to compare the results obtained with our approach with the recent contribution of Fogli and Perri (2006) we also run the experiment of the 'great moderation' in US business cycle volatility. Column 2 of figure 3.5 plots the results of the great moderation.<sup>10</sup> Column 3 of figure 3.5 then incorporates both facts: capital liberalization plus 'great moderation'. The

<sup>10</sup>Note that the model used by Fogli and Perri (2006) is different as they include capital accumulation in their model. We also include an additional asset in the next section.

results from these experiments are reported for different values of the coefficients of relative risk aversion.

### 3.4 A model with production and capital accumulation

It can be argued that in a setup in which agents' only option to save and to smooth consumption intertemporally is by making use of the international bond, that the effects of changes in the strength of precautionary savings motives across countries have an unrealistically strong impact on the external position. We therefore now turn to a model setup in which the domestic representative agent is owner of the economy's capital stock which is used in production. This gives her another asset that can be used to smooth intertemporal consumption and to hold savings for precautionary reasons. Now, the domestic representative agent maximizes eq. (3.1) with respect to borrowing constraint (3.4) and lending limit (3.5). As in the endowment economy, international asset markets can therefore be used only incompletely for consumption smoothing purposes. The budget constraint under this set-up and the law of motion for capital are:

$$c_t + x_t + \frac{b_{t+1}}{r_t} = \omega_t n + r_t^k k_t + b_t \quad (3.14)$$

$$k_{t+1} = (1 - \delta)k_t + x_t - \frac{\phi}{2} \left[ \frac{k_{t+1} - k_t}{k_t} \right]^2 \quad (3.15)$$

where  $k_t$  is capital,  $w_t$  and  $r_t^k$  refer to the wage rate and the return of capital. To avoid a counterfactual volatile investment,  $x_t$ , there are adjustment costs to install new capital. Households are assumed to supply their labor inelastically. For simplicity, we continue to model the foreign country's output as an endowment process (or, implicitly, continue to hold the foreign capital stock fixed).<sup>11</sup>

Firms produce output according to a Cobb-Douglas production function and face a country specific productivity. They are assumed to be competitive such that profit maximization leads to factors being paid their marginal products.

---

<sup>11</sup>This is done mainly for ease of computation.

$$\max \pi = (z_t k_t^\alpha n^{1-\alpha} - \omega_t n - r_t^k k_t) \quad (3.16)$$

Technologies are modeled as exogenous processes which follow a bivariate autoregressive process of order 1.<sup>12</sup>

$$\begin{pmatrix} \ln(z_t) - \ln(\bar{z}) \\ \ln(z_t^*) - \ln(\bar{z}^*) \end{pmatrix} = A \begin{pmatrix} \ln(z_{t-1}) - \ln(\bar{z}) \\ \ln(z_{t-1}^*) - \ln(\bar{z}^*) \end{pmatrix} + \begin{pmatrix} \varepsilon_t \\ \varepsilon_t^* \end{pmatrix} \quad (3.17)$$

where  $\bar{z}$  is a parameter reflecting the mean productivity,  $A$  is a 2x2 matrix of coefficients describing the autocorrelation properties of the process, and  $\mathbf{e} = (\varepsilon_t \ \varepsilon_t^*)'$  is a vector of shocks from a bivariate normal distribution with mean zero and variance-covariance matrix  $V(\mathbf{e})$ , i.e.  $\mathbf{e}_t \sim N(0, V(\mathbf{e}))$ .

The equilibrium of this economy is defined as a path of interest rates  $r = \{r_t\}_{t=0}^\infty$  and input prices  $w = \{w_t\}_{t=0}^\infty$  and  $r^k = \{r_t^k\}_{t=0}^\infty$  together with consumption plans  $c = \{c_t\}_{t=0}^\infty$  and  $c^* = \{c_t^*\}_{t=0}^\infty$ , capital accumulation plans  $k = \{k_t\}_{t=0}^\infty$  and debt plans  $b = \{b_t\}_{t=0}^\infty$  and  $b^* = \{b_t^*\}_{t=0}^\infty$  such that households and firms solve their optimization problem and markets for bonds, consumption and capital clears in each market.

The equilibrium conditions of the full model are given by the set of equilibrium conditions of the endowment model, equations (3.6)-(3.13) -where the budget constraints are replaced by their versions of equation (3.14) - plus the additional Euler equation with respect to the choice of the optimal capital stock, given by:

$$\left(1 + \frac{\phi}{k_t} \left(\frac{k_{t+1}}{k_t} - 1\right)\right) c_t^{-\sigma} = \beta E_t \left\{ c_{t+1}^{-\sigma} \left[ (1 - \delta) + \alpha z_{t+1} \left(\frac{k_{t+1}}{n}\right)^{\alpha-1} + \frac{\phi}{k_{t+1}} \left(\frac{k_{t+2}}{k_{t+1}} - 1\right) \frac{k_{t+2}}{k_{t+1}} \right] \right\} \quad (3.18)$$

**Solution method and parameters values** The model is solved with the same technique as in the endowment economy model. In the full model with production we iterate on policy

<sup>12</sup>this is the same assumption we made for the endowment model, just that the exogenous processes describe productivity instead of output.



function guesses of  $b''$ ,  $k''$  and  $r'$  as functions of  $(b', k'; z', z^*)$ .

In the model with capital we have another set of standard parameters. Table 3.1 presents our baseline parameter values for the quantitative experiments of our model economy. The capital share  $\alpha$  is set equal to 0.36. The quarterly depreciation rate,  $\delta$ , is set to 2.5%. In order to avoid counterfactual volatile investment, we include quadratic capital adjustment costs with parameter  $\phi$  equal to 8. The domestic economy's country size parameter  $n$  is taken to be 0.25 which corresponds approximately to the US population share in the OECD in 2007. The level of long run productivity in the US is taken to be slightly higher than in the RoW, with parameters  $\bar{Z} = 1.01$  and  $\bar{Z}^* = 1$ .

For the model with capital we aim to capture a more realistic setting and allow for differences in country size and productivity, and, more importantly, differences in initial borrowing and lending constraints and the catching up of the RoW's financial account openness. We claim that the US borrowing and lending constraints,  $\underline{B}^{BL}$  and  $\bar{B}^{BL}$ , in the period *before liberalization* in the rest of the world are already relatively loose, and set these to 100% of US output. For the RoW, while for most countries capital was not being prevented from flowing into the country, there were tight controls on capital outflows. We assume, for simplicity, an equally loose borrowing constraint,  $\underline{B}^{*BL}$ , for the RoW up to 100% of its output. The outward capital controls reflect this in a relatively tight constraint on the RoW's lending,  $\bar{B}^{*BL}$ , which will be set to 50% of RoW's output level. We assume after capitals controls in the RoW have been dismantled, the bond holdings of the rest of the world can also take on 100% of its output level,  $\bar{B}^{*AL} = \bar{y}^*$ .

### 3.4.1 Responses to financial account liberalization in the full model with capital

In the previous section we have seen that large imbalances can result from changes in financial openness, reflected in changes in the effective borrowing constraint of the domestic economy. This may not seem surprising given that in the endowment economy the internationally traded bond is the only asset which can be used for agents' desired holding of buffer assets. Then, any

change in the relative importance of the precautionary savings motive of the US vs. the RoW is necessarily expressed in (large) equilibrium responses of the long run external asset position.

In the model with capital the domestic agent is allowed another asset that can help her in the desire to achieve smooth consumption on the one hand, and for precautionary motives on the other hand. It is because of the latter that the long-run level of the capital stock in a stochastic equilibrium lies above the deterministic steady state capital stock, reflecting that also capital is held as a buffer against having to have very low consumption in bad states of the economy.

Figure 3.6 presents the equilibrium responses when the RoW is initially facing a high level of capital controls and is therefore very much restricted from holding foreign assets. After capital liberalization takes place in the RoW, the foreign lending constraint softens which also relaxes the US' effective borrowing constraint. In particular, we parameterize the initial constraints the US is facing such that it would be able to borrow and lend up to 50% of its current output level, that is,  $\bar{B}^{BL} = \underline{B}^{BL} = 0.5$ . For the RoW, before capital liberalization, the initial constraint on capital outflows is set to  $\bar{B}^{*BL} = 0.01$ , essentially entirely preventing the RoW from taking their financial wealth abroad. Controls on capital inflows were much less prevalent even before liberalization, and we assume the RoW's borrowing constraint initially to be  $\underline{B}^{*BL} = 0.5$ . After liberalization, when capital controls in the RoW have been dismantled, the RoW's lending constraint is also at 50% of its output level,  $\bar{B}^{*AL} = 0.5$ . We can observe that the US net foreign asset position before the onset of capital liberalization in the rest of the world is slightly positive<sup>13</sup> and then starts its subsequent decline. Our model is therefore able to rationalize the stylized facts we observe in the data -which were presented in figure 3.1 and figure 3.2- as a result of the process of capital liberalization. As figure 3.6 shows, the drop in the US net foreign asset position remains substantial in the capital model, despite the fact that part of the decrease of buffer stock holdings that result from lower precautionary motives of the US is expressed by lowering investment, and therefore, by a decrease in the economy's long-run capital stock level. The experiment of the capital model also gives a quantitative indication on these effects. While the drop in domestic variables (in-

<sup>13</sup>In fact, with our choice of initial constraints, it would be even more positive if the long run productivity levels across the two countries were equal.

vestment, capital stock) are relatively small quantitatively, the effects on the external position are quite substantial -a model prediction that is in line with the experience of the US economy.

### 3.5 Conclusions

Since the mid 80's we have observed a persistent decline in the US net foreign asset position. Contrary to conventional wisdom, where an adjustment was expected, the US continues to be the main world net borrower. In this paper we have quantitatively explored the role of the process of capital liberalization and risk aversion in driving the US net foreign asset position into deficit. For doing so we used a stylized two country one good model with borrowing and lending constraints.

We have shown that the current US net external imbalance can be a natural outcome of the catching up process of other advanced and emerging market economies in terms of financial account openness in the last 25 years.

## 3.6 Appendix

The models in section 3.2.1 are solved by making policy function guesses combined with the method of endogenous grid points. Below we briefly outline the steps of the algorithm used:

- We discretize the exogenous process following Adda and Cooper (2003). We use the Adda Cooper method instead of the more conventional Tauchen and Hussey (1991) since, as shown by Flodn (2006), the accuracy of the discretization in terms of the unconditional variance of  $y$  and  $y^*$  ( $z$  and  $z^*$ ) is better under this method when the degree of autocorrelation is high and when there are only few discretization nodes. In the following, we denote  $t+1$  variables with a prime (accordingly  $b''$  is  $b_{t+2}$ ). We construct a grid of endogenous state variables at time  $t+1$ . For the endowment economy we therefore have, for each combination of  $y'$  and  $y^{*'}$ , a one-dimensional grid in  $b'$  which consists of  $nb$  grid points and ranges from  $\min(-\underline{B}, \overline{B}^*)$  to  $\max(\overline{B}, -\underline{B}^*)$ . For the capital economy we construct, for each combination of  $z'$  and  $z^{*'}$ , a 2-dimensional grid in  $k', b'$  consisting of  $nk * nb$  grid points. The range for  $k'$  is set from .7 to 1.3 times the non-stochastic steady state level of the capital stock.
- Set counter equal to 1. We make initial policy function guesses using the log-linear solution as starting point. In the endowment economy guesses are made for  $b''(b'; y', y^{*'})$  and  $r'(b'; y', y^{*'})$ . In the capital economy initial guesses are made for  $b''(k', b'; z', z^{*'})$ ,  $k''(k', b'; z', z^{*'})$ , and  $r'(k', k^{*'}, b'; z', z^{*'})$ .
- Using these initial policy function guesses, and using the discretized states and transition matrix for the exogenous processes, the conditional expectations in the Euler Equations can be computed. In particular, in both economies, we compute  $E[c'^{-\sigma}]$  and  $E[c^{*'}^{-\sigma}]$  from equations (3.6)-(3.7). For the capital economy we also derive an expression for  $E[c'^{-\sigma}(f_{k'} + 1 - \delta + \Phi_{k'})]$  from equation (3.18).
- Using the so computed expressions for the conditional expectations, the values of  $b$  (or, respectively, the values of  $k$  and  $b$ ) are found for each grid-point  $b'$  (combination of grid-points  $k'$  and  $b'$ ) by using a nonlinear equations solver.
- Finally, the policy function guesses are updated using interpolation methods. As the function  $b'(b; y, y^*)$  and  $r(b; y, y^*)$  (or, in the capital economy,  $k'(k, b; z, z^*)$ ,  $b'(k, b; z, z^*)$  and  $r(k, b; z, z^*)$ ) are known, one can obtain the updated guesses by interpolating  $b''$  and  $r'$  at points  $(b'; y', y^{*'})$  (or, in the capital economy,  $k'', b''$  and  $r'$  at points  $(k', b'; z', z^{*'})$ ).
- The above steps are repeated until convergence is achieved.

**Table 3.1:** BASELINE PARAMETER VALUES

		economy with capital	
$\sigma$	5	$\alpha$	0.36
$\beta$	.9895	$\delta$	0.0255
$\bar{y}$	1	$\phi$	8
$\rho$	.98	$n$	0.25
$\sigma_\varepsilon$	.0075	$\bar{Z}, \bar{Z}^*$	1.01, 1

**Table 3.2:** SENSITIVITY ANALYSIS  
Sensitivity analysis endowment economy model

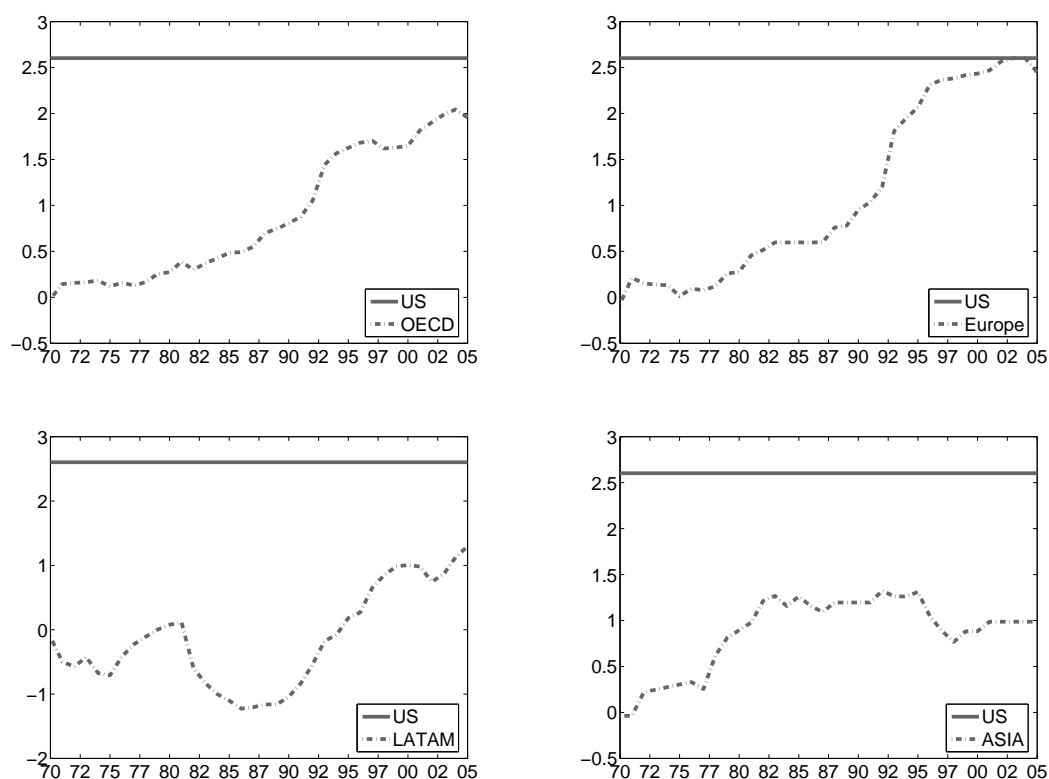
Risk aversion, $\sigma$			
	$\sigma = 2$	$\sigma = 3$	$\sigma = 5$
Financ. dev.	-12.94	-11.83	-10.11
Borrowing constraints: changes in differences			
	$\bar{B}_{BL} = \bar{B}_{BL}^* = 0.01$	$\bar{B}_{BL} = \bar{B}_{BL}^* = 0.5$	$\bar{B}_{BL} = \bar{B}_{BL}^* = 1$
	$\rightarrow \bar{B}_{AL} = 0.5$	$\rightarrow \bar{B}_{AL} = 1.0$	$\rightarrow \bar{B}_{AL} = 1.5$
Ext. Imb.	-12.94	-20.87	-26.02
Borrowing constraints: changes in level			
	$\bar{B}_{BL} = \bar{B}_{BL}^* = 0.5$	$\bar{B}_{BL} = \bar{B}_{BL}^* = 0.5$	$\bar{B}_{BL} = \bar{B}_{BL}^* = 0.5$
	$\rightarrow \bar{B}_{AL} = 1$	$\rightarrow \bar{B}_{AL} = 1.5$	$\rightarrow \bar{B}_{AL} = 2.0$
Ext. Imb.	-20.58	-12.94	-7.46

**Table 3.3:** Impact on external imbalances as percentage of GDP to different parameter values

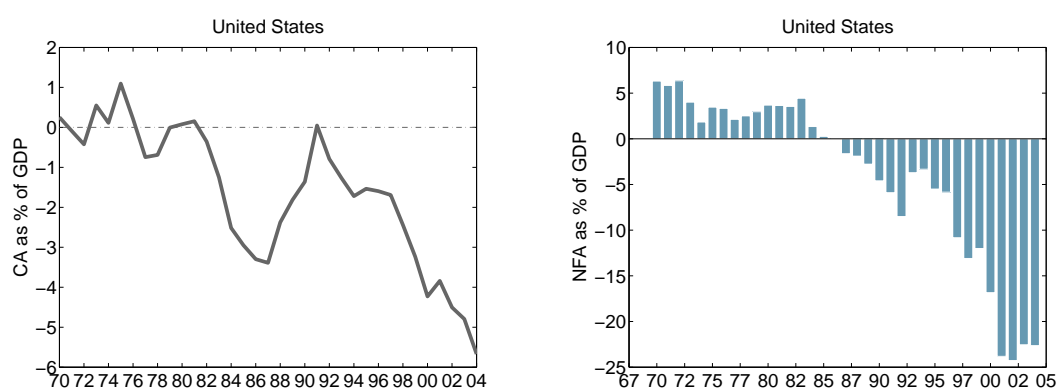
**Table 3.4:** BASELINE ALGORITHM PARAMETERS

<b>1. Endowment economy</b>			
Number of gridpoints			
bonds	$nodes_b$		31
output	$nodes_y$		5
Size of the grid			
output			
	max	$y_{\max}, y_{\max}^*$	$= -0.032$
	min	$y_{\min}, y_{\min}^*$	$= 0.032$
bonds			
	before		
	max	$b_{\max}, b_{\max}^*$	$= -0.500$
	min	$b_{\min}, b_{\min}^*$	$= 0.500$
	percentage of st.st output		50%
	”		50%
	after		
	max	$b_{\max}, b_{\max}^*$	$= -1.000$
	min	$b_{\min}, b_{\min}^*$	$= 0.500$
	percentage of st.st output		100%
	”		50%
<b>2. Capital economy</b>			
Number of gridpoints			
bonds	$nodes_b$		31
capital	$nodes_k$		31
technology	$nodes_z$		3
Size of the grid			
technology			
	max	$z_{\max}, z_{\max}^*$	$= 1.042$
	min	$z_{\min}, z_{\min}^*$	$= 0.959$
capital			
	max	$k_{\max}$	$= 8.540$
	min	$k_{\min}$	$= 15.859$
bonds			
	before		
	max	$b_{\max}, b_{\max}^*$	$= -0.013$
	min	$b_{\min}, b_{\min}^*$	$= 0.633$
	percentage of st.st output		1%
	”		50%
	after		
	max	$b_{\max}, b_{\max}^*$	$= -0.633$
	min	$b_{\min}, b_{\min}^*$	$= 0.633$
	percentage of st.st output		50%
	”		50%

## Financial Openness Index

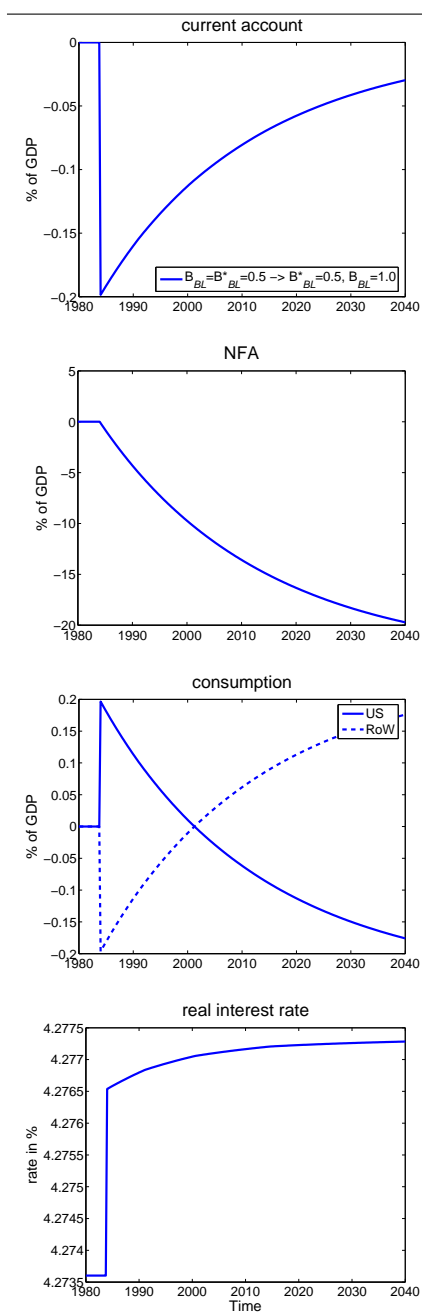


**Figure 3.1:** Average financial openness index compiled by Chinn and Ito (2005) for different groups of countries compared with US



**Figure 3.2:** US current account and net foreign assets as percentage of GDP. Source: IMF statistics, Lane and Milesi-Ferretti database and World Development Indicators

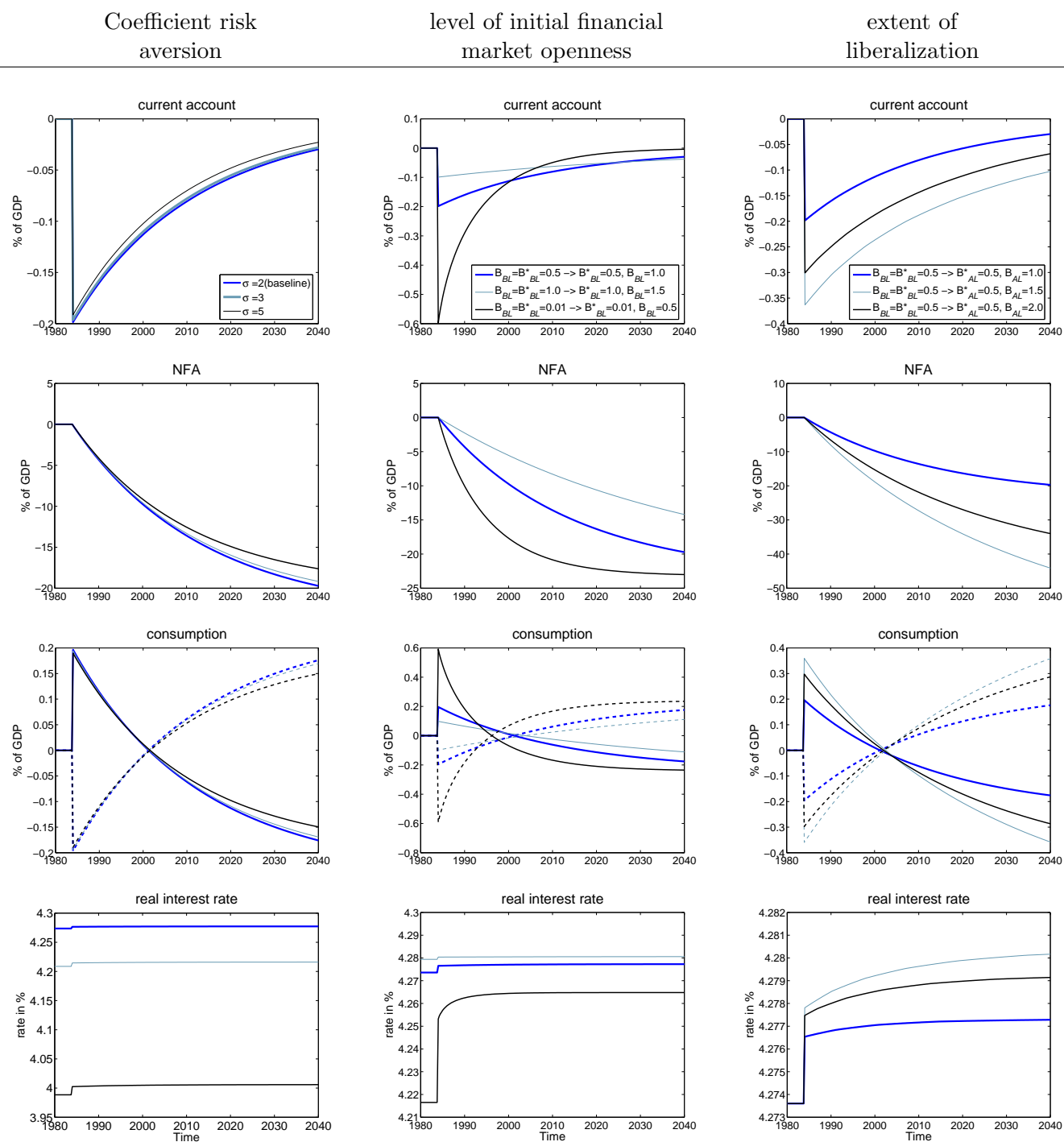
### Capital Liberalization



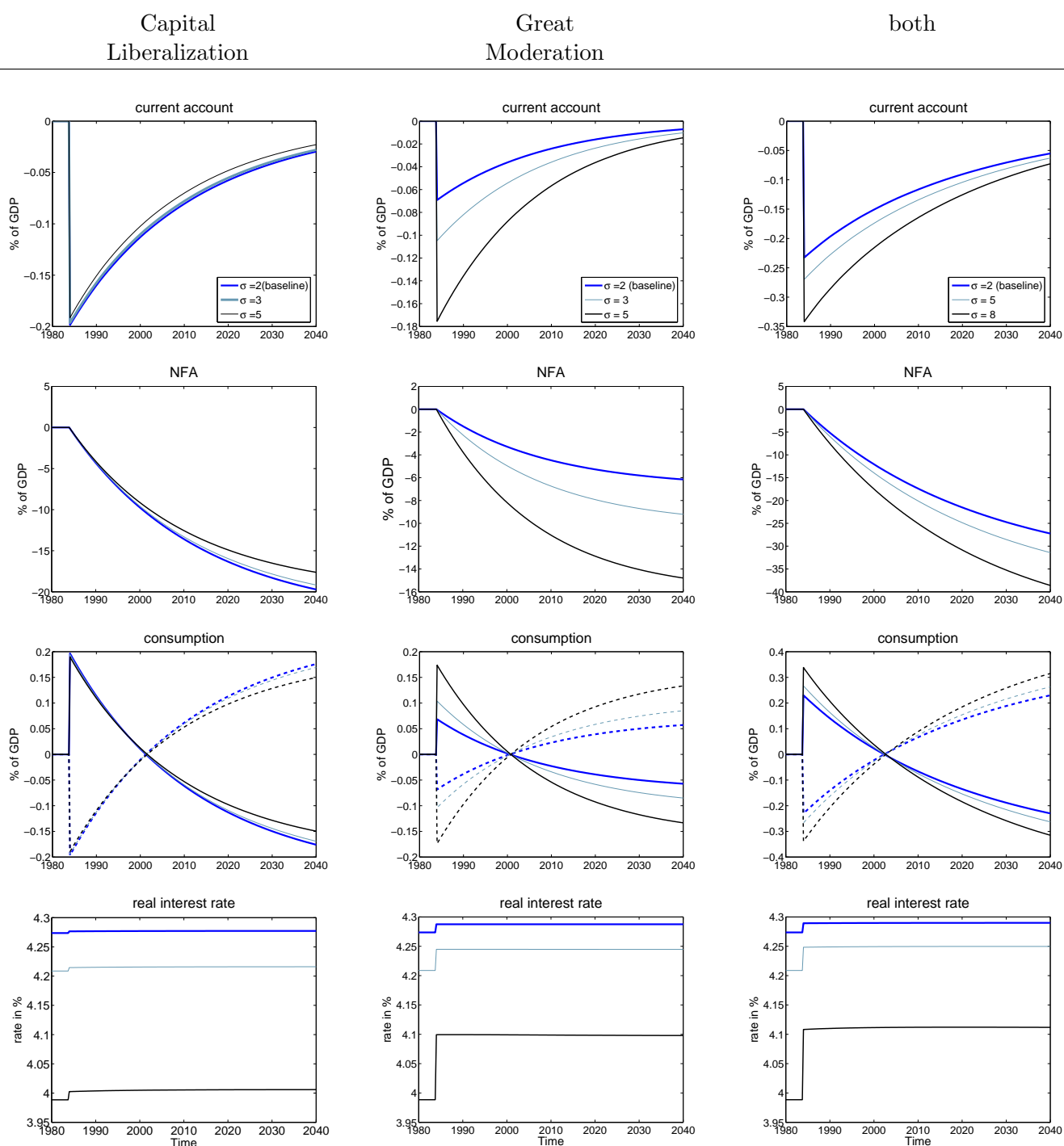
**Figure 3.3:** Response to a relaxation in the US effective borrowing constraint



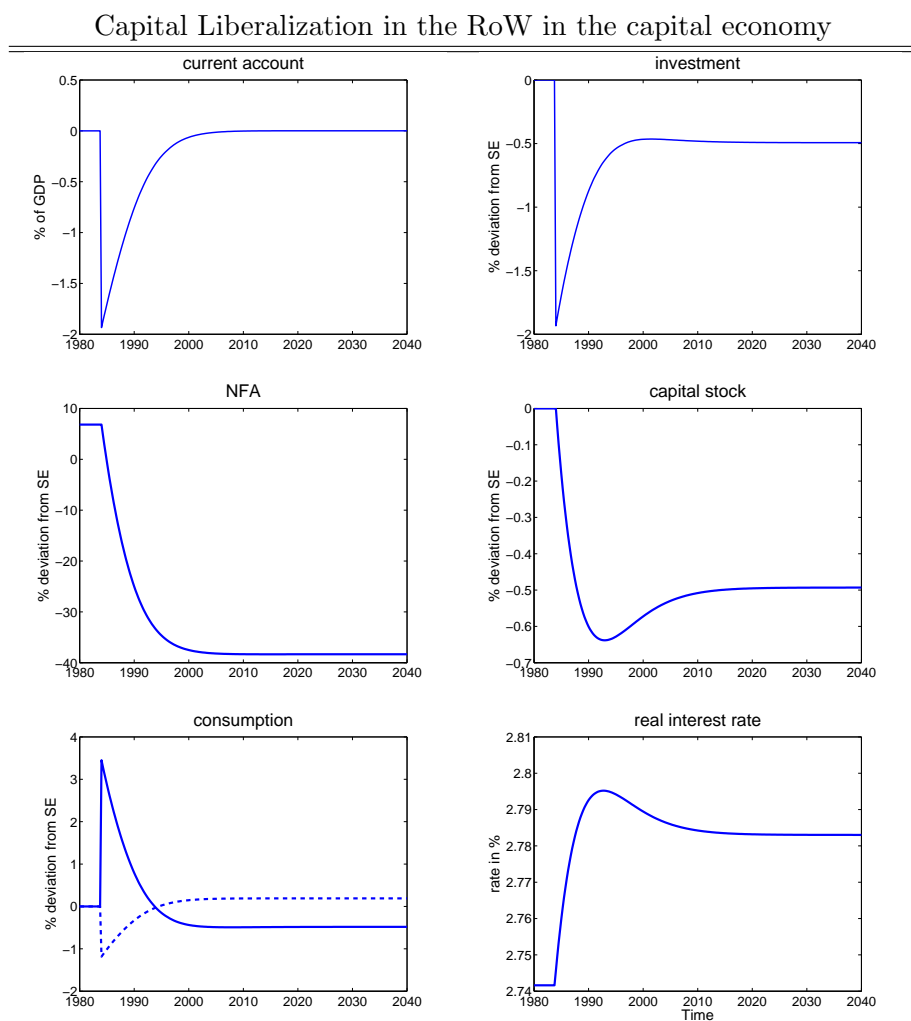
## Capital Liberalization, Sensitivity Analysis



**Figure 3.4:** Response to a relaxation in the US effective borrowing constraint: column 1) different coefficients of risk aversion, column 2) different initial levels of debt limits and, column 3) and different sizes of relaxation



**Figure 3.5:** Response to a relaxation in the US effective borrowing constraint: Column 1) different coefficients of risk aversion, Column 2) great moderation in US income volatility and, Column 3) great moderation and US borrowing limit relaxation



**Figure 3.6:** Response to an relaxation of controls on capital outflows in the RoW

# Bibliography

- Adda, J. and Cooper, R. (2003), ‘Dynamic economics’, *MIT Press* .
- Anagnostopoulos, A. (2006), ‘Consumption and debt dynamics with (rarely binding) borrowing constraints’, *mimeo* .
- Ayagari, R. (1994), ‘Uninsured idiosyncratic risk and aggregate savings’, *Quarterly Journal of Economics* (59(3)), 659–84.
- Backus, D., Kehoe, P. and Kydland, F. (1992), ‘International real business cycles’, *Journal of Political Economy* (100), 745–775.
- Baxter, M. and Crucini, M. (1995), ‘Business cycles and the asset structure of foreign trade’, *International Economic Review* (36(4)).
- Blanchard, O., Giavazzi, F. and Sa, F. (2005), ‘The u.s. current account and the dollar’, *NBER Working Paper* (11137).
- Caballero, R., Farhi, E. and Gourinchas, P.-O. (2006), ‘An equilibrium model of ‘global imbalances’ and low interest rates’, *NBER Working Paper* (11996).
- Carroll, C. D. (2006), ‘The method of endogenous gridpoints for solving dynamic stochastic optimization problems’, *Economics Letters* (91(3)), 312–320.
- Chinn, M. and Ito, H. (n.d.), ‘Financial openness measure’.
- Coleman, W. J. (1990), ‘Solving the stochastic growth model by policy-function iteration’, *Journal of Business and Economic Statistics* .
- Flodn, M. (2006), ‘A note on the accuracy of markov-chain approximations to highly persistent ar(1)-processes’, *SSE/EFI Working Paper Series in Economics and Finance* (656).
- Fogli, A. and Perri, F. (2006), ‘The ‘great moderation’ and the us external balance’, *NBER Working Paper* .
- Mendoza, E., Quadrini, V. and Rios-Rull, J. V. (2006), ‘Financial integration, financial deepness and global imbalances’, *mimeo* .
- Obstfeld, M. and Rogoff, K. (2004), ‘The unsustainable us current account position revisited’, *NBER Working Paper* (10869).
- Roubini, N. and Setser, B. (2005), ‘Will the bretton woods 2 regime unravel soon? the risk of a hard landing in 2005-2006’, *Unpublished Manuscript* .

- Tauchen, G. and Hussey, R. (1991), 'Quadrature-based methods for obtaining approximate solutions to nonlinear asset pricing models', *Econometrica* (59), 371–396.