Essays on Exchange Rate Regime Choice for Emerging Market Countries

Masato Takahashi

Master of Philosophy

University of York
Department of Economics and Related Studies
July 2011

Abstract

This thesis includes two essays which attempt to investigate what type of exchange rate regime is more desirable in welfare terms when there are balance sheet constraints in emerging market countries (EMCs). This is accomplished through a rigorous welfare-based comparison of fixed and flexible exchange rate regimes in the context of different dynamic stochastic general equilibrium small open economy models which incorporate some characteristics designed for the emerging market environment: balance sheet effects, foreign currency debt, and vulnerabilities to external shocks. More specifically, this thesis investigates whether and how (i) the level of foreign currency debt and (ii) the degree of exchange rate volatility affect balance sheets and welfare under different exchange rate regimes.

Chapter 2 investigates the effects of debt levels on balance sheets and welfare. This chapter evaluates the welfare properties of exchange rate regimes by employing the model of Devereux et al. (2006). In contrast to the 'Fear of Floating' view highlighted by Calvo and Reinhart (2002), our results show that the float welfare-dominates the peg for a broad range of debt levels. In addition, as the level of foreign currency debt rises, the welfare difference between the two regimes becomes wider – the float becomes more desirable. Moreover, the results hold irrespective of the degree of exchange rate pass-through.

In Chapter 3, we extend the model of the previous chapter to investigate how the degree of exchange rate volatility affects the choice of exchange rate regime. The main feature of the extended model is to introduce an exogenous shock to the UIP (uncovered interest parity) condition under flexible exchange rates, which allows the model to generate more realistic exchange rate volatility. Using the extended model, we compare the peg with several types of floats in terms of welfare. The main findings are: (a) the peg welfare-dominates strict CPI-inflation targeting under plausible calibrations of exchange rate volatility and the welfare difference between the two regimes becomes larger as exchange rate volatility increases - the peg becomes more desirable; (b) the peg is welfare-superior to strict domestic-inflation targeting when exchange rate volatility is high. The results are basically consistent with the 'Fear of Floating' view.

Contents

List of Tables

List of Figures

Acknowledgements

I would like to express my gratitude to my supervisors Neil Rankin and Gulcin Ozkan for their useful suggestions, comments, and advice. Of course, all remaining errors are mine. I am also grateful to Nippon Export and Investment Insurance (NEXI) for financial support.

Author’s Declaration

I hereby declare that this thesis is my own original work and I am the single author of all chapters presented.

Chapter 1

Introduction

The question of whether monetary authorities should react directly to the exchange rate is a matter of debate in the academic world. Edwards (2006) and Taylor (2001) argue that, at least in developed countries, monetary policy rules that directly respond to the exchange rate are not efficient at stabilizing inflation and real output and perform worse than those that do not react directly to the exchange rate. They explain that (i) even if the monetary policy rule has no direct reaction of interest rates to the exchange rate, it has an indirect reaction of interest rates to the exchange rate[1] and that (ii) monetary policy rules which directly respond to the exchange rate are likely to increase the volatility of the interest rate. Therefore, they argue that the exchange rate should not be explicitly incorporated into the monetary policy rule.

On the other hand, Calvo and Reinhart (2002), Ho and McCauley (2003) and other empirical studies find that many monetary authorities in emerging market countries (EMCs) are reluctant to allow their currencies to float freely and care about exchange rate fluctuations because such changes could pose significant challenges in EMCs. This is referred to as 'Fear of Floating,' which is highlighted by Calvo and Reinhart (2002). One of the main challenges is balance sheet vulnerabilities induced by

[1] For example, consider the case of an exchange rate depreciation. In a standard open economy model, an exchange rate depreciation today would increase the level of real output and inflation in the future, which raises expectations of future short-term interest rates. With a rational expectations model of the term structure of interest rates, the expectations of higher future short-term interest rates would raise long-term interest rates today. Thus, the exchange rate depreciation would raise interest rates today, even though the exchange rate is not explicitly included in the monetary policy rule. They call this 'an indirect reaction of interest rates to the exchange rate.'

currency mismatches.[2] Since banks and non-banks in many EMCs cannot borrow from abroad in their own currency, they have to borrow in foreign currency. This generates an accumulation of foreign currency debt which is insufficiently matched by their foreign currency assets (this is called 'currency mismatches'). Under the circumstances, so-called 'contractionary devaluations' occur. A significant exchange rate depreciation would inflate debt servicing costs and consequently damage the value of their collateral or their net worth. Then, the decline in net worth could adversely affect their access to capital markets and raise the risk premium substantially, which could reduce investment spending dramatically, thereby leading to a severe recession.[3] This is referred to as balance sheet effects, balance sheet constraints, or the financial accelerator. Contractionary devaluations contrast with the conventional wisdom of expenditure switching, which argues that an exchange rate depreciation makes exports competitive, thereby generating expansionary effects.

In recent years, balance sheet effects coupled with foreign currency debt have become a focal point of interest in theoretical studies on the appropriate monetary and exchange rate regime for EMCs. Recent papers incorporating balance sheet effects in combination with foreign currency debt include Céspedes et al. (2002, 2004), Choi and Cook (2004), Cook (2004), Devereux et al. (2006), Elekdağ and Tchakarov (2007), and Gertler et al. (2007).[4] Most of the studies develop a standard small open-economy model which incorporates the financial accelerator mechanism à la Bernanke et al. (1999) and Carlstrom and Fuerst (1997). The key aspect of the framework is that the cost of external borrowing (the risk premium) is modeled as an endogenous variable and is linked to balance sheets. When firm's balance sheets deteriorate dramatically, e.g. owing to a sudden exchange rate depreciation, the risk premium increases substantially, thereby generating a severe recession. Thus, the model succeeds in accounting for contractionary devaluations and provides a useful

[2] See Note 1 of Chapter 2 for other reasons.
[3] This phenomenon was observed in the Asian financial crisis of the late 1990s (see Cook (2004)).
[4] See Note 1 of Chapter 3 for other related work.

insight into the behavior of EMCs.

The objective of this thesis is to study what type of exchange rate regime is more desirable in welfare terms when there are balance sheet constraints in EMCs. The thesis investigates the question by performing a rigorous welfare comparison of fixed and flexible exchange rate regimes in different dynamic stochastic general equilibrium small open economy models which incorporate balance sheet effects and foreign currency debt.

In this context, we extend the previous literature in the following two dimensions. First, we deal with a wide range of debt levels in order to investigate whether and how the degree of foreign currency debt affects balance sheets and welfare under different exchange rate regimes. Second, we evaluate the welfare properties of exchange rate regimes by employing a model that generates more realistic exchange rate volatility. To the best of our knowledge, few previous studies in this field consider these two issues. Regarding the former, most of the previous studies – with the noteworthy exception of Elekdağ and Tchakarov (2007) - do not examine the welfare implications of various debt levels under different exchange rate regimes. They deal with at most two steady-state calibrations of the debt level.[5] Thus, they do not present convincing answers to the question of what type of exchange rate regime is more suitable for EMCs when the level of foreign currency debt is low or high. With respect to the latter, since most of the existing studies assume a stable relationship between the nominal exchange rate and the nominal interest rate, their models generate predicted exchange rate volatility that is extremely low, compared to that seen in historical data (log-linearizing their models, the path of the nominal exchange rate basically depends on the standard UIP, uncovered interest parity, condition). Therefore, the impact of exchange rate variability on balance sheets could be

[5] Céspedes et al. (2000) consider two steady-state calibrations of the debt level. However, they compare fixed and flexible exchange rate regimes by employing the welfare measure based on a first-order approximation method, not using a second-order accurate welfare metric.

underestimated in their models. In other words, they might understate balance sheet effects and thus tend to underestimate balance sheet vulnerabilities. This thesis attempts to fill the gaps in the existing literature.

In this thesis, we conduct a quantitative analysis of exchange rate regimes. The models are calibrated using standard values from the literature and some values that match data from East Asian emerging markets. The second-order approximation method developed by Schmitt-Grohe and Uribe (2004b) is used to solve the models numerically. This method allows us to obtain a second-order accurate representation of expected utility and to conduct a rigorous welfare evaluation of exchange rate regimes. Bergin et al. (2007), Elekdağ and Tchakarov (2007) and others studies argue that a second-order approximation method is more suitable for assessing welfare than a first-order approximation method, since this higher-order approximation can capture the effects of uncertainty on the average levels of consumption and labor and thus utility.

Chapter 2 focuses on the role of debt levels and examines how the degree of foreign currency debt affects balance sheets and welfare under different exchange rate regimes. The ‘Fear of Floating’ view argues that the higher the level of foreign currency debt, the stronger the impacts of exchange rate fluctuations on balance sheets become, thus making flexible exchange rates less desirable. This is because, with a large amount of foreign currency debt, even a small exchange rate depreciation could inflate debt servicing costs, which could reduce firms’ net worth, thereby intensifying balance sheet vulnerabilities. Based on this argument, the main hypothesis of this chapter is that fixed exchange rates are more desirable in terms of welfare, the higher the level of foreign currency debt. The model used in this chapter is a dynamic stochastic general equilibrium small open economy model developed by Devereux et al. (2006). The model features two production sectors (the non-traded sector and the export sector), sticky prices in the non-traded sector, imperfect international risk sharing, balance sheet effects in combination with foreign currency debt, and exogenous foreign interest rate and export price shocks. The model also includes variable exchange rate pass-through, which enables us to analyze its effects on monetary policy rules.

The main findings of Chapter 2 are summarized as follows. First, in contrast to the 'Fear of Floating' view, the flexible exchange rate regime welfare-dominates the fixed exchange rate regime for a broad range of debt levels. In addition, as the level of foreign currency debt rises, the welfare difference between the two regimes becomes wider – the float becomes more desirable. Since by design the peg need not care about domestic-inflation (non-traded goods inflation), the peg generates more volatile domestic-inflation and hence higher price adjustment costs in the non-traded sector than the float. As we elaborate in detail in Chapter. 2, the price adjustment cost induces output loss and reduces final-output in the non-traded sector. Therefore, the peg yields lower final-output than the float – which lowers consumption (and welfare) relative to the float. Second, the degree of exchange rate pass-through does not change the welfare ranking of the two exchange rate regimes. However, the degree of exchange rate pass-through affects the welfare difference between the two regimes: the welfare difference between the two regimes is larger under low exchange rate pass-through than under full pass-through.

Chapter 3 highlights the role of exchange rate volatility and considers how the degree of exchange rate volatility affects the choice of exchange rate regime. The 'Fear of Floating' view argues that fixed exchange rates are more desirable in welfare terms, the more volatile are exchange rates. Chapter 3 tests this argument. This chapter employs an extended version of the Devereux et al. (2006) model. The main feature of the extended model is to introduce a stationary and exogenous AR(1) shock to the UIP condition *under floating exchange rates*, which allows the model to generate more volatile exchange rates. We regard this shock as reflecting a bias in the agent's exchange rate forecast. On the other hand, we assume that *under fixed exchange rates* there is no bias in exchange rate forecasts, on the basis of the fact that deviations from UIP were substantially small in the Bretton Woods era (e.g., Kollmann, 2005). Using the extended model, we evaluate the welfare properties of the peg and several types of flexible exchange rate regimes (the strict CPI inflation targeting regime, the strict domestic-inflation targeting regime, etc.).

The results are basically consistent with the 'Fear of Floating' view. The primary findings are: (i) the peg welfare-dominates the strict CPI-inflation targeting regime under plausible calibrations of exchange rate volatility and the welfare difference between the two regimes becomes larger as exchange rate volatility increases – the peg becomes more desirable; (2) whether the peg is welfare-superior to the strict domestic-inflation targeting regime or not depends on the degree of exchange rate volatility – the peg is more desirable in welfare terms when exchange rate volatility is high; (3) the presence of balance sheet effects is very important for the welfare assessment of exchange rate regimes. In the economy *without* balance sheet constraints, strict domestic-inflation targeting welfare-dominates the peg under plausible calibrations of exchange rate volatility. On the other hand, in the economy *with* balance sheet constraints, the peg welfare-dominates strict domestic-inflation targeting when exchange rate volatility is high (as mentioned above). The presence of balance sheet constraints alters the welfare ranking of the two regimes in the case of high exchange rate volatility.

Chapter 2

Foreign Currency Debt and Balance Sheet Effects

2.1. Introduction

It has been argued that many monetary authorities in emerging market countries (EMCs) are reluctant to let their currencies float freely. As suggested by Calvo and Reinhart (2002), one of the reasons is balance sheet vulnerabilities.[1] In many EMCs, so-called currency mismatches exist: banks and non-banks hold a large amount of debt denominated in foreign currencies which is insufficiently matched by foreign currency assets. Under the circumstances, a significant exchange rate depreciation would increase debt servicing costs and consequently reduce the value of their collateral or their net worth. Then the decline in net worth could adversely affect their access to capital markets and raise the risk premium substantially, which could reduce investment spending dramatically, thereby generating macroeconomic instability. This is referred to as balance sheet effects, balance sheet constraints, or the financial accelerator.

Recently, research on balance sheet effects and the appropriate choice of monetary policy for EMCs has been explored. Most of the studies in this field develop a standard small open-economy model which incorporates the financial accelerator

[1] In addition to balance sheet vulnerabilities, Calvo and Reinhart (2000) argue that lack of credibility, acute adjustments in the current account, exchange rate pass-through, etc. could give rise to 'fear of floating.'

mechanism à la Bernanke et al. (1999) and Carlstrom and Fuerst (1997). The key aspect of the framework is that the cost of external borrowing (the risk premium) is modeled as an endogenous variable and is linked to balance sheets. When firm's balance sheets deteriorate dramatically, e.g. owing to a sudden exchange rate depreciation, the risk premium increases substantially, thereby generating a severe recession. Thus, the model succeeds in accounting for balance sheet effects.

However, the studies do not always present the same conclusion on the appropriate choice of exchange rate regime. For example, Céspedes et al. (2002) find that a flexible exchange rate regime is better than a fixed exchange rate regime in terms of welfare.[2] They conduct a welfare comparison based on a quadratic loss function which consists of the unconditional variances of inflation, output and the real exchange rate. On the other hand, Choi and Cook (2004) and Cook (2004) show that a peg is welfare-superior to a float. Their welfare criteria depend on the standard deviation of a weighted average of representative agent's consumption and labour. As suggested by Elekdağ and Tchakarov (2007), one of the reasons for the different conclusions might be that the studies resort to first-order approximation techniques. Elekdağ and Tchakarov (2007) argue that, since the welfare measure based on a first-order approximation depends only on variances, a log-linear approximation of model equations is not appropriate for assessing welfare and that a second-order approximation is more suitable for assessing welfare because this higher approximation can pick up the effects of risk on the average levels of consumption and labour and thus utility.[3]

In addition, the above studies do not investigate how the level of foreign currency debt affects overall welfare and the choice of exchange rate regime. In other words, they do not present clear answers to the following question: when EMCs suffer from

---

[2] Céspedes et al. (2004), Devereux et al. (2006) and Gertler et al. (2007) also find that a flexible exchange rate regime is more desirable than a fixed exchange rate regime in welfare terms.

[3] Also see Bergin et al. (2007) and Kollmann (2002, 2004) for the advantage of second-order approximation methods.

excessive levels of external debt and significant balance sheet vulnerabilities, which exchange rate regime is more desirable, fixed exchange rates or flexible exchange rates? A theoretical exception is Elekdağ and Tchakarov (2007). They reveal the debt threshold above which a fixed exchange rate regime becomes welfare-superior to a flexible exchange rate regime. They consider multiple steady-state calibrations of the debt-to-net worth (debt-to-equity) ratio and perform a welfare comparison based on a second-order approximation method. They find that a peg welfare-dominates a float once the debt-to-net worth ratio exceeds 137%. Their result suggests that implementing flexible exchange rate regimes might not be effective in EMCs with even moderate levels of foreign currency debt.

This chapter attempts to conduct a welfare comparison of fixed and flexible exchange rate regimes which is based on a second-order accurate welfare metric. The main objective of this chapter is to investigate whether and how the level of foreign currency debt affects welfare under different exchange rate regimes. To this end, we deal with a wide range of debt-to-net worth ratios. The model used in this chapter is a dynamic stochastic general equilibrium small open economy model developed by Devereux et al. (2006).[4] Using this model, this chapter evaluates the welfare implications of the fixed exchange rate regime and a flexible exchange rate regime where the monetary authority strictly targets the inflation rate of the CPI.

Although the model of Devereux et al (2006) and that of Elekdağ and Tchakarov (2007) build on some common characteristics designed towards the emerging market environment, e.g. balance sheet effects, foreign currency debt, and vulnerabilities to external shocks, the former mainly differs from the latter in the following three dimensions. First, the former develops a *two-sector* (non-traded sector and export sector) model, which assumes staggered price setting in the non-traded sector. On the

[4] Devereux et al. (2006) compare fixed and flexible exchange rate regimes by using a second-order approximation. However, they do not evaluate the welfare implications of various debt levels under fixed and flexible exchange rate regimes.

other hand, the latter's analysis is solely based on a *one-sector* model. The former could offer useful insights into the behaviour of the non-traded and export sectors. As we shall see in subsection 2.3.1., the financial accelerator does not have uniform impacts on the two sectors. With a large stock of foreign currency debt, the economic downturn could become more serious in the export sector than in the non-traded sector. Second, the former deals with both a full exchange rate pass-through environment and a delayed one, while the latter considers only a full exchange rate pass-through environment. The former can analyze the effects of exchange rate pass-through on monetary policy rules. Third, in Devereux et al., the (steady-state) risk premium is assumed to be an increasing and *convex* function of the leverage ratio within a certain range. On the other hand, in Elekdağ and Tchakarov, it is assumed that the risk premium is an increasing and *concave* function of the leverage ratio. The marginal effect of the leverage ratio on the risk premium is more serious with the former relative to the latter.

The main findings can be summarized as follows. First, under full exchange rate pass-through, the flexible exchange rate regime is welfare-superior to the fixed exchange rate regime for all debt-to-net worth ratios. Moreover, as the debt-to-net worth ratio rises, the welfare difference between the two regimes becomes wider. This implies that flexible exchange rates are more desirable, the higher the level of foreign currency debt. Since by design the peg acts so as to eliminate exchange rate fluctuations completely and not to directly respond to domestic-inflation (non-traded goods inflation), the peg generates more volatile domestic-inflation and hence higher price adjustment costs in the non-traded sector than the float. As we will discuss in subsection 2.3.2., the price adjustment cost induces output loss and reduces final-output in the non-traded sector. Therefore, the peg yields lower final-output than the float – which lowers consumption (and welfare) relative to the float.

Second, comparing the float with the peg under low exchange rate pass-through, we find that the degree of exchange rate pass-through does not change the welfare ranking of the two exchange rate regimes. However, our results show that the degree of exchange rate pass-through affects the welfare difference between both regimes: the welfare difference between the two regimes is larger under low exchange rate pass-through than under full pass-through. The results suggest that flexible exchange rates are more attractive in terms of welfare, the slower exchange rate pass-through.

We also perform different robustness experiments in order to check the sensitivity of our main results to alternative calibrations. The main message of this chapter is robust to various parameterizations of the risk premium, preferences, and the debt-to-net worth ratio. Moreover, we investigate another specification of the risk premium and similar results are obtained. In contrast to the 'Fear of Floating' view highlighted by Calvo and Reinhart (2002), our results suggest that flexible exchange rates could be more desirable than fixed exchange rates in welfare terms even when EMCs have excessive levels of foreign currency debt and face significant balance sheet vulnerabilities.

The structure of this chapter is as follows. Section 2.2. presents a brief description of the model developed by Devereux et al. (2006). Section 2.3. provides the main results and Section 2.4. presents the results of different robustness experiments. Section 2.5. concludes.

2.2. The model

As mentioned above, this chapter employs the model of Devereux et al. (2006). In this section, we present a brief description of the model.

The model constructs a small open economy with households, firms, capitalists, foreign lenders, and the monetary authority. Firms consist of three sets of players: production firms, importers, and unfinished capital goods firms. In addition, production firms, unfinished capital goods firms, and capitalists are divided into two sectors: the non-traded sector and the export sector. Two final goods (the non-traded good and the export good) are produced by production firms in each sector using labour and capital. Labour is supplied by households and capitalists, while capital is rented from capitalists. Unfinished capital goods firms produce 'unfinished' capital goods by using 'finished' capital and the investment composite, and sell them to capitalists. Capitalists borrow money denominated in foreign currency from foreign lenders by offering their own net worth as collateral, purchase 'unfinished' capital, and convert them into 'finished' capital. The monetary authority adjusts the nominal interest rate in order to peg the exchange rate or to control CPI inflation. Taking into account a line of empirical evidence that EMCs tend to be very vulnerable to external shocks (e.g., Schaechter et al., 2000), the model incorporates the following two external shocks: foreign interest rate and export price shocks.

2.2.1. Households

There is a continuum of measure 1 of consumers. The representative consumer's inter-temporal lifetime utility function is given by

$$U = E_0 \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \left(\frac{C_{\mathrm{t}}^{1-\sigma}}{1-\sigma} - \eta \frac{H_{\mathrm{t}}^{1+\psi}}{1+\psi}\right) \tag{2.1}$$

where $0 < \beta < 1$ is the discount factor, H_{t} is labour effort, and C_{t} is a composite consumption index defined by the following CES function:

$$C_{\mathrm{t}} = (a^{\frac{1}{\rho}} C_{N\mathrm{t}}^{\frac{\rho-1}{\rho}} + (1-a)^{\frac{1}{\rho}} C_{M\mathrm{t}}^{\frac{\rho-1}{\rho}})^{\frac{\rho}{\rho-1}}$$

where ρ (> 0) is the elasticity of substitution between non-traded and imported goods and a is the share of non-traded goods in the consumer price index. $C_{N\mathrm{t}}$ and $C_{M\mathrm{t}}$ are the consumption of non-traded and imported goods, respectively. They are defined, as in Dixit and Stiglitz (1977), by the following CES aggregate of the continuum of differentiated goods:

$$C_{N\mathrm{t}} = [\int_0^1 C_{N\mathrm{t}}(i)^{\frac{\lambda-1}{\lambda}} di]^{\frac{\lambda}{\lambda-1}}$$

$$C_{M\mathrm{t}} = [\int_0^1 C_{M\mathrm{t}}(i)^{\frac{\lambda-1}{\lambda}} di]^{\frac{\lambda}{\lambda-1}}$$

where $i \in [0,1]$ and λ (> 1) is the elasticity of substitution between varieties (it is assumed that λ is the same across the sectors). $C_{N\mathrm{t}}(i)$ is produced by a monopolistically competitive production firm and $C_{M\mathrm{t}}(i)$ is distributed by a monopolistically competitive importer. The consumer price index (P_{t}) is then:

$$P_{\mathrm{t}} = (a\, P_{N\mathrm{t}}^{1-\rho} + (1-a)\, P_{M\mathrm{t}}^{1-\rho})^{\frac{1}{1-\rho}} \tag{2.2}$$

where $P_{N\mathrm{t}}$ and $P_{M\mathrm{t}}$ denote the prices of non-traded and imported goods, respectively.

The representative consumer's budget constraint is given by

$$P_{\mathrm{t}}C_{\mathrm{t}} = W_{\mathrm{t}}H_{\mathrm{t}} + \Pi_{\mathrm{t}} + S_{\mathrm{t}}D_{\mathrm{t+1}} + B_{\mathrm{t+1}} - P_{\mathrm{t}}\frac{\psi_D}{2}(D_{\mathrm{t+1}} - \overline{D})^2 - (1+i_{\mathrm{t}}^*)S_{\mathrm{t}}D_{\mathrm{t}}$$
$$-(1+i_{\mathrm{t}})B_{\mathrm{t}} \tag{2.3}$$

where W_{t} is the nominal wage, S_{t} is the nominal exchange rate, and $\psi_D > 0$ (a constant). Here B_{t} and D_{t} are nominal stocks of local and foreign currency-denominated debt, respectively. The representative consumer can borrow from domestic financial markets at a given interest rate i_{t} while he can borrow abroad at a given interest rate i_{t}^*, which is assumed to follow an exogenous AR(1) process. But, foreign borrowing is subject to a small transaction cost, $P_{\mathrm{t}}\frac{\psi_D}{2}(D_{\mathrm{t+1}} - \overline{D})^2$, where the cost is denominated in the composite consumption index and $\overline{D}$ is a deterministic steady-state level of net foreign debt.[5] Finally, since households own all

[5] To ensure that the model is solved numerically using a second-order approximation, this small transaction cost is required. Without this cost, the stocks of local and foreign debt and consumption would be non-stationary. Moreover, it is assumed that households' foreign borrowing is not subject to informational problems, while foreign borrowing by capitalists is subject to informational

domestic firms, they receive any profits from the firms. Assuming that export goods firms and unfinished capital goods firms are perfectly competitive, households receive profits from the non-traded sector and the import sector, Π_t.

The representative consumer's problem is to maximize its expected utility (Eq. (2.1)) with respect to $C_t, H_t, B_{t+1},$ and D_{t+1} subject to the budget constraint (Eq. (2.3)). It follows that the first order conditions are:

$$W_t = \eta H_t^{\psi} P_t C_t^{\sigma} \tag{2.4}$$

$$\frac{1}{1+i_{t+1}^*}\left[1 - \frac{\psi_D P_t}{S_t}(D_{t+1} - \bar{D})\right] = \beta E_t \left\{ \frac{C_t^{\sigma} P_t}{C_{t+1}^{\sigma} P_{t+1}} \frac{S_{t+1}}{S_t} \right\} \tag{2.5}$$

$$\frac{1}{1+i_{t+1}} = \beta E_t \left\{ \frac{C_t^{\sigma} P_t}{C_{t+1}^{\sigma} P_{t+1}} \right\} \tag{2.6}$$

Eq. (2.4) represents the labour supply condition. Eqs. (2.5) and (2.6) correspond to the Euler equations for foreign and domestic currency debt, respectively.

2.2.2. Production firms

The production technology for a non-traded good firm $i \in [0,1]$ is given by:

$$Y_{Nt}(i) = K_{Nt}(i)^{\alpha} H_{Nt}(i)^{(1-\alpha)\Omega} (H_{Nt}^e(i))^{(1-\Omega)(1-\alpha)}$$

The production technology for an exporter $i \in [0,1]$ is given by:

$$Y_{Xt}(i) = K_{Xt}(i)^{\gamma} H_{Xt}(i)^{(1-\gamma)\Omega} (H_{Xt}^e(i))^{(1-\Omega)(1-\gamma)}$$

α and γ are the shares of capital in each sector. Ω is the share of household-labour. Production firms in the non-traded sector hire labour from households (H_{Nt}) and from capitalists in the same sector (H_{Nt}^e). In return, capitalists in the non-traded sector earn wages, W_{Nt}^e. Capital, K_{Nt}, is supplied by capitalists in the non-traded sector. The

(*footnote continued*)
asymmetries (see subsection 2.2.5.).

export sector is entirely analogous.

Cost minimization in the non-traded sector implies:

$$W_{\mathrm{t}} = MC_{N\mathrm{t}}(1-\alpha)\Omega\frac{Y_{N\mathrm{t}}}{H_{N\mathrm{t}}} \tag{2.7}$$

$$W_{N\mathrm{t}}^{e} = MC_{N\mathrm{t}}(1-\alpha)(1-\Omega)\frac{Y_{N\mathrm{t}}}{H_{N\mathrm{t}}^{e}} \tag{2.8}$$

$$R_{N\mathrm{t}} = MC_{N\mathrm{t}}\alpha\frac{Y_{N\mathrm{t}}}{K_{N\mathrm{t}}} \tag{2.9}$$

where $MC_{N\mathrm{t}}$ is the marginal cost, $R_{N\mathrm{t}}$ denotes the rental rate of capital, and $Y_{N\mathrm{t}}$ is total output in the non-traded sector given by

$$Y_{N\mathrm{t}} = K_{N\mathrm{t}}^{\alpha}H_{N\mathrm{t}}^{(1-\alpha)\Omega}(H_{N\mathrm{t}}^{e})^{(1-\Omega)(1-\alpha)} \tag{2.10}$$

Similarly, the following optimality conditions in the export sector can be derived from cost minimization:

$$W_{\mathrm{t}} = P_{X\mathrm{t}}(1-\gamma)\Omega\frac{Y_{X\mathrm{t}}}{H_{X\mathrm{t}}} \tag{2.11}$$

$$W_{X\mathrm{t}}^{e} = P_{X\mathrm{t}}(1-\gamma)(1-\Omega)\frac{Y_{X\mathrm{t}}}{H_{X\mathrm{t}}^{e}} \tag{2.12}$$

$$R_{X\mathrm{t}} = P_{X\mathrm{t}}\gamma\,\frac{Y_{X\mathrm{t}}}{K_{X\mathrm{t}}} \tag{2.13}$$

where $R_{X\mathrm{t}}$ is the rental rate of capital, and $Y_{X\mathrm{t}}$ is total output in the export sector given by

$$Y_{X\mathrm{t}} = K_{X\mathrm{t}}^{\gamma}H_{X\mathrm{t}}^{(1-\gamma)\Omega}(H_{X\mathrm{t}}^{e})^{(1-\Omega)(1-\gamma)} \tag{2.14}$$

$P_{X\mathrm{t}}$ is the unit price of the export good and also the unit production cost since the export sector is perfectly competitive. It is assumed that the law of one price holds for export goods:

$$P_{X\mathrm{t}} = S_{\mathrm{t}}P_{X\mathrm{t}}^{*} \tag{2.15}$$

where $P^*_{X\mathrm{t}}$ is the foreign currency price of the export good. We assume that $P^*_{X\mathrm{t}}$ is exogenously determined on world markets and follows a stochastic process.[6]

2.2.3. Price setting

The model employs a price setting process à la Rotemberg (1982). Production firms in the non-traded sector can behave as monopolistic competitors, but they must incur quadratic price adjustment costs in setting their prices.

Firm *i* chooses $P_{N\mathrm{t}}(i)$ in order to maximize the following profit function subject to demand for firm *i*'s product, $Y_{N\mathrm{t}}(i) = (\frac{P_{N\mathrm{t}}(i)}{P_{N\mathrm{t}}})^{-\lambda} Y_{N\mathrm{t}}$:

$$E_0 \sum_{\mathrm{t}=0}^{\infty} \Gamma_{\mathrm{t}} [P_{N\mathrm{t}}(i) Y_{N\mathrm{t}}(i) - MC_{N\mathrm{t}} Y_{N\mathrm{t}}(i) - P_{\mathrm{t}} \frac{\psi_{P_N}}{2} (\frac{P_{N\mathrm{t}}(i) - P_{N\mathrm{t}-1}(i)}{P_{N\mathrm{t}-1}(i)})^2] \tag{2.16}$$

where Γ_{t} is the household's discount factor given by

$$\Gamma_{\mathrm{t}} = \beta^{\mathrm{t}} \frac{1}{C_{\mathrm{t}}^{\sigma} P_{\mathrm{t}}} \tag{2.17}$$

Since non-traded firms are owned by households, the expected profit stream needs to be discounted using the household's discount factor. The third term inside brackets in Eq. (2.16) describes the price adjustment cost (denominated in the composite final good) and the parameter ψ_{P_N} represents the degree of nominal price rigidities.

Under the assumption of symmetry, the optimal price setting rule is derived as

$$P_{N\mathrm{t}} = \left(\frac{\lambda}{\lambda - 1}\right) MC_{N\mathrm{t}} - \frac{\psi_{P_N}}{\lambda - 1} \frac{P_{\mathrm{t}}}{Y_{N\mathrm{t}}} \frac{P_{N\mathrm{t}}}{P_{N\mathrm{t}-1}} (\frac{P_{N\mathrm{t}}}{P_{N\mathrm{t}-1}} - 1)$$

---

[6] We assume that $P^*_{X\mathrm{t}}$ is the following AR(1) process:

$\ln (P^*_{X\mathrm{t}}) = \rho_X \ln (P^*_{X\mathrm{t}-1}) + \varepsilon_{X\mathrm{t}}$

where $\varepsilon_{X\mathrm{t}}$ is the i.i.d. disturbance with the standard deviation σ_X .

$$+\frac{\psi_{P_N}}{\lambda-1}E_{\mathrm{t}}\left[\frac{\Gamma_{\mathrm{t}+1}}{\Gamma_{\mathrm{t}}}\frac{P_{\mathrm{t}+1}}{Y_{N\mathrm{t}}}\frac{P_{N\mathrm{t}+1}}{P_{N\mathrm{t}}}\left(\frac{P_{N\mathrm{t}+1}}{P_{N\mathrm{t}}}-1\right)\right] \tag{2.18}$$

Importers also set their prices as monopolistic competitors and confront similar price adjustment costs. Hence, the importer *i*'s profit function is described in the identical way:

$$E_0\sum_{\mathrm{t}=0}^{\infty}\Gamma_{\mathrm{t}}\left[P_{M\mathrm{t}}(i)T_{M\mathrm{t}}(i)-S_{\mathrm{t}}P^*_{M\mathrm{t}}T_{M\mathrm{t}}(i)-P_{\mathrm{t}}\frac{\psi_{P_M}}{2}(\frac{P_{M\mathrm{t}}(i)-P_{M\mathrm{t}-1}(i)}{P_{M\mathrm{t}-1}(i)})^2\right]$$

where $P^*_{M\mathrm{t}}$ denotes the unit price of the imported good in foreign currency, $T_{M\mathrm{t}}(i)=(\frac{P_{M\mathrm{t}}(i)}{P_{M\mathrm{t}}})^{-\lambda}T_{M\mathrm{t}}$ is demand for importer *i*'s good, and $T_{M\mathrm{t}}$ is total demand for imports. We assume that $P^*_{M\mathrm{t}}$ is exogenously determined on world markets, that is, EMCs are price- takers. For simplicity, $P^*_{M\mathrm{t}}$, is normalised to unity.

Similarly, the optimal price setting rule is given by

$$P_{M\mathrm{t}}=\left(\frac{\lambda}{\lambda-1}\right)S_{\mathrm{t}}P^*_{M\mathrm{t}}-\frac{\psi_{P_M}}{\lambda-1}\frac{P_{\mathrm{t}}}{T_{M\mathrm{t}}}\frac{P_{M\mathrm{t}}}{P_{M\mathrm{t}-1}}(\frac{P_{M\mathrm{t}}}{P_{M\mathrm{t}-1}}-1)$$

$$+\frac{\psi_{P_M}}{\lambda-1}E_{\mathrm{t}}\left[\frac{\Gamma_{\mathrm{t}+1}}{\Gamma_{\mathrm{t}}}\frac{P_{\mathrm{t}+1}}{T_{M\mathrm{t}}}\frac{P_{M\mathrm{t}+1}}{P_{M\mathrm{t}}}\left(\frac{P_{M\mathrm{t}+1}}{P_{M\mathrm{t}}}-1\right)\right] \tag{2.19}$$

Here, the parameter ψ_{P_M} indicates the degree of exchange rate pass-through. When $\psi_{P_M}=0$, it indicates that exchange rate pass-through is complete.

2.2.4. Unfinished capital goods firms

As mentioned above, unfinished capital goods firms are perfectly competitive. The firms produce unfinished capital goods and sell them to capitalists. It is assumed that new unfinished capital goods in the non-traded sector are produced by combining both the investment composite, $I_{N\mathrm{t}}$, and the exiting capital stock, $K_{N\mathrm{t}}$. The investment composite consists of the same mixture as the household's consumption basket. The model assumes that unfinished capital goods firms incur quadratic adjustment costs of investment. More specifically, the production technology is the following CRS (constant return to scale) function:

$$\left[\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta\right)^2\right] K_{N\mathrm{t}}$$

where the second term inside brackets represents investment adjustment costs ($\psi_I > 0$, a constant) and δ is the depreciation rate.

Since the investment composite comprises the same combination as the household's consumption basket, the price of a unit of the investment composite is P_{t}. Defining $Q_{N\mathrm{t}}$ as the price of an unfinished capital good and $R^G_{KN\mathrm{t}}$ as the rental rate of capital provided by capitalists (in the non-traded sector), the profit function of unfinished capital goods firms in the non-traded sector can be written as:

$$Q_{Nt}\left[\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta\right)^2\right] K_{N\mathrm{t}} - P_{\mathrm{t}} I_{N\mathrm{t}} - R^G_{KN\mathrm{t}} K_{N\mathrm{t}}$$

Then, profit maximization implies:

$$Q_{N\mathrm{t}} = \frac{P_{\mathrm{t}}}{1 - \psi_I(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta)} \tag{2.20}$$

$$R^G_{KN\mathrm{t}} = Q_{Nt}\left[\psi_I(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta)\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta\right)^2\right] \tag{2.21}$$

The problem is analogous for unfinished capital goods firms in the export sector. Defining $Q_{X\mathrm{t}}$ as the price of an unfinished capital good and $R^G_{KX\mathrm{t}}$ as the rental rate of capital, the first-order conditions in the export sector are then

$$Q_{X\mathrm{t}} = \frac{P_{\mathrm{t}}}{1 - \psi_I(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta)} \tag{2.22}$$

$$R^G_{KX\mathrm{t}} = Q_{Xt}\left[\psi_I\left(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta\right)\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta\right)^2\right] \tag{2.23}$$

The production technology and incomplete capital depreciation imply that capital stocks in the two sectors evolve according to

$$K_{N\mathrm{t}+1} = \left[\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta\right)^2\right]K_{N\mathrm{t}} + (1-\delta)K_{N\mathrm{t}} \tag{2.24}$$

$$K_{X\mathrm{t}+1} = \left[\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta\right)^2\right]K_{X\mathrm{t}} + (1-\delta)K_{X\mathrm{t}} \tag{2.25}$$

2.2.5. Capitalists

Regarding the behaviour of capitalists, the model closely follows the set-up of Bernanke et al. (1999). Here, we focus on capitalists in the non-traded sector.[7]

At the end of period *t*, capitalists in the non-traded sector invest in new capital, $K_{N\mathrm{t}+1}$, both by purchasing unfinished capital goods at price $Q_{N\mathrm{t}}$ per unit from unfinished capital goods firms (and then transforming them into finished capital) and by buying existing capital, $(1-\delta)K_{N\mathrm{t}}$, at price $Q_{N\mathrm{t}}$ per unit from the domestic market. It is assumed that only capitalists have access to a technology for converting unfinished capital goods into finished capital and that they can do it without any costs. But, capitalists do not have sufficient money for their investment. Therefore, they need to finance their investment with their own net worth, $Z_{N\mathrm{t}+1}$, and with foreign loans. Then, the amount borrowed abroad $(D^{\mathrm{e}}_{N\mathrm{t}+1})$ is given by

$$D^{\mathrm{e}}_{N\mathrm{t}+1} = \left(\frac{1}{S_\mathrm{t}}\right)(Q_{N\mathrm{t}}K_{N\mathrm{t}+1} - Z_{N\mathrm{t}+1})$$

However, foreign borrowing is subject to agency costs owing to moral hazard. Each investment project faces an idiosyncratic productivity shock, $\omega \in (0, \infty)$. It is

[7] For notational simplicity, below we drop capitalist-specific indices.

assumed that ω is log-normally distributed and $E(\omega)$ =1. If $K_{N\mathrm{t}+1}$ is invested in, the total return on the investment will be $\omega R_{KN\mathrm{t}+1}Q_{N\mathrm{t}}K_{N\mathrm{t}+1}$ where $R_{KN\mathrm{t}+1}$ is the real gross return on capital. Capitalists can observe ω without any costs, while foreign lenders have to pay monitoring costs, μ times the value of the project ($\mu\omega R_{KN\mathrm{t}+1}Q_{N\mathrm{t}}K_{N\mathrm{t}+1}$), in order to observe ω. The model assumes that capitalists and foreign lenders are risk neutral.

Under these circumstances, the expected share of the return on capital going to capitalists, $A(\overline{\omega}_{N\mathrm{t}+1})$, is determined as follows:

$$A(\overline{\omega}_{N\mathrm{t}+1}) = \int_{\overline{\omega}_{N\mathrm{t}+1}}^{\infty} \omega f(\omega)d\omega - \overline{\omega}_{N\mathrm{t}+1}\int_{\overline{\omega}_{N\mathrm{t}+1}}^{\infty} f(\omega)d\omega$$

where $f(\omega)$ is the pdf of ω. This implies that if ω is larger than a threshold level $\overline{\omega}_{Nt+1}$, capitalists pay $\overline{\omega}_{Nt+1}R_{KN\mathrm{t}+1}Q_{N\mathrm{t}}K_{N\mathrm{t}+1}$ to foreign lenders and receive the total return net of the payment to foreign lenders, and that if $\omega < \overline{\omega}_{Nt+1}$, they receive nothing. On the other hand, the expected share of the return on capital going to foreign lenders, $B(\overline{\omega}_{N\mathrm{t}+1})$, is

$$B(\overline{\omega}_{N\mathrm{t}+1}) = \overline{\omega}_{N\mathrm{t}+1}\int_{\overline{\omega}_{N\mathrm{t}+1}}^{\infty} f(\omega)d\omega + (1-\mu)\int_{0}^{\overline{\omega}_{N\mathrm{t}+1}} \omega f(\omega)d\omega$$

where $\mu\int_0^{\overline{\omega}_{N\mathrm{t}+1}} \omega f(\omega)d\omega \ (= \phi_{N\mathrm{t}+1})$ is the expected fraction of the return on capital that is used up in monitoring and $0 < \mu < 1$. This means that if $\omega > \overline{\omega}_{Nt+1}$, foreign lenders receive $\overline{\omega}_{Nt+1}R_{KN\mathrm{t}+1}Q_{N\mathrm{t}}K_{N\mathrm{t}+1}$, and that if $\omega < \overline{\omega}_{Nt+1}$, foreign lenders monitor the investment by paying monitoring costs and seize the whole yield on the investment net of the monitoring costs. It is assumed that monitoring costs are denominated in the composite final good.

Then, capitalists choose the threshold value $\overline{\omega}_{Nt+1}$ and the stock of capital $K_{N\mathrm{t}+1}$ in order to maximize their expected profits subject to the foreign lenders' participation constraint:

$$\max \quad E_t[R_{KNt+1}Q_{Nt}K_{Nt+1}\,A(\overline{\omega}_{Nt+1})]$$
$$\text{subject to} \quad R_{KNt+1}Q_{Nt}K_{Nt+1}B(\overline{\omega}_{Nt+1}) = (1+i^*_{t+1})S_{t+1}D^{e}_{Nt+1}$$

The optimal financial contract condition is determined as follows:[8]

$$\frac{E_t\left[R_{KNt+1}\left\{B(\overline{\omega}_{Nt+1})\dfrac{A'(\overline{\omega}_{Nt+1})}{B'(\overline{\omega}_{Nt+1})} - A(\overline{\omega}_{Nt+1})\right\}\right]}{E_t\left[\dfrac{A'(\overline{\omega}_{Nt+1})}{B'(\overline{\omega}_{Nt+1})}\dfrac{S_{t+1}}{S_t}\right]} = (1+i^*_{t+1}) \tag{2.26}$$

Eq. (2.26) implies that, owing to informational problems, the expected gross return on capital, $E(R_{KNt+1})$, is greater than the opportunity cost of funds for foreign lenders, $(1+i^*_{t+1})E\left(\frac{S_{t+1}}{S_t}\right)$. In other words, the risk premium, $\frac{E(R_{KNt+1})}{(1+i^*_{t+1})E\left(\frac{S_{t+1}}{S_t}\right)}$, is imposed when capitalists borrow from foreign lenders. We now consider the relationship between the risk premium and the amount borrowed abroad. In deterministic steady state, Eq. (2.26) and the foreign lenders' participation constraint can be written as:

$$R_{KN}\frac{1}{rp_N} = (1+i^*)$$

$$R_{KN}B(\overline{\omega}_N) = (1+i^*)(1-\frac{1}{LR})$$

where *LR* denotes the leverage ratio, $\frac{Q_N K_N}{Z_N}$, and rp_N is the risk premium given by

$$rp_N = \frac{\dfrac{A'(\overline{\omega}_N)}{B'(\overline{\omega}_N)}}{B(\overline{\omega}_N)\dfrac{A'(\overline{\omega}_N)}{B'(\overline{\omega}_N)} - A(\overline{\omega}_N)}$$

Combining both equations gives the relationship between the risk premium and the leverage ratio:

[8] See Appendix A.1. for more detailed discussions of the optimal financial contract. The derivation of $A(\overline{\omega})$, $B(\overline{\omega})$, ϕ, $A'(\overline{\omega})$, and $B'(\overline{\omega})$ is shown in Appendix A.2.

$$rp_N B(\varpi_N) = (1 - \frac{1}{LR})$$

Figure 2.1 shows this relationship graphically: the risk premium is increasing in the leverage ratio and is convex within a certain range of leverage ratios.[9]

At the beginning of each period, capitalists collect the returns on investment and repay foreign debt. Assuming that capitalists die at any time period with probability $(1-\nu)$ [10] and consume the returns on capital only when they die, their consumption in the non-traded sector is given by

$$P_{\mathrm{t}} C_{\mathrm{t}}^{Ne} = (1-\nu) R_{KN\mathrm{t}} Q_{N\mathrm{t}-1} K_{N\mathrm{t}}\, A(\varpi_{N\mathrm{t}}) \tag{2.27}$$

C_{t}^{Ne} is assumed to comprise the same mix as the household's consumption basket. Recall that wages ($W_{N\mathrm{t}}^{e}$) are earned by capitalists working in the non-traded production sector.[11] Their net worth thus consists of the unconsumed fraction of the returns and the wages, that is,

$$Z_{N\mathrm{t}+1} = \nu R_{KN\mathrm{t}} Q_{N\mathrm{t}-1} K_{N\mathrm{t}}\, A(\varpi_{N\mathrm{t}}) + W_{N\mathrm{t}}^{e} \tag{2.28}$$

Note that the expected share of the return on capital going to capitalists, $A(\varpi_{N\mathrm{t}})$, and the participation constraint for foreign lenders are expressed as follows:

$$A(\varpi_{N\mathrm{t}}) = 1 - B(\varpi_{N\mathrm{t}}) - \mu \int_0^{\varpi_{N\mathrm{t}}} \omega f(\omega) d\omega = 1 - B(\varpi_{N\mathrm{t}}) - \phi_{N\mathrm{t}} \tag{2.29}$$

$$\begin{aligned} R_{KN\mathrm{t}} Q_{N\mathrm{t}-1} K_{N\mathrm{t}} B(\varpi_{N\mathrm{t}}) &= (1 + i_{\mathrm{t}}^{*}) S_{\mathrm{t}} \left(\frac{Q_{N\mathrm{t}-1} K_{N\mathrm{t}} - Z_{N\mathrm{t}}}{S_{\mathrm{t}-1}} \right) \\ &= (1 + i_{\mathrm{t}}^{*}) S_{\mathrm{t}} D_{N\mathrm{t}}^{\mathrm{e}} \end{aligned} \tag{2.30}$$

[9] Figure 2.1 coincides with the case when the standard error of the productivity shock (σ_ω) is set at 0.217. This value (0.217) is used to calibrate a deterministic steady-state debt-to-net worth ratio of 200% in the baseline experiment. The dotted line indicates a leverage ratio of 290%, which corresponds to a deterministic steady-state debt-to-net worth ratio of 200% in the baseline experiment.

[10] To ensure that capitalists always need to borrow, that is, capitalists cannot accumulate enough wealth to fully finance their investment, this assumption is required. Capitalists who exit are replaced by new capitalists, so that the total population of capitalists is constant in every period.

[11] By assuming that capitalists earn wages, new capitalists can have some funds and invest when they arrive.

where $D^{\mathrm{e}}_{N\mathrm{t}} = (Q_{N\mathrm{t}-1}K_{N\mathrm{t}} - Z_{N\mathrm{t}})\ /S_{\mathrm{t}-1}$ represents the amount borrowed abroad at the end of period *t*-1. Using Eq. (2.29) - (2.30), $Z_{N\mathrm{t}+1}$ can be rewritten as:

$$Z_{N\mathrm{t}+1} = \nu(1-\phi_{N\mathrm{t}})R_{KN\mathrm{t}}Q_{N\mathrm{t}-1}K_{N\mathrm{t}} - \nu S_{\mathrm{t}}(1+i^{*}_{\mathrm{t}})D^{\mathrm{e}}_{N\mathrm{t}} + W^{e}_{N\mathrm{t}} \tag{2.31}$$

Eq. (2.31) implies that a exchange rate depreciation, e.g. triggered by a sudden increase in the foreign interest rate and an unanticipated worsening of terms of trade, would reduce $Z_{N\mathrm{t}+1}$, which could raise the risk premium due to a increase in the leverage ratio. This could reduce investment, thereby causing a fall in output. In addition, with a large stock of foreign currency debt, the exchange rate depreciation could further damage $Z_{N\mathrm{t}+1}$, thereby intensifying balance sheet vulnerabilities by even more. Devereux et al. (2006) investigate the impact of a nominal exchange rate depreciation on the economy by using impulse response analysis. Their results show that a nominal exchange rate depreciation, triggered by an unanticipated increase in the foreign interest rate, cause a fall in capitalists' net worth, which reduces investment and non-traded output by raising the risk premium.[12]

Since capitalists rent their finished capital to production firms and to unfinished capital goods firms and capital depreciates at the rate of δ, the real gross return on capital in the non-traded sector, $R_{KN\mathrm{t}+1}$, is defined as the sum of $R_{N\mathrm{t}+1}$, $R^{G}_{KN\mathrm{t}+1}$, and $(1-\delta)Q_{N\mathrm{t}+1}$, divided by the purchase price of capital, that is,

$$R_{KN\mathrm{t}+1} = \frac{R_{N\mathrm{t}+1} + R^{G}_{KN\mathrm{t}+1} + Q_{N\mathrm{t}+1}(1-\delta)}{Q_{N\mathrm{t}}} \tag{2.32}$$

The details of capitalists' behaviour in the export sector are described analogously (see Appendix A.3.).

2.2.6. Monetary policy rules

The monetary authority manages a short-term nominal interest rate, $i_{\mathrm{t}+1}$, which is

[12] See Devereux et al. (2006, Fig. 3).

adjusted at the end of period *t*. A change in the interest rate has a direct effect on households' behaviour via Eq. (2.6). The interest rule takes the following simple form:

$$1 + i_{t+1} = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\mu_\pi} \left(\frac{S_t}{\bar{S}}\right)^{\mu_s} (1 + \bar{\imath}) \tag{2.33}$$

where π_t denotes consumer price inflation ($\frac{P_t}{P_{t-1}}$), and $\bar{\pi}$ is a deterministic steady-state level of CPI inflation (throughout this paper, the term 'steady state' indicates the deterministic steady state). $\bar{S}$ is a nominal exchange rate target and $\bar{\imath}$ is a deterministic steady-state level of the short-term nominal interest rate. Here, $\bar{\pi}$ and $\bar{S}$ are set to unity.

The monetary authority changes the short-term interest rate in response to consumer price inflation and the nominal exchange rate. $\mu_\pi \to \infty$ corresponds to strict CPI inflation targeting. On the other hand, $\mu_s \to \infty$ indicates that the monetary authority implements a fixed exchange rate regime. Following Bergin et al. (2007), Devereux et al. (2006), Elekdağ and Tchakarov (2007), and Kollmann (2002, 2004), we assume that all monetary policy rules are completely credible.

2.2.7. Equilibrium

As mentioned above, (i) price adjustment costs in the non-traded and import sectors, (ii) foreign borrowing costs by households, and (iii) monitoring costs by foreign lenders are denominated in the composite final good. The market clearing condition for non-traded goods is thus

$$Y_{Nt} = a\left(\frac{P_{Nt}}{P_t}\right)^{-\rho} [C_t + I_{Nt} + I_{Xt} + C_t^{Ne} + C_t^{Xe} + \frac{\psi_D}{2}(D_{t+1} - \bar{D})^2$$

$$+ \frac{\psi_{P_N}}{2}\left(\frac{P_{Nt} - P_{Nt-1}}{P_{Nt-1}}\right)^2 + \frac{\psi_{P_M}}{2}(\frac{P_{Mt} - P_{Mt-1}}{P_{Mt-1}})^2$$

$$+\frac{\phi_{Nt}R_{KNt}Q_{Nt-1}K_{Nt}}{P_t}+\frac{\phi_{Xt}R_{KXt}Q_{Xt-1}K_{Xt}}{P_t}] \qquad (2.34)$$

Eq. (2.34) implies that (i) real price adjustment costs, $\frac{\psi_{P_N}}{2}\left(\frac{P_{Nt}-P_{Nt-1}}{P_{Nt-1}}\right)^2$ and $\frac{\psi_{P_M}}{2}(\frac{P_{Mt}-P_{Mt-1}}{P_{Mt-1}})^2$, (ii) real foreign borrowing costs, and (iii) real monitoring costs entail output loss since a portion of Y_{Nt} is used up by these costs. In other words, given Y_{Nt}, an increase in these costs reduces consumption and investment, that is, it reduces final-output (actual-output).[13] As indicated by Eq. (2.34), real price adjustment costs in the non-traded sector increase with domestic-inflation, whereas real price adjustment costs in the import sector increase with inflation in imported goods. Analogously, the market clearing condition for imported goods is described as:

$$T_{Mt}=(1-a)\left(\frac{P_{Mt}}{P_t}\right)^{-\rho}[C_t+I_{Nt}+I_{Xt}+C_t^{Ne}+C_t^{Xe}+\frac{\psi_D}{2}(D_{t+1}-\overline{D})^2$$

$$+\frac{\psi_{P_N}}{2}\left(\frac{P_{Nt}-P_{Nt-1}}{P_{Nt-1}}\right)^2+\frac{\psi_{P_M}}{2}(\frac{P_{Mt}-P_{Mt-1}}{P_{Mt-1}})^2$$

$$+\frac{\phi_{Nt}R_{KNt}Q_{Nt-1}K_{Nt}}{P_t}+\frac{\phi_{Xt}R_{KXt}Q_{Xt-1}K_{Xt}}{P_t}] \qquad (2.35)$$

The labour market must also clear. Assuming that labour supply by capitalists is completely inelastic, or fixed at one for each sector,

$$H_{Nt}+H_{Xt}=H_t \qquad (2.36)$$

$$H_{Nt}^e=1$$

$$H_{Xt}^e=1$$

In addition, the market clearing condition for local currency-denominated debt, B_t, must be satisfied, which means $B_t=0$ (it is assumed that foreigners do not hold B_t).

[13] Real price adjustment costs are similar to resource costs in a Calvo-type sticky price model, in which resource costs entail output loss. We will deal with the resource cost in Chapter 3.

Equilibrium is a set of 37 sequences (P_{t}, $P_{N\mathrm{t}}$, $P_{M\mathrm{t}}$, $P_{X\mathrm{t}}$, C_{t}, C_{t}^{Ne}, C_{t}^{Xe}, W_{t}, $W_{N\mathrm{t}}^{e}$, $W_{X\mathrm{t}}^{e}$ H_{t}, $H_{N\mathrm{t}}$, $H_{X\mathrm{t}}$, S_{t}, $Y_{N\mathrm{t}}$, $Y_{X\mathrm{t}}$, $MC_{N\mathrm{t}}$, Γ_{t}, $T_{M\mathrm{t}}$, $I_{N\mathrm{t}}$, $I_{X\mathrm{t}}$, $Q_{N\mathrm{t}}$, $Q_{X\mathrm{t}}$, $R_{N\mathrm{t}}$, $R_{X\mathrm{t}}$, $R_{KN\mathrm{t}}^{G}$, $R_{KX\mathrm{t}}^{G}$, $R_{KN\mathrm{t}}$, $R_{KX\mathrm{t}}$, $\overline{\omega}_{N\mathrm{t}}$, $\overline{\omega}_{X\mathrm{t}}$, D_{t}, $K_{N\mathrm{t}}$, $K_{X\mathrm{t}}$, $Z_{N\mathrm{t}}$, $Z_{X\mathrm{t}}$, and i_{t}), which satisfies Eqs. (2.2) – (2.15), (2.17) – (2.28), (2.30), (2.32) – (2.36) in the text and Eqs. (A.11) – (A.15) in Appendix A.3, given the dynamic processes of the foreign interest rate and the export price. Here, D_{t}, $K_{N\mathrm{t}}$, $K_{X\mathrm{t}}$, $Z_{N\mathrm{t}}$, $Z_{X\mathrm{t}}$, and i_{t} are predetermined variables.

When $\rho = 1$, one may replace the household's budget constraint (Eq.(2.3)) with the following balance of payments condition:

$$S_{\mathrm{t}}(1+i_{\mathrm{t}}^{*})(D_{\mathrm{t}}+D_{N\mathrm{t}}^{\mathrm{e}}+D_{X\mathrm{t}}^{\mathrm{e}})-S_{\mathrm{t}}(D_{\mathrm{t+1}}+D_{N\mathrm{t+1}}^{\mathrm{e}}+D_{X\mathrm{t+1}}^{\mathrm{e}})$$
$$=P_{\mathrm{Xt}}Y_{X\mathrm{t}}-S_{\mathrm{t}}P_{M\mathrm{t}}^{*}T_{M\mathrm{t}}$$

2.2.8. Calibration

2.2.8.1. The risk premium and the debt-to- net worth ratio

Consistent with Devereux et al. (2006), we set the deterministic steady-state (quarterly) risk premium of the non-traded sector to 2.47% and that of the export sector to 3.08%. (i) The capitalists' saving rate, ν, (ii) the standard error of the productivity shock, σ_{ω}, and (iii) the coefficient of the monitoring cost, μ, basically govern the deterministic steady-state risk premium: as σ_{ω} or μ rises, or as ν falls, the deterministic steady-state risk premium increases. In our baseline experiment, we adjust $\sigma_{\omega N}$ [$\sigma_{\omega X}$] and ν to set the deterministic steady-state risk premium in the non-traded [export] sector.

Elekdağ and Tchakarov (2007) report the average debt-to-net worth (debt-to-equity) ratios of each year for eight major EMCs over the 1995-2004 period. According to their estimates, the average ratio ranges from 102.6% (in 1995) to 200.7% (in 1998) and the total average ratio over the period is 143.4%. Taking into account the estimates, we consider debt-to-net worth ratios, $\frac{S(D_N^e+D_X^e)}{(Z_N+Z_X)}$, ranging from 80% to 220%. The above three parameters (ν, σ_ω, and μ) basically govern the deterministic steady-state debt-to-net worth ratio: as ν, σ_ω, or μ falls, the debt- to-net worth ratio rises. In our baseline experiment, we maintain the deterministic steady-state risk premiums across all the debt-to-net worth ratios and adjust the capitalists' saving rate (ν) and the standard errors of the productivity shock in the non-traded and traded sectors ($\sigma_{\omega N}$ and $\sigma_{\omega X}$) to obtain the deterministic steady-state debt-to-net worth ratios. In the baseline experiment, the values of ν, $\sigma_{\omega N}$, and $\sigma_{\omega X}$ range from 0.903 to 0.936, from 0.201 to 0.424, and from 0.202 to 0.424, respectively. For example, at a deterministic steady-state debt-to-net worth ratio of 220%, ν is 0.903, $\sigma_{\omega N}$ is 0.201, and $\sigma_{\omega X}$ is 0.202.[14]

2.2.8.2. Other parameter values

Regarding other parameter values, we follow Devereux et al. (2006). However, we explore alternative calibrations of some parameters in Section 2.4. in order to investigate whether our baseline results are sensitive to the choice of the parameter.

The other baseline parameter values are shown in Table 2.1. Most of them are standard and selected from the previous literature. Some remarks are in order. The price adjustment cost parameter in the non-traded sector (ψ_{P_N}) is set at 120, which implies that the average price-adjustment period in this sector is four quarters. This chapter assumes that, under delayed exchange rate pass-through, the average price-adjustment interval in the import sector is identical to that in the non-traded sector. Hence, ψ_{P_M} is set to 120 under delayed pass-through.

[14] In Devereux et al. (2006), the capitalists' saving rate (ν) is set to 0.94, while the standard error of the productivity shock (σ_ω) is set equal to 0.5. The average of debt-to-net worth ratios in the two sectors is 62.25%. They report that a flexible exchange rate regime is welfare-superior to a fixed exchange rate regime at a debt-to-net worth ratio of 62.25%.

Some of the baseline parameters are calibrated to match data from the U.S. and Asian countries. To calibrate the foreign interest rate shock (i^*_t) and the export price shock (P^*_{Xt}), Devereux et al. (2006) use the quarterly U.S. real interest rate (the prime lending rate minus the inflation rate) and an aggregate of quarterly export price data for Asian countries. They run a VAR for the U.S. interest rate and the aggregate export price and obtain the following parameter estimates: the autocorrelation (ρ_{i^*}) and the standard deviation (σ_{i^*}) of foreign interest rate shocks are 0.46 and 0.012, respectively, whereas the autocorrelation (ρ_X) and the standard deviation (σ_X) of export price shocks are 0.77 and 0.013, respectively. The capital share of non-traded goods (α**)** and that of export goods (γ**)** are set at 0.3 and 0.7, respectively, on the basis of the findings of Cook and Devereux (2006) for Thailand and Malaysia. Cook and Devereux (2006) find that the export sector is much more capital intensive than the non-traded sector in the two countries. The share of non-traded goods in the CPI (a) is set equal to 0.55, which implies that the deterministic steady-state share of non-traded goods in GDP is 54% - consistent with Thai and Malaysian data.

2.2.9. Solution method and the welfare metric

A second-order approximation technique is used to solve the model numerically because this higher-order approximation is more suitable for welfare evaluations than a first-order approximation method.[15] In this chapter, we employ the solution method of Schmitt-Grohe and Uribe (2004b).[16]

In line with Devereux et al. (2006), we use the following welfare metric. Since the population of risk neutral capitalists in each sector is one and they die at any time period with probability $(1 - \nu)$, the total expected utility of the economy under flexible exchange rates can be written as:

---

15 See Section 2.1.

16 We use the Matlab codes of Schmitt-Grohe and Uribe, which are available at the following URL: http://www.econ.upenn.edu/~uribe/2nd_order.htm

$$V_f = E_0 \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \left(\frac{C_{f\mathrm{t}}^{1-\sigma}}{1-\sigma} - \eta \frac{H_{f\mathrm{t}}^{1+\psi}}{1+\psi} \right) + E_0 \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \nu^{\mathrm{t}} (C_{f\mathrm{t}}^{Ne} + C_{f\mathrm{t}}^{Xe})$$

where the subscript *f* indicates a flexible exchange rate regime. We assume that the discount factor is the same for households and capitalists.

Then, we define C_f, H_f, C_f^{Ne}, and C_f^{Xe} implicitly as

$$E_0 \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \frac{C_{f\mathrm{t}}^{1-\sigma}}{1-\sigma} = \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \frac{C_f^{1-\sigma}}{1-\sigma},$$

$$E_0 \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \eta \frac{H_{f\mathrm{t}}^{1+\psi}}{1+\psi} = \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \eta \frac{H_f^{1+\psi}}{1+\psi},$$

$$E_0 \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \nu^{\mathrm{t}} C_{f\mathrm{t}}^{Ne} = \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \nu^{\mathrm{t}} C_f^{Ne}, \text{ and}$$

$$E_0 \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \nu^{\mathrm{t}} C_{f\mathrm{t}}^{Xe} = \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \nu^{\mathrm{t}} C_f^{Xe}, \text{ respectively.}$$

We may call C_f and H_f the permanent consumption and labour effort of households and refer to C_f^{Ne} and C_f^{Xe} as the permanent consumption of capitalists in the non-traded and export sectors under the flexible exchange rate regime, respectively. Using C_f, H_f, C_f^{Ne}, and C_f^{Xe}, the total expected utility under the flexible exchange rate regime can be rewritten as:

$$V_f = \frac{C_f^{1-\sigma}}{(1-\sigma)(1-\beta)} - \eta \frac{H_f^{1+\psi}}{(1+\psi)(1-\beta)} + \frac{(C_f^{Ne} + C_f^{Xe})}{(1-\beta\nu)}$$

Similarly, the total expected utility of the economy under fixed exchange rates can be written as:

$$V_s = \frac{C_s^{1-\sigma}}{(1-\sigma)(1-\beta)} - \eta \frac{H_s^{1+\psi}}{(1+\psi)(1-\beta)} + \frac{(C_s^{Ne} + C_s^{Xe})}{(1-\beta\nu)}$$

where the subscript *s* indicates a fixed exchange rate regime.

Describing ϵ as the fraction of permanent consumption required to achieve the same expected utility or to make households and capitalists indifferent between the two regimes, ϵ is implicitly defined as

$$\frac{\left[(1-\varepsilon)C_f\right]^{1-\sigma}}{(1-\sigma)(1-\beta)} - \eta\frac{H_f^{1+\psi}}{(1+\psi)(1-\beta)} + \frac{(1-\epsilon)(C_f^{Ne}+C_f^{Xe})}{(1-\beta\nu)} = V_s$$

In other words, the value of ϵ represents the *consumption cost* of shift from the flexible exchange rate regime to the fixed exchange rate regime. If a value of ϵ is positive, it indicates that the flexible exchange rate regime is welfare-superior to the fixed exchange rate regime, and vice versa.

2.3. Welfare evaluations

This section presents the welfare results of our baseline experiment. Here, we analyze the welfare implications of fixed and flexible exchange rate regimes when the economy faces the two exogenous shocks (foreign interest rate and export price shocks) simultaneously. This section considers the following two cases: complete (full) exchange rate pass-through and delayed (low) pass-through.

2.3.1. Balance sheet effects on macroeconomic variables

Before presenting the welfare results, we now consider the implications of balance sheet effects on macroeconomic variables. Table 2.2 shows the means and standard deviations of key variables. In the table, ξ_N is real price adjustment costs in the non-traded sector, divided by the deterministic steady-state value of non-traded output: $\xi_{N\mathrm{t}} = \left[\frac{\psi_{P_N}}{2}\left(\frac{P_{N\mathrm{t}}-P_{N\mathrm{t}-1}}{P_{N\mathrm{t}-1}}\right)^2\right] / Y_N$, where Y_N denotes the deterministic steady-state value of non-traded output. ξ_M is real price adjustment costs in the import sector, divided by Y_N: $\xi_{M\mathrm{t}} = \left[\frac{\psi_{P_M}}{2}\left(\frac{P_{M\mathrm{t}}-P_{M\mathrm{t}-1}}{P_{M\mathrm{t}-1}}\right)^2\right] / Y_N$. rp_N and rp_X are risk premiums in the non-traded and export sectors, respectively :

$$rp_{N\mathrm{t}} = \left(\frac{A'(\bar{\omega}_{N\mathrm{t}})}{B'(\bar{\omega}_{N\mathrm{t}})}\right) \Big/ \left[B(\bar{\omega}_{N\mathrm{t}})\frac{A'(\bar{\omega}_{N\mathrm{t}})}{B'(\bar{\omega}_{N\mathrm{t}})} - A(\bar{\omega}_{N\mathrm{t}})\right]$$

$$rp_{X\mathrm{t}} = \left(\frac{A'(\bar{\omega}_{X\mathrm{t}})}{B'(\bar{\omega}_{X\mathrm{t}})}\right) \Big/ \left[B(\bar{\omega}_{X\mathrm{t}})\frac{A'(\bar{\omega}_{X\mathrm{t}})}{B'(\bar{\omega}_{X\mathrm{t}})} - A(\bar{\omega}_{X\mathrm{t}})\right]$$

π_N is domestic-inflation (non-traded goods inflation): $\pi_{N\mathrm{t}} = P_{N\mathrm{t}}/P_{N\mathrm{t}-1}$. The other variables correspond to those in the text and Appendix A.3. The means of ξ_N and ξ_M refer to differences from their deterministic steady-state values. The statistics of the other variables are defined as percentage deviations from their deterministic steady-state values: $\widehat{x_\mathrm{t}} = \frac{(x_\mathrm{t}-x)}{x}$ denotes the percentage deviation of a variable x_t from its deterministic steady-state value, where *x* is its deterministic steady-state value. All statistics and the consumption cost are measured in per cent, that is, they are multiplied by 100.

Columns [1] and [2] correspond to the case with a debt-to-net worth ratio of 62% under full exchange rate pass-through, which is consistent with the calibration of Devereux et al. (2006). Columns [3] and [4] coincide with the case with a debt-to-net worth ratio of 200% under full pass-through. As can be seen from the table, as the debt-to-net worth ratio rises, balance sheet effects become stronger and uncertainty and macroeconomic instability increase. We observe that, when the debt-to-net worth ratio rises from 62% to 200%, average risk premiums in the non-traded and export sectors (E$\widehat{rp_{N\mathrm{t}}}$ and E$\widehat{rp_{X\mathrm{t}}}$) increase and the average levels of output in the two sectors (E$\widehat{Y_{N\mathrm{t}}}$ and E$\widehat{Y_{X\mathrm{t}}}$) fall. In addition, average consumption (E$\widehat{C_\mathrm{t}}$) declines and average labour supply (E$\widehat{H_\mathrm{t}}$) increases, which lowers household welfare. Moreover, we see that, when the debt-to-net worth ratio rises from 62% to 200%, the standard deviations of the key variables increase[17]- which implies that uncertainty intensifies as the debt-to-net worth ratio rises.

We also notice that, with a large stock of foreign currency debt, the financial accelerator could have more adverse impacts on the export sector than on the non-traded sector. At a debt-to-net worth ratio of 62%, non-traded output falls more than traded output (or the decline rate is almost the same for both sectors). On the other hand, at a debt-to-net worth ratio of 200%, traded output declines far more than non-traded output. At a debt-to-net worth ratio of 200%, firms reduce investment by more - equivalently reduce the stock of capital by more -, since the effective cost of foreign borrowing is higher, compared to the case with a debt-to-net worth ratio of 62%. Then, they further increase labour because it is relatively cheaper.[18] By increasing labour inputs, the non-traded sector can mitigate large declines in output, since the non-traded sector is labour intensive. On the other hand, the export sector fails to do it, since the export sector is capital intensive. As a result, traded output falls much more than non-traded output. This implies that, with a large stock of foreign currency debt, the economic slowdown could become more severe in the export sector than in the non-traded sector.

2.3.2. Welfare evaluations in the case of complete pass-through

We now consider the welfare comparison of fixed and flexible exchange rate regimes under complete (full) exchange rate pass-through, where ψ_{P_M} is set at 0. Although there are many types of flexible exchange rate regimes, here we refer to strict CPI inflation targeting as the flexible exchange rate regime. This policy rule corresponds to the interest rule when $\mu_\pi \to \infty$ in Eq. (2.33).

[17] The nominal exchange rate under the peg is an exception, since by definition the peg completely eliminates nominal exchange rate volatility.

[18] We notice from Table 2.2 that the real wage declines when the debt-to-net worth ratio rises from 62% to 200%.

The results are summarized in Fig. 2.2. The vertical axis indicates the consumption cost, ϵ (ϵ is measured in per cent, that is, it is multiplied by 100), while the horizontal axis does the debt-to-net worth ratio. The solid line describes the consumption cost under full pass-through. Figure 2.2 shows that ϵ exceeds zero for all debt-to-net worth ratios. This means that the flexible exchange rate regime is welfare-superior to the fixed exchange rate regime.

We now focus on the means and the standard deviations under columns [3] and [4], which correspond to the case with a debt-to-net worth ratio of 200%. Notice that average consumption is lower with the peg relative to the float ($\mathrm{E}\widehat{C_t} = -2.83$ % under the peg, while $\mathrm{E}\widehat{C_t} = -2.49$ % under the float). The welfare-superiority of the float over the peg is mainly accounted for by the lower consumption under the peg.[19] The main reason for the lower consumption under the peg is that output loss due to price adjustment costs (the amount of non-traded output which is used up by these costs) is larger under the peg. Since by design the peg acts so as to stabilize the nominal exchange rate completely and not to directly respond to domestic-inflation (π_N), the peg generates more volatile domestic-inflation[20] and hence higher price adjustment costs than the float[21]: $\mathrm{E}\xi_{Nt} =$1.19% under the peg, whereas $\mathrm{E}\xi_{Nt} =$ 0.45% under the float. (recall that price adjustment costs in the non-traded sector increase with domestic–inflation). As discussed in subsection 2.2.7., this implies that the peg generates larger output loss in the non-traded sector, that is, the peg generates lower final-output in the non-traded sector than the float.[22] Therefore, households under the peg enjoy a lower average level of consumption – which lowers welfare relative to the

---

[19] We also notice that average labor ($\mathrm{E}\widehat{H_t}$) is higher under the peg relative to the float. This gives us another explanation about why the float is welfare-superior to the peg.

[20] Note that the standard deviation of domestic-inflation is 1.49 % under the peg (column [4]), whereas that is 0.92% under the float (column [3])..

[21] The float cares about the effects of non-traded goods prices on the CPI, since the CPI consists of both non-traded goods prices and imported goods prices.

[22] Average price adjustment costs ($\mathrm{E}\xi_{Nt}$) are of non-negligible size, compared to the average levels of consumption and investment. For instance, at a debt-to-net worth ratio of 200%, $\mathrm{E}\xi_{Nt}$ = 1.19%, $\mathrm{E}\,[(I_{Nt} - I_N)/Y_N]$ = −1.72%, $\mathrm{E}\,[(C_t^{Ne} - C^{Ne})/Y_N]$ = −0.86%, and $\mathrm{E}\,[(C_t - C)/Y_N]$ = −5.54% under the peg.

float.[23]

In addition, Fig. 2.2 indicates that, as the debt-to-net worth ratio rises – that is, as balance sheet effects become stronger -, the welfare difference between the two regimes becomes wider. This result implies that flexible exchange rates are more desirable in terms of welfare, the higher the level of foreign currency debt. This is mainly because the relative difference between the price adjustment costs of each regime becomes greater as the debt-to-net worth ratio rises. As a result, the relative difference between consumption in each regime increases - which widens the welfare difference between the two regimes.

This can be seen when comparing the means of price adjustment cots (ξ_N) and consumption (*C*) under columns [1] and [2] to those under columns [3] and [4]. When the debt-to-net worth ratio rises from 62% to 200%, the relative difference between the price adjustment costs of each regime increases from *0.22%* (= 0.36% − 0.14%) to *0.74%* (= 1.19% − 0.45%). The relative difference between consumption in each regime also increases from *0.06%* (= −0.26% − −0.32%) to *0.34%* (= −2.49% − −2.83%).

2.3.3. Welfare evaluations in the case of low pass-through

Next, we now compare the float with the peg under low exchange rate pass-through, where ψ_{P_M} is set at 120. Columns [5] and [6] of Table 2.2 correspond to the case with a debt-to-net worth ratio of 200% under low pass-through. Notice that, when the monetary authority is engaged in the peg, means, standard deviations and total expected utility are the same for low pass-through and full pass-through, since import prices are identical under the two cases. Further notice that, under low pass-through, two types

[23] The standard deviations of consumption and labor effort are lower with the float relative to the peg. This implies that the conclusion of this subsection could hold if the model is solved by a first-order approximation, since its welfare measure is based on the variances of these variables.

of price adjustment costs are incurred: price adjustment costs in the non-traded and import sectors (ξ_N and ξ_M).

The results are shown in Fig. 2.2. The dashed line represents the consumption cost under low pass-through. The figure illustrates that the degree of exchange rate pass-through has no effect on the welfare ranking of 'flexible versus fixed' exchange rate regimes: ϵ is greater than zero for all debt-to-net worth ratios. Figure 2.2 also indicates that the degree of exchange rate pass-through affects the welfare difference between the two regimes. In other words, this figure indicates that the welfare difference between the two regimes is larger under low exchange rate pass-through than under full pass-through. The reason behind this is that, when the flexible exchange rate regime is implemented, overall welfare is higher under delayed pass-through than under full pass-through (recall that, when the peg is applied, total expected utility is identical in the two cases). We now focus on the case where the monetary authority implements the flexible exchange rate regime and compare the means under column [3] to those under column [5]. We notice that total price adjustment costs are lower under low pass-through than under full pass-through: $\mathrm{E}\xi_{N\mathrm{t}}+\mathrm{E}\xi_{M\mathrm{t}}$ = 0.31% (= 0.12% + 0.19%) under low pass-through, while $\mathrm{E}\xi_{N\mathrm{t}}+\mathrm{E}\xi_{M\mathrm{t}}$ = 0.45% under full pass-through. This implies that output loss is smaller, that is, final-output in the non-traded sector is higher under low pass-through than under full-pass through.[24]

In addition, we observe that average households' foreign debt is lower under delayed pass-through than under full pass-through ($\mathrm{E}\widehat{D_\mathrm{t}}$ = −2.32% under low pass-through, while $\mathrm{E}\widehat{D_\mathrm{t}}$ = −1.85% under full pass-through). Put differently, under low pass-through, the mean net foreign asset position improves relative to that under full pass-through. As stressed by Kollmann (2002) and Elekdağ and Tchakarov (2007), in models with imperfect risk sharing (as assumed in this chapter), the average net foreign asset position has substantial impacts on household welfare. In their

[24] We notice that under columns [3] and [5] the standard deviation of domestic-inflation (π_N) is much lower under delayed pass-through than under full pass-through.

models, uncertainty induces households to increase their net foreign assets, which raises households' wealth and provides protection against potentially large declines in consumption. Bergin et al. (2007) and Elekdağ and Tchakarov (2007) refer to this foreign asset holdings as 'precautionary saving.'

Both of these effects (higher final-output and a lower stock of foreign debt) work in conjunction, generating a higher average level of consumption (and hence higher welfare) under low pass-through: $\mathrm{E}\widehat{C_t} = -2.23\%$ (column [5]) under low pass-through, while $\mathrm{E}\widehat{C_t} = -2.49\%$ (column [3]) under full pass-through. This result suggests that flexible exchange rates are more attractive in welfare terms, the slower exchange rate pass-through.

When CPI inflation targeting is implemented under complete exchange rate pass-through, the monetary authority needs to care about exchange rate fluctuations since exchange rate fluctuations affect the CPI immediately. On the other hand, in the case of low pass-through, as indicated by Devereux et al. (2006), the monetary authority could use exchange rate fluctuations in order to mitigate the effects of external shocks and to stabilize the real economy, since the CPI responds slowly to exchange rate fluctuations. This can be confirmed when focusing on the standard deviations under columns [3] and [5] of Table 2.2. The standard deviation of the nominal exchange rate is higher with low pass-through relative to full pass-through, whereas those of real variables such as consumption, labour, and output are lower under low pass-through.

2.4. Robustness experiments

This section provides the results of different robustness experiments which check the sensitivity of our baseline results to alternative calibrations. We consider various parameterizations of the risk premium, preferences, and the debt-to-net worth ratio.

Moreover, we investigate an alternative specification of the risk premium. Since we confirm in subsection 2.3.3. that overall welfare is higher under low exchange rate pass-through than under full pass-through when the flexible exchange rate regime is implemented, below we focus on the welfare implications of exchange rate regimes under complete exchange rate pass-through.

2.4.1. The external risk premium

Initially, we consider an alternative choice of the steady-state risk premium in order to see whether the value of the (steady-state) risk premium affects the welfare ranking of 'flexible versus fixed' exchange rate regimes. In the baseline experiment, we set the deterministic steady-state (quarterly) risk premiums to the same values as Devereux et al. (2006). We now consider the case where the steady-state quarterly risk premiums are increased to the values plus 100 basis points, that is, 3.47% for the non-traded sector and 4.08% for the export sector. In general, as the risk premium decreases, the impact of the risk premium on external borrowing tends to become weaker. Therefore, we do not investigate lower values of the risk premium.

The result is shown in Fig. 2.3. This robustness experiment reinforces the main message of the baseline experiment: the float is welfare-superior to the peg for all debt-to-net worth ratios. Moreover, the consumption cost (ϵ) is increasing in the debt-to-net worth ratio. The figure also indicates that the consumption cost of the robustness experiment is nearly identical to that of the baseline experiment, although the former is slightly lower than the latter when the level of indebtedness is high.

2.4.2. The inter-temporal elasticity of substitution

As discussed in Section 2.3., household consumption is an important factor in the welfare ranking of the two regimes. Therefore, it is useful to investigate whether and how the value of the inter-temporal elasticity of substitution ($1/\sigma$) affects household consumption under each regime and the welfare ranking. Specifically, we analyze the two cases: $\sigma = 1.1$ and $\sigma = 4$.

The results are summarized in Fig. 2.4. The results support the main message of the baseline experiment: the float is better than the peg in welfare terms. Comparing the consumption cost when $\sigma = 1.1$ to that when $\sigma = 4$, the figure illustrates that the former outweighs the latter. This is because, as σ rises or households become more risk averse, the relative difference between consumption in each regime decreases and consequently the consumption cost falls. We now consider mean consumption at a (steady-state) debt-to-net worth ratio of 200%, When $\sigma = 1.1$, mean consumption ($\mathrm{E}\widehat{C}_{\mathrm{t}}$) under the float is −3.57% and mean consumption under the peg is −4.06%. On the other hand, when $\sigma = 4$, mean consumption under the float is −1.49% and mean consumption under the peg is −1.68%. We observe that, when σ rises from 1.1 to 4, the relative difference between consumption in each regime decreases from *0.49*% (= −3.57% − −4.06%) to *0.19*% (= −1.49% − −1.68%).

2.4.3. The capitalists' saving rate

In the experiments so far, we have changed the capitalists' saving rate (ν) and the standard errors of the productivity shock in the non-traded and export sectors ($\sigma_{\omega N}$ and $\sigma_{\omega X}$) to obtain the deterministic steady-state debt-to-net worth ratios. The deterministic steady-state (quarterly) risk premiums in the non-traded and export sectors are kept constant across all the debt-to-net worth ratios in the experiments. Next, we adjust only the capitalists' saving rate to obtain the deterministic steady-state debt-to-net worth ratios (as ν falls, the debt-to-net worth ratio rises). In this case, the deterministic steady-state risk premium increases with the debt-to-net worth ratio. Regarding the standard error of the productivity shock (σ_ω), we follow Devereux et al. (2006) to set $\sigma_{\omega N} = \sigma_{\omega X} = 0.5$.

The result is depicted in Fig. 2.5. The result is basically consistent with that of the baseline experiment: the float welfare-dominates the peg and the consumption cost is increasing in the debt-to-net worth ratio. The main reason for the superiority of the float over the peg is that price adjustment costs are higher with the peg relative to the float, as in the baseline case. The peg generates more volatile domestic-inflation and hence lower final-output than the float. Therefore, the peg reduces consumption, compared to the float.[25]

2.4.4. An alternative risk premium specification

Finally, we consider an alternative specification of the risk premium. As shown in Fig. 2.1, the model of this chapter assumes that the (steady-state) risk premium is an increasing and *convex* function of the leverage ratio within a certain range of leverage ratios. However, there are various ways to model the risk premium. For example, in Elekdağ and Tchakarov (2007), it is assumed that the risk premium is an increasing and *concave* function of the leverage ratio. When compared to the Elekdağ and Tchakarov (2007) model, the marginal effect of the leverage ratio on the risk premium is more serious in the model of this chapter. We now examine whether the main message of the baseline experiment will hold when we employ the Elekdağ and Tchakarov-type risk premium. For concreteness, in line with Céspedes et al.(2000) and Elekdağ and Tchakarov (2007), we use the following specification with the constant implicit-elasticity of the risk premium to the leverage ratio:

$$rp_{N\mathrm{t}+1} = b_1\left(\frac{Q_{N\mathrm{t}}K_{N\mathrm{t}+1}}{Z_{N\mathrm{t}+1}}\right)^{b_2}$$

where $b_1 > 0$ and $0 < b_2 < 1$. Then, following Céspedes et al.(2000), Elekdağ and Tchakarov (2007), and Gertler et al. (2007), the optimal financial contract condition, capitalist consumption, and their net worth in the non-traded sector are modified as

[25] For instance, at a (steady-state) debt-to-net worth ratio of 200%, E $\xi_{N\mathrm{t}}$ = 0.11% and E$\widehat{C}_{\mathrm{t}}$ = −0.58% under the float. On the other hand, E $\xi_{N\mathrm{t}}$= 0.24 % and E$\widehat{C}_{\mathrm{t}}$= −0.67% under the peg.

$$E_tR_{KNt+1} = (1 + i^*_{t+1})\, rp_{Nt+1} E_t\left(\frac{S_{t+1}}{S_t}\right), \tag{2.37}$$

$P_tC^{Ne}_t = (1-\nu)R_{KNt}Q_{Nt-1}K_{Nt} - (1-\nu)S_t(1+i^*_t)\, rp_{Nt}\, D^e_{Nt}$, and

$Z_{Nt+1} = \nu R_{KNt}Q_{Nt-1}K_{Nt} - \nu S_t(1+i^*_t)\, rp_{Nt}\, D^e_{Nt} + W^e_{Nt},$ respectively.[26]

In this robustness experiment, the deterministic steady-state risk premium is set at the same value (2.47%) as in the baseline experiment and kept constant across all the debt-to-net worth ratios. To obtain the deterministic steady-state debt-to-net worth ratios, we vary both the capitalists' saving rate (ν) and the implicit-elasticity of the risk premium to the leverage ratio (b_2). Consistent with Elekdağ and Tchakarov (2007), we set b_2 equal to 0.02 at a deterministic steady-state debt-to-net worth ratio of 137%. Given the calibration of b_2, b_1 is set such that the deterministic steady-state risk premium is identical to 2.47%.[27] The export sector is exactly analogous.

The welfare comparison is depicted in Fig. 2.6. Figure 2.6 indicates that the main message of the baseline experiment is robust to the alternative specification of the risk premium: the float is welfare-superior to the peg and the consumption cost increases with the level of indebtedness. The main reason for this is very similar to that of the baseline experiment. Price adjustment costs in the non-traded sector are higher with the peg relative to the float. Therefore, the peg reduces consumption compared to the float.[28]

---

[26] When Eq. (2.26) is replaced with Eq. (2.37), ϖ_{Nt} and one equation need to be eliminated by combining the foreign lenders' participation constraint (Eq. (2.30)) and Eqs. (2.27) – (2.28).

[27] Elekdağ and Tchakarov (2007) use a method to calibrate the debt-to-net worth ratio which is different from our method. To obtain the steady-state debt-to-net worth ratios, they probably vary two parameters: one is the implicit-elasticity of the risk premium to the leverage ratio (b_2) and another is unknown (they do not use the capitalists' saving rate in their baseline experiment).

[28] For instance, at a (steady-state) debt-to-net worth ratio of 200%, E ξ_{Nt} = 0.35% and E$\widehat{C}_t$ = −2.09% under the float. On the other hand, E ξ_{Nt}= 1.02% and E$\widehat{C}_t$= −2.51% under the peg.

2.5. Conclusions

This chapter carries out a welfare comparison of fixed and flexible exchange rate regimes by employing the model of Devereux et al. (2006), which incorporates balance sheet effects in combination with foreign currency debt and variable exchange rate pass-through. This chapter deals with a wide range of debt-to-net worth ratios that allows us to investigate whether and how the degree of indebtedness affects the choice of exchange rate regime.

Although Calvo and Reinhart (2002) argue that many monetary authorities in EMCs are reluctant to allow their currencies to float freely owing to balance sheet vulnerabilities, we find that, under complete exchange rate pass-through, the float welfare-dominates the peg for a broad range of debt-to-net worth ratios. In addition, the welfare difference between the two regimes becomes wider as the debt-to-net worth ratio rises. The results imply that flexible exchange rates are more desirable in terms of welfare, the higher the level of foreign currency debt. The different robustness experiments also support the main message of this chapter.

Moreover, when comparing the float with the peg under low exchange rate pass-through, our results show that the degree of exchange rate pass-through has no effect on the welfare ranking of the two regimes. However, we find that the degree of exchange rate pass-through affects the welfare difference between the two regimes: the welfare difference between the two regimes is larger under low exchange rate pass-through than under full pass-through. This suggests that flexible exchange rates are more attractive in welfare terms, the slower exchange rate pass-through.

Chapter 3

Exchange Rate Volatility and Balance Sheet Effects

3.1. Introduction

What type of exchange rate regime is more desirable when there are financial market imperfections in emerging market countries (EMCs)? This chapter investigates the question using a dynamic stochastic general equilibrium small open economy model.

There have been significant advances in the field of monetary and exchange rate policy analysis in EMCs. Some recent studies in this field have focused on imperfect financial markets, especially balance sheet effects and liability dollarization, and have provided useful insights into the behaviour of EMCs. For instance, Devereux et al. (2006) develop a small open economy model which incorporates balance sheet effects coupled with foreign currency debt [1] Their model accounts for so-called 'contractionary devaluations', which are empirically observed in EMCs: an exchange rate depreciation has a negative effect on firms' balance sheets, which raises the cost of foreign borrowing, thereby bringing about real contractions (See Chapter 1 for balance sheet effects and contractionary devaluations). They conduct a welfare-based

[1] For a sample of other related work, see Cavoli (2009), Céspedes et al. (2002, 2004), Choi and Cook (2004), Cook (2004), Elekdağ and Tchakarov (2007), Gertler et al. (2007), Morón and Winkelried (2005). The model of Cavoli (2009) and that of Morón and Winkelried (2005) do not include micro-foundations.

comparison of fixed and flexible exchange rate regimes based on a second-order accurate welfare measure and their model predicts that flexible exchange rates welfare-dominate fixed exchange rates even in the presence of balance sheet effects and foreign currency debt.

However, the model of Devereux et al. (2006) generates predicted exchange rate volatility that is extremely low, compared to that seen in historical data. Thus, it might underestimate balance sheet vulnerabilities under flexible exchange rates. They report that, when exchange rate pass-though is complete, the predicted standard deviation of the quarterly nominal exchange rate under strict CPI inflation targeting is only 1.80 %.[2] This is because, as we will discuss below, their model assumes a stable relationship between the nominal exchange rate and the nominal interest rate. On the other hand, Kollmann (2005) finds that the estimated standard deviation of the quarterly nominal exchange rate between the U.S. and a basket of major EU countries (France, Germany and Italy) during 1973:1-1994:4 was 8.75%. Taking into account a line of empirical evidence that EMCs tend to be more vulnerable to volatile capital flows than industrialized countries (e.g., Schaechter et al., 2000), nominal exchange rate volatility in EMCs could be even greater than the estimate of Kollmann (8.75%). This implies that the impact of exchange rate variability on the net worth position of domestic firms could be more severe than that reported in Devereux et al. (2006).

This chapter attempts to conduct a welfare-based comparison of fixed and flexible exchange rate regimes by using an extended version of the Devereux et al. (2006) model. This extended model mainly differs from that of Devereux et al. in that it emphasises the role of exchange rate volatility and generates more realistic exchange

[2] They also present the predicted standard deviation of the nominal exchange rate under strict domestic-inflation targeting (non-traded goods price targeting): the predicted standard deviation is 3.4%. Their predicted standard deviations of the nominal exchange rate seem lower, compared to those reported in the literature on monetary policy in emerging market countries. For example, the model of Ravenna and Natalucci (2008) generates much more volatile nominal exchange rates than that of Devereux et al. (2006): the standard deviation in their baseline experiment is 8.02%.

rate volatility. Although there are various ways to model the nominal exchange rate[3], we employ the specification developed by Kollmann (2002, 2005). Motivated by the fact that empirical results find no support for the uncovered interest parity (UIP) condition under flexible exchange rates, his model allows for a stationary and exogenous AR(1) shock to the UIP condition in order to generate sufficient exchange rate variability. He regards the UIP shock as reflecting a temporary but persistent bias in the agent's exchange rate forecast. This chapter assumes that *under flexible exchange rates* the forecast bias disturbs the stable relationship between the exchange rate and the interest rate (we refer to the shock as the 'forecast bias shock', hereafter). On the other hand, we assume that *under fixed exchange rates* there is no bias in exchange rate forecasts (that is, the forecast bias shock applies only under flexible exchange rates)[4], on the basis of the fact that deviations from UIP were considerably small in the Bretton Woods era (e.g., Kollmann, 2005). We will discuss this issue in subsection 3.3.1.

Besides the forecast bias shock, the model here features two production sectors (the non-traded sector and the export sector), Calvo-type sticky prices in the non-traded sector, imperfect international risk sharing, balance sheet effects in combination with foreign currency debt, and exogenous foreign interest rate and export price shocks. The model is calibrated using parameter values from the literature and some values that match Thai data (we call this calibrated model the 'baseline model', hereafter). Given the calibration, we assess the welfare implications of the fixed exchange rate regime (the peg) and a flexible exchange rate regime where the monetary authority strictly targets the inflation rate of the CPI (denoted the 'CPI rule', henceforth).

This chapter also performs different simulations in order to check the sensitivity of the baseline model to alternative calibrations. We consider alternative calibrations of

[3] For instance, Wollmershäuser (2006) uses six different types of exchange rate specifications in order to describe realistic exchange rate behavior.

[4] In Kollmann (2002, 2004), this assumption is employed. See subsection 3.3.1.

the forecast bias shock to see whether and how the parameter value of the forecast bias shock affects the baseline results. In addition, we compare the peg to alternative flexible exchange rate regimes whereby the central bank implements strict domestic-inflation targeting (non-traded goods price targeting) or Taylor rules. Further, we compare exchange rate regimes *with* and *without* balance sheet constraints in order to examine whether and how the presence of these constraints affects the welfare assessment of exchange rate regimes.

The model is solved using a quadratic approximation method which allows us to obtain a second-order accurate representation of expected utility and to conduct a rigorous welfare evaluation of exchange rate regimes. Elekdağ and Tchakarov (2007) argue that, since a second-order approximation method can capture the effects of uncertainty on the means of endogenous variables (e.g., consumption and labour), the method is more suitable for assessing welfare than a first-order approximation method (the welfare measure based on a first-order approximation depends only on variances) .

The main findings can be summarized as follows. First, the peg is welfare-superior to the CPI rule for realistic calibrations of the forecast bias shock. In addition, as exchange rate volatility increases, the welfare difference between the two regimes becomes wider (the peg becomes more attractive in terms of welfare). Under the CPI rule, forecast bias shocks increase exchange rate variability, which causes a marked deterioration in balance sheets – the shocks thus have a more harmful effect on the average level of capitalist consumption under the CPI rule. Moreover, under the CPI rule, price dispersion across non-traded goods firms increases with exchange rate volatility, which in combination with marked balance sheet deterioration induces a large fall in non-traded output[5], thereby lowing household consumption relative to the peg. These two negative effects work together, generating lower welfare under the CPI rule.

[5] We assume Calvo-type sticky prices in the non-traded sector. The nature of price rigidity generates inefficient price dispersion across non-traded goods firms and thus output loss. We will discuss this topic in subsection 3.2.8.

Second, strict domestic-inflation targeting outperforms the CPI rule, since strict domestic-inflation targeting completely eliminates inefficient price dispersion across non-traded goods firms. Whether the peg is welfare-superior to strict domestic-inflation targeting or not depends on the degree of exchange rate volatility – the peg is more desirable in welfare terms when exchange rate volatility is high.

Third, the presence of balance sheet effects is very important for the welfare assessment of exchange rate regimes. When comparing the peg with the CPI rule, we find that the presence of balance sheet constraints affects the welfare difference across the two regimes, that is, it increases the welfare difference between the two regimes -, although the presence of the constraints does not alter the welfare ranking of the two regimes (the peg is welfare-superior to the CPI rule in the economy *with* and *without* balance sheet constraints). In the comparison of the peg relative to strict domestic-inflation targeting, our results reveal that the presence of balance sheet constraints alters the welfare ranking of the two regimes when exchange rate volatility is high. In the economy *without* balance sheet constraints, strict domestic-inflation targeting welfare-dominates the peg under plausible calibrations of exchange rate volatility, whereas in the economy *with* balance sheet constraints the peg welfare-dominates the strict domestic-inflation targeting regime when exchange rates are highly volatile (as mentioned above).

This chapter is organized as follows. Section 3.2. presents the model and calibration. Section 3.3. describes the results of the baseline model and Section 3.4. presents the results of sensitivity analysis. Section 3.5. concludes.

3.2. The model

Based on the previous research of Devereux et al. (2006) and Kollmann (2002, 2004), we construct a small open economy model which includes some characteristics designed for the emerging market environment: balance sheet effects coupled with foreign currency debt, volatile exchange rates, and vulnerabilities to external shocks (foreign interest rate and export price shocks).

The economy consists of four sets of domestic players: households, firms (production firms and unfinished capital goods firms), capitalists, and the monetary authority. Firms and capitalists are divided into two sectors: the non-traded goods sector and the export goods sector. Two final goods (the non-traded good and the export good) are produced by production firms in each sector using labour and capital. Non-traded production firms are monopolistically competitive – non-traded goods prices are assumed to be sticky –, whereas traded (export) goods firms are perfectly competitive. Labour is supplied by households and capitalists while capital is rented from capitalists. Unfinished capital goods firms produce ‘unfinished’ capital goods in a competitive environment by using ‘finished’ capital and the investment composite (the same form as the household’s consumption basket), and sell them to capitalists. Capitalists borrow money from foreign lenders by offering their own net worth as collateral, purchase ‘unfinished’ capital, and convert them into ‘finished’ capital. The monetary authority adjusts the nominal interest rate in order to fix the exchange rate or to control inflation (and output).

3.2.1. Households

There is a continuum of measure 1 of consumers. The representative consumer’s inter-temporal lifetime utility function is given by

$$U = E_0 \sum_{t=0}^{\infty} \beta^{t} \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \eta \frac{H_t^{1+\psi}}{1+\psi}\right) \tag{3.1}$$

where $0 < \beta < 1$ is the discount factor and H_t is labour effort. C_t is a composite consumption index defined by the following CES function:

$$C_t = (a^{\frac{1}{\rho}} C_{Nt}^{\frac{\rho-1}{\rho}} + (1-a)^{\frac{1}{\rho}} C_{Mt}^{\frac{\rho-1}{\rho}})^{\frac{\rho}{\rho-1}}$$

where ρ (> 0) is the elasticity of substitution between non-traded and imported goods and a is the share of non-traded goods in the consumer price index. C_{Nt} is the consumption of non-traded goods while C_{Mt} denotes the consumption of imported goods. C_{Nt} is defined, as in Dixit and Stiglitz (1977), by the following CES aggregate of the continuum of differentiated goods:

$$C_{Nt} = [\int_0^1 C_{Nt}(i)^{\frac{\lambda-1}{\lambda}} di]^{\frac{\lambda}{\lambda-1}} \tag{3.2}$$

where $i \in [0,1]$ and λ (> 1) is the elasticity of substitution between varieties. $C_{Nt}(i)$ is produced by firm i in a monopolistically competitive environment. Demand for $C_{Nt}(i)$ results from cost minimization subject to Eq. (3.2):

$$C_{Nt}(i) = (\frac{P_{Nt}(i)}{P_{Nt}})^{-\lambda} C_{Nt}$$

where $P_{Nt}(i)$ is the price of $C_{Nt}(i)$ and P_{Nt} is the price index for non-traded goods given by

$$P_{Nt} = [\int_0^1 P_{Nt}(i)^{1-\lambda} di]^{\frac{1}{1-\lambda}} \tag{3.3}$$

On the other hand, it is assumed that the law of one price holds for imports[6], so that the price of imports in terms of domestic currency (P_{Mt}) is

$$P_{Mt} = S_t P_{Mt}^* \tag{3.4}$$

where S_t is the nominal exchange rate and P_{Mt}^* is the price of imports in foreign

[6] In Chapter 2, we introduce price adjustment costs in the import sector to investigate whether and how the degree of exchange rate pass-through affects the welfare assessment of exchange rate regimes. In Chapter 3, we focus only on full exchange rate pass-through.

currency. We assume that $P^*_{M\mathrm{t}}$ is exogenously determined on world markets, that is, EMCs are price- takers. For simplicity, $P^*_{M\mathrm{t}}$, is normalised to unity.

The consumer price index (P_{t}) is then:

$$P_{\mathrm{t}} = (a\, P_{N\mathrm{t}}^{1-\rho} + (1-a)\, P_{M\mathrm{t}}^{1-\rho})^{\frac{1}{1-\rho}} \tag{3.5}$$

The representative consumer's budget constraint is given by

$$P_{\mathrm{t}}C_{\mathrm{t}} = W_{\mathrm{t}}H_{\mathrm{t}} + \int_0^1 \pi_t^N(i)di - S_{\mathrm{t}}F^*_{\mathrm{t+1}} - B_{\mathrm{t+1}} - P_{\mathrm{t}}\frac{\psi_{F^*}}{2}(\frac{S_{\mathrm{t}}F^*_{\mathrm{t+1}}}{P_{\mathrm{t}}})^2$$
$$+(1+i^*_{\mathrm{t-1}})S_{\mathrm{t}}F^*_{\mathrm{t}} + (1+i_{\mathrm{t-1}})B_{\mathrm{t}} \tag{3.6}$$

where W_{t} is the nominal wage rate and $\psi_{F^*} > 0$, a constant. Here B_{t} and F^*_{t} are nominal stocks of one-period local and foreign currency bonds, respectively. i_{t} is the nominal interest rate on the domestic bond maturing in period t +1, while i^*_{t}, denotes the nominal interest rate on the foreign bond maturing in period t +1, which is assumed to follow an exogenous stochastic process. It is assumed that holding foreign currency bonds is subject to a small transaction cost, $P_{\mathrm{t}}\frac{\psi_{F^*}}{2}(\frac{S_{\mathrm{t}}F^*_{\mathrm{t+1}}}{P_{\mathrm{t}}})^2$, where the cost is denominated in the composite consumption index.[7] Finally, since households own all domestic firms, they receive any profits from the firms. Assuming that traded goods firms and unfinished capital goods firms are perfectly competitive, households receive profits only from the non-traded sector, $\int_0^1 \pi_t^N(i)di$.

The representative consumer's problem is to maximize its expected utility (Eq. (3.1)) with respect to $C_{\mathrm{t}}, H_{\mathrm{t}}, B_{\mathrm{t+1}},$ and $F^*_{\mathrm{t+1}}$ subject to the budget constraint (Eq.

[7] To ensure that the model is solved numerically using a second-order approximation, this small transaction cost is required. Without this cost, local and foreign currency bonds and consumption would be non-stationary. Further, we assume that holding foreign currency bonds by households is not subject to informational problems, while foreign borrowing by capitalists is subject to informational asymmetries (see subsection 2.2.5.).

(3.6)). It follows that the first order conditions are:

$$W_{\mathrm{t}} = \eta H_{\mathrm{t}}^{\psi} P_{\mathrm{t}} C_{\mathrm{t}}^{\sigma} \tag{3.7}$$

$$1 = \left[1 + \psi_{F^*} \frac{S_{\mathrm{t}} F_{\mathrm{t+1}}^*}{P_{\mathrm{t}}}\right]^{-1} \beta(1 + i_{\mathrm{t}}^*) E_{\mathrm{t}} \left\{\frac{C_{\mathrm{t}}^{\sigma} P_{\mathrm{t}}}{C_{\mathrm{t+1}}^{\sigma} P_{\mathrm{t+1}}} \frac{S_{\mathrm{t+1}}}{S_{\mathrm{t}}}\right\} \tag{3.8}$$

$$1 = \beta(1 + i_{\mathrm{t}}) E_{\mathrm{t}} \left\{\frac{C_{\mathrm{t}}^{\sigma} P_{\mathrm{t}}}{C_{\mathrm{t+1}}^{\sigma} P_{\mathrm{t+1}}}\right\} \tag{3.9}$$

Eq. (3.7) represents the labour supply condition. Eqs. (3.8) - (3.9) correspond to the Euler equations for foreign and domestic currency bonds, respectively.

3.2.2. Production firms

The production technology for a non-traded good firm $i \in [0,1]$ is given by:

$$Y_{N\mathrm{t}}(i) = K_{N\mathrm{t}}(i)^{\alpha} H_{N\mathrm{t}}(i)^{(1-\alpha)\Omega} (H_{N\mathrm{t}}^{e}(i))^{(1-\Omega)(1-\alpha)} \tag{3.10}$$

The production technology for an exporter $i \in [0,1]$ is given by:

$$Y_{X\mathrm{t}}(i) = K_{X\mathrm{t}}(i)^{\gamma} H_{X\mathrm{t}}(i)^{(1-\gamma)\Omega} (H_{X\mathrm{t}}^{e}(i))^{(1-\Omega)(1-\gamma)}$$

where α and γ are the shares of capital in each sector. Ω is the share of household-labour. Production firms in the non-traded sector hire labour from households, $H_{N\mathrm{t}}$, and from capitalists in the same sector, $H_{N\mathrm{t}}^{e}$. In return, capitalists in the non-traded sector earn wages, $W_{N\mathrm{t}}^{e}$. Capital, $K_{N\mathrm{t}}$, is supplied by capitalists in the non-traded sector. The export sector is entirely analogous ($H_{X\mathrm{t}}$ is labour services supplied by households and $H_{X\mathrm{t}}^{e}$ denotes those by capitalists in the export sector. $K_{X\mathrm{t}}$ is capital provided by capitalists in the export sector).

Firm i in the non-traded sector chooses $K_{N\mathrm{t}}(i)$, $H_{N\mathrm{t}}(i)$, and $H_{N\mathrm{t}}^{e}(i)$ so as to minimize its total cost

$$\min \quad R_{N\mathrm{t}} K_{N\mathrm{t}}(i) + W_{\mathrm{t}} H_{N\mathrm{t}}(i) + W_{N\mathrm{t}}^{e} H_{N\mathrm{t}}^{e}(i),$$

subject to the production function (Eq. (3.10)) and to taking $Y_{N\mathrm{t}}(i)$ as given. Here, $R_{N\mathrm{t}}$ denotes the rental rate of capital in the non-traded sector. The first-order conditions are then

$$MC_{N\mathrm{t}}(i)=\frac{R_{N\mathrm{t}}^{\alpha}\,W_{\mathrm{t}}^{\Omega(1-\alpha)}(W_{N\mathrm{t}}^{e})^{(1-\Omega)(1-\alpha)}}{\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}(1-\Omega)^{(1-\Omega)(1-\alpha)}\Omega^{\Omega(1-\alpha)}}$$

$$\frac{H_{N\mathrm{t}}(i)}{K_{N\mathrm{t}}(i)}=\frac{R_{N\mathrm{t}}\Omega(1-\alpha)}{\alpha W_{\mathrm{t}}}$$

$$\frac{H_{N\mathrm{t}}^{e}(i)}{K_{N\mathrm{t}}(i)}=\frac{R_{N\mathrm{t}}(1-\Omega)(1-\alpha)}{\alpha W_{N\mathrm{t}}^{e}}$$

where we have made use of the fact that the Lagrange multiplier is equal to the marginal cost, and $MC_{N\mathrm{t}}(i)$ denotes the marginal cost . We notice that the marginal cost, the household-labour capital ratio ($\frac{H_{N\mathrm{t}}}{K_{N\mathrm{t}}}$), and the capitalist-labour capital ratio ($\frac{H_{N\mathrm{t}}^{e}}{K_{N\mathrm{t}}}$) are identical across firms. We thus drop the index *i*.

$$MC_{N\mathrm{t}}=\frac{R_{N\mathrm{t}}^{\alpha}\,W_{\mathrm{t}}^{\Omega(1-\alpha)}(W_{N\mathrm{t}}^{e})^{(1-\Omega)(1-\alpha)}}{\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}(1-\Omega)^{(1-\Omega)(1-\alpha)}\Omega^{\Omega(1-\alpha)}} \tag{3.11}$$

$$\frac{H_{N\mathrm{t}}}{K_{N\mathrm{t}}}=\frac{R_{N\mathrm{t}}\Omega(1-\alpha)}{\alpha W_{\mathrm{t}}} \tag{3.12}$$

$$\frac{H_{N\mathrm{t}}^{e}}{K_{N\mathrm{t}}}=\frac{R_{N\mathrm{t}}(1-\Omega)(1-\alpha)}{\alpha W_{N\mathrm{t}}^{e}} \tag{3.13}$$

Similarly, the following optimality conditions in the export sector can be derived from cost minimization:

$$W_{\mathrm{t}}=P_{X\mathrm{t}}(1-\gamma)\Omega\,\frac{Y_{X\mathrm{t}}}{H_{X\mathrm{t}}} \tag{3.14}$$

$$W_{X\mathrm{t}}^{e}=P_{X\mathrm{t}}(1-\gamma)(1-\Omega)\,\frac{Y_{X\mathrm{t}}}{H_{X\mathrm{t}}^{e}} \tag{3.15}$$

$$R_{X\mathrm{t}}=P_{X\mathrm{t}}\gamma\,\frac{Y_{X\mathrm{t}}}{K_{X\mathrm{t}}} \tag{3.16}$$

where $W_{X\mathrm{t}}^{e}$ and $R_{X\mathrm{t}}$ denote the nominal wage rate for capitalists and the rental rate of capital in the export sector, respectively, and $Y_{X\mathrm{t}}$ is total traded output given by

$$Y_{X\mathrm{t}} = {K_{X\mathrm{t}}}^{\gamma} {H_{X\mathrm{t}}}^{(1-\gamma)\Omega} (H_{X\mathrm{t}}^{e})^{(1-\Omega)(1-\gamma)} \tag{3.17}$$

$P_{X\mathrm{t}}$ is the unit price of the export good and also the unit production cost since the export sector is perfectly competitive. It is assumed that the law of one price holds for export goods:

$$P_{X\mathrm{t}} = S_{\mathrm{t}} P_{X\mathrm{t}}^{*} \tag{3.18}$$

where $P_{X\mathrm{t}}^{*}$ is the foreign currency price of the export good, which is exogenously determined on world markets and follows a stochastic process.

3.2.3. Price setting

Non-traded production firms are monopolistically competitive and thus set prices for their products. The present model assumes staggered price setting *à* la Calvo (1983) and Yun (1996). In each period, production firm *i* in the non-traded sector receives the chance to set its price optimally with probability $(1-\kappa)$, a constant, which is independent of history and other firms. If the firm does not get the chance, he/she has to keep charging the same price as last period.

Suppose that firm *i* receives this opportunity in period *t*. Let denote $\widetilde{P_{N\mathrm{t}}}(i)$ the price that the firm chooses. The firm chooses $\widetilde{P_{N\mathrm{t}}}(i)$ so as to maximize the following profit function subject to demand for firm *i*'s product, $q_{\mathrm{t}+\tau}^{N}(i) = (\frac{P_{N\mathrm{t}}(i)}{P_{N\mathrm{t}+\tau}})^{-\lambda} Q_{\mathrm{t}+\tau}^{d}$:

$$\sum_{\tau=0}^{\tau=\infty} \kappa^{\tau} E_t\left[\Gamma_{\mathrm{t},\mathrm{t}+\tau} \pi_{\mathrm{t}+\tau}^{N}(i)\right]$$
$$= \sum_{\tau=0}^{\tau=\infty} \kappa^{\tau} E_t\left[\Gamma_{\mathrm{t},\mathrm{t}+\tau} (P_{N\mathrm{t}}(i) - MC_{N\mathrm{t}+\tau}) q_{\mathrm{t}+\tau}^{N}(i)\right]$$

where $Q^{d}_{t+\tau}$ denotes aggregate demand for non-traded goods and $\Gamma_{t,t+\tau}$ is the households' discount factor given by

$$\Gamma_{t,t+\tau} = \beta^{\tau}\frac{C_{t}^{\sigma}P_{t}}{C_{t+\tau}^{\sigma}P_{t+\tau}}$$

Since non-traded firms are owned by households, the expected profit stream needs to be discounted using the household's discount factor. It is assumed that the firms must satisfy all demand at posted prices.

Notice that all firms that set their new prices select the same price. Thus, we drop the index *i*. Defining $\varXi_{t,t+\tau} = \beta^{\tau}\frac{C_{t}^{\sigma}P_{t}}{C_{t+\tau}^{\sigma}P_{t+\tau}}Q^{d}_{t+\tau}(P_{Nt+\tau})^{\lambda}$, the optimal pricing condition is then

$$\widetilde{P_{Nt}} = \frac{\lambda}{\lambda-1}\frac{\sum_{\tau=0}^{\tau=\infty}\kappa^{\tau}E_{t}\varXi_{t,t+\tau}MC_{Nt+\tau}}{\sum_{\tau=0}^{\tau=\infty}\kappa^{\tau}E_{t}\varXi_{t,t+\tau}} \tag{3.19}$$

In order to use a higher order approximation to the equilibrium conditions of the model, we need to rewrite Eq. (3.19) in a recursive representation. In line with Schmitt-Grohe and Uribe (2004a), rearranging Eq. (3.19) yields

$$E_{t}\sum_{\tau=0}^{\tau=\infty}\kappa^{\tau}\Gamma_{t,t+\tau}P_{Nt+\tau}\left(\frac{\widetilde{P_{Nt}}}{P_{Nt+\tau}}\right)^{-\lambda}Q^{d}_{t+\tau}\left[\frac{\lambda-1}{\lambda}\left(\frac{\widetilde{P_{Nt}}}{P_{Nt+\tau}}\right)-\frac{MC_{Nt+\tau}}{P_{Nt+\tau}}\right] = 0$$

Define x_{t}^{1} and x_{t}^{2} as

$$P_{Nt}x_{t}^{1} \equiv E_{t}\sum_{\tau=0}^{\tau=\infty}\kappa^{\tau}\Gamma_{t,t+\tau}P_{Nt+\tau}\left(\frac{\widetilde{P_{Nt}}}{P_{Nt+\tau}}\right)^{-\lambda}Q^{d}_{t+\tau}\frac{\lambda-1}{\lambda}\left(\frac{\widetilde{P_{Nt}}}{P_{Nt+\tau}}\right), \text{and}$$

$$P_{Nt}x_{t}^{2} \equiv E_{t}\sum_{\tau=0}^{\tau=\infty}\kappa^{\tau}\Gamma_{t,t+\tau}\left(\frac{\widetilde{P_{Nt}}}{P_{Nt+\tau}}\right)^{-\lambda}Q^{d}_{t+\tau}MC_{Nt+\tau}, \text{respectively.}$$

Using x_{t}^{1} and x_{t}^{2}, Eq. (3.19) can be rewritten in the following three first-order difference equations:

$$P_{N\mathrm{t}}x_{\mathrm{t}}^{1} = (\frac{\widetilde{P_{N\mathrm{t}}}}{P_{N\mathrm{t}}})^{1-\lambda}P_{N\mathrm{t}}Q_{\mathrm{t}}^{d}\frac{\lambda-1}{\lambda} + \kappa E_{t}(\frac{\widetilde{P_{N\mathrm{t}}}}{\widetilde{P_{N\mathrm{t+1}}}})^{1-\lambda}\Gamma_{\mathrm{t,t+1}}P_{N\mathrm{t+1}}x_{\mathrm{t+1}}^{1} \tag{3.20}$$

$$P_{N\mathrm{t}}x_{\mathrm{t}}^{2} = (\frac{\widetilde{P_{N\mathrm{t}}}}{P_{N\mathrm{t}}})^{-\lambda}Q_{\mathrm{t}}^{d}MC_{N\mathrm{t}} + \kappa E_{t}(\frac{\widetilde{P_{N\mathrm{t}}}}{\widetilde{P_{N\mathrm{t+1}}}})^{-\lambda}\Gamma_{\mathrm{t,t+1}}P_{N\mathrm{t+1}}x_{\mathrm{t+1}}^{2} \tag{3.21}$$

$$x_{\mathrm{t}}^{1} = x_{\mathrm{t}}^{2} \tag{3.22}$$

Eq. (3.3) implies that the price index $P_{N\mathrm{t}}$ evolves according to

$$P_{N\mathrm{t}}{}^{1-\lambda} = \kappa P_{N\mathrm{t-1}}{}^{1-\lambda} + (1-\kappa)\widetilde{P_{N\mathrm{t}}}{}^{1-\lambda} \tag{3.23}$$

3.2.4. Unfinished capital goods firms

The behaviour of unfinished capital goods firms is completely identical to that of unfinished capital goods firms in Chapter 2. Below, we outline the specification of unfinished capital goods firms' behaviour.

As in Chapter 2, unfinished capital goods firms are perfectly competitive. It is assumed that new unfinished capital goods in the non-traded sector are produced by combining both the investment composite, $I_{N\mathrm{t}}$, and the exiting capital stock, $K_{N\mathrm{t}}$. The investment composite consists of the same mixture as the household's consumption basket. Defining $Q_{N\mathrm{t}}$ as the price of an unfinished capital good and $R_{KN\mathrm{t}}^{G}$ as the rental rate of capital provided by capitalists, the profit function of unfinished capital goods firms in the non-traded sector is given by

$$Q_{Nt}\left[\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta\right)^2\right]K_{N\mathrm{t}} - P_{\mathrm{t}}I_{N\mathrm{t}} - R_{KN\mathrm{t}}^{G}K_{N\mathrm{t}}$$

where ψ_I represents the investment adjustment cost parameter ($\psi_I > 0$) and δ is the depreciation rate. Then, profit maximization implies that

$$Q_{N\mathrm{t}} = \frac{P_{\mathrm{t}}}{1-\psi_I(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}}-\delta)} \tag{3.24}$$

$$R^G_{KN\mathrm{t}} = Q_{Nt}\left[\psi_I(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta)\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta\right)^2\right] \tag{3.25}$$

The problem is analogous for unfinished capital goods firms in the export sector. Defining $Q_{X\mathrm{t}}$ as the price of an unfinished capital good and $R^G_{KX\mathrm{t}}$ as the rental rate of capital, the first-order conditions in the export sector are then

$$Q_{X\mathrm{t}} = \frac{P_{\mathrm{t}}}{1 - \psi_I(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta)} \tag{3.26}$$

$$R^G_{KX\mathrm{t}} = Q_{Xt}\left[\psi_I(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta)\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta\right)^2\right] \tag{3.27}$$

Capital stocks in the two sectors evolve according to

$$K_{N\mathrm{t}+1} = \left[\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta\right)^2\right]K_{N\mathrm{t}} + (1-\delta)K_{N\mathrm{t}} \tag{3.28}$$

$$K_{X\mathrm{t}+1} = \left[\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \frac{\psi_I}{2}\left(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta\right)^2\right]K_{X\mathrm{t}} + (1-\delta)K_{X\mathrm{t}} \tag{3.29}$$

3.2.5. Capitalists

The behaviour of capitalists is the same as in Chapter 2. Therefore, here we provide a brief outline of the capitalist sector.[8] For notational simplicity, below we drop capitalist-specific indices.

Profit maximizing behaviour in the non-traded sector implies the following optimal financial contract condition:[9]

[8] See Chapter 2 (subsection 2.2.5.) for more details.

[9] See Appendix A.1. for the derivation of the optimal financial contract condition. The derivation and definition of $A(\overline{\omega})$, $B(\overline{\omega})$, ϕ, $A'(\overline{\omega})$, and $B'(\overline{\omega})$ are shown in Appendix A.2.

$$\frac{E_{\mathrm{t}}\left[R_{KN\mathrm{t}+1}\left\{B(\bar{\omega}_{N\mathrm{t}+1})\frac{A'(\bar{\omega}_{N\mathrm{t}+1})}{B'(\bar{\omega}_{N\mathrm{t}+1})}-A(\bar{\omega}_{N\mathrm{t}+1})\right\}\right]}{E_{\mathrm{t}}\left[\frac{A'(\bar{\omega}_{N\mathrm{t}+1})}{B'(\bar{\omega}_{N\mathrm{t}+1})}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right]}=(1+i_{\mathrm{t}}^{*}) \tag{3.30}$$

where $A(\bar{\omega}_{N\mathrm{t}+1})$ and $B(\bar{\omega}_{N\mathrm{t}+1})$ are the expected shares of the return on capital going to capitalists and to foreign lenders, respectively, and $R_{KN\mathrm{t}+1}$ is the real gross return on capital. The foreign lenders' participation constraint in the non-traded sector is given by

$$R_{KN\mathrm{t}}Q_{N\mathrm{t}-1}K_{N\mathrm{t}}B(\bar{\omega}_{N\mathrm{t}})=(1+i_{\mathrm{t}-1}^{*})S_{\mathrm{t}}\left(\frac{Q_{N\mathrm{t}-1}K_{N\mathrm{t}}-Z_{N\mathrm{t}}}{S_{\mathrm{t}-1}}\right) \tag{3.31}$$

Assuming that capitalists die at any time period with probability $(1-\nu)$ and consume the returns on capital only when they die, the aggregate consumption of capitalists in the non-traded sector is given by

$$\begin{aligned} P_{\mathrm{t}}C_{\mathrm{t}}^{Ne} &= (1-\nu)R_{KN\mathrm{t}}Q_{N\mathrm{t}-1}K_{N\mathrm{t}}\,A(\bar{\omega}_{N\mathrm{t}}) \\ &= (1-\nu)(1-\phi_{N\mathrm{t}})R_{KN\mathrm{t}}Q_{N\mathrm{t}-1}K_{N\mathrm{t}}-(1-\nu)S_{\mathrm{t}}(1+i_{\mathrm{t}-1}^{*})D_{N\mathrm{t}}^{\mathrm{e}} \end{aligned} \tag{3.32}$$

where $D_{N\mathrm{t}}^{\mathrm{e}}=\left(\frac{Q_{N\mathrm{t}-1}K_{N\mathrm{t}}-Z_{N\mathrm{t}}}{S_{\mathrm{t}-1}}\right)$ is the amount borrowed abroad at the end of period *t*-1 and $\phi_{N\mathrm{t}}$ is the expected fraction of the return on capital that is used up in monitoring (monitoring costs are assumed to be denominated in the composite final good). We assume that C_{t}^{Ne} comprises the same mix as the household's consumption basket.

Aggregate net worth consists of the unconsumed fraction of the returns and wages earned by capitalists working in the non-traded production sector, that is,

$$\begin{aligned} Z_{N\mathrm{t}+1} &= \nu R_{KN\mathrm{t}}Q_{N\mathrm{t}-1}K_{N\mathrm{t}}\,A(\bar{\omega}_{N\mathrm{t}})+W_{N\mathrm{t}}^{e} \\ &= \nu(1-\phi_{N\mathrm{t}})R_{KN\mathrm{t}}Q_{N\mathrm{t}-1}K_{N\mathrm{t}}-\nu S_{\mathrm{t}}(1+i_{\mathrm{t}-1}^{*})D_{N\mathrm{t}}^{\mathrm{e}}+W_{N\mathrm{t}}^{e} \end{aligned} \tag{3.33}$$

Eqs. (3.32)-(3.33) imply that an exchange rate depreciation, e.g. triggered by a sudden increase in the foreign interest rate and an unanticipated worsening of terms of trade, would reduce capitalist consumption and their net-worth.

Recalling that capitalists rent their finished capital to production firms and to unfinished capital goods firms and capital depreciates at the rate of δ, the real gross return on capital in the non-traded sector, $R_{KN\mathrm{t}+1}$, is defined as the sum of $R_{N\mathrm{t}+1}$, $R^{G}_{KN\mathrm{t}+1}$, and $(1-\delta)Q_{N\mathrm{t}+1}$, divided by the purchase price of capital, that is,

$$R_{KN\mathrm{t}+1} = \frac{R_{N\mathrm{t}+1} + R^{G}_{KN\mathrm{t}+1} + Q_{N\mathrm{t}+1}(1-\delta)}{Q_{N\mathrm{t}}} \tag{3.34}$$

The behaviour of capitalists in the export sector is described analogously. Let the subscript *X* denote the export sector. Eqs. (3.35) - (3.36) describe the optimal financial contract condition and the foreign lenders' participation constraint in the export sector, respectively:

$$\frac{E_{\mathrm{t}}\left[R_{KX\mathrm{t}+1}\left\{B(\bar{\omega}_{X\mathrm{t}+1})\frac{A'(\bar{\omega}_{X\mathrm{t}+1})}{B'(\bar{\omega}_{X\mathrm{t}+1})} - A(\bar{\omega}_{X\mathrm{t}+1})\right\}\right]}{E_{\mathrm{t}}\left[\frac{A'(\bar{\omega}_{X\mathrm{t}+1})}{B'(\bar{\omega}_{X\mathrm{t}+1})}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right]} = (1+i^{*}_{\mathrm{t}}) \tag{3.35}$$

$$R_{KX\mathrm{t}}Q_{X\mathrm{t}-1}K_{X\mathrm{t}}B(\bar{\omega}_{X\mathrm{t}}) = (1+i^{*}_{\mathrm{t}-1})S_{\mathrm{t}}\left(\frac{Q_{X\mathrm{t}-1}K_{X\mathrm{t}} - Z_{X\mathrm{t}}}{S_{\mathrm{t}-1}}\right) \tag{3.36}$$

The consumption of capitalists, C^{Xe}_{t}, and their net worth, $Z_{X\mathrm{t}+1}$, are given by

$$\begin{aligned} P_{\mathrm{t}}C^{Xe}_{\mathrm{t}} &= (1-\nu)R_{KX\mathrm{t}}Q_{X\mathrm{t}-1}K_{X\mathrm{t}}\,A(\bar{\omega}_{X\mathrm{t}}) \\ &= (1-\nu)(1-\phi_{X\mathrm{t}})R_{KX\mathrm{t}}Q_{X\mathrm{t}-1}K_{X\mathrm{t}} - (1-\nu)S_{\mathrm{t}}(1+i^{*}_{\mathrm{t}-1})D^{\mathrm{e}}_{X\mathrm{t}} \end{aligned} \tag{3.37}$$

and

$$\begin{aligned} Z_{X\mathrm{t}+1} &= \nu R_{KX\mathrm{t}}Q_{X\mathrm{t}-1}K_{X\mathrm{t}}\,A(\bar{\omega}_{X\mathrm{t}}) + W^{e}_{X\mathrm{t}} \\ &= \nu(1-\phi_{X\mathrm{t}})R_{KX\mathrm{t}}Q_{X\mathrm{t}-1}K_{X\mathrm{t}} - \nu S_{\mathrm{t}}(1+i^{*}_{\mathrm{t}-1})D^{\mathrm{e}}_{X\mathrm{t}} + W^{e}_{X\mathrm{t}} \end{aligned} \tag{3.38}$$

where $D^{\mathrm{e}}_{X\mathrm{t}} = \left(\frac{Q_{X\mathrm{t}-1}K_{X\mathrm{t}} - Z_{X\mathrm{t}}}{S_{\mathrm{t}-1}}\right)$.

Finally, the real gross return on capital, $R_{KX\mathrm{t}+1}$, is expressed as

$$R_{KX\mathrm{t}+1} = \frac{R_{X\mathrm{t}+1} + R^{G}_{KX\mathrm{t}+1} + Q_{X\mathrm{t}+1}(1-\delta)}{Q_{X\mathrm{t}}} \tag{3.39}$$

3.2.6. UIP (uncovered interest parity) and biased exchange rate forecasts

Combining Eqs. (3.8) and (3.9) yields:

$$(1+i_{\mathrm{t}})E_{\mathrm{t}}\left\{\frac{C_{\mathrm{t}}^{\sigma}P_{\mathrm{t}}}{C_{\mathrm{t}+1}^{\sigma}P_{\mathrm{t}+1}}\right\} = \left[1+\psi_{F^*}\frac{S_{\mathrm{t}}F^*_{\mathrm{t}+1}}{P_{\mathrm{t}}}\right]^{-1}(1+i^*_{\mathrm{t}})E_{\mathrm{t}}\left\{\frac{C_{\mathrm{t}}^{\sigma}P_{\mathrm{t}}}{C_{\mathrm{t}+1}^{\sigma}P_{\mathrm{t}+1}}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right\} \tag{3.40}$$

Taking a log linear approximation of Eq. (3.40), we obtain the modified UIP condition:

$$i_{\mathrm{t}} - i^*_{\mathrm{t}} \cong E_{\mathrm{t}}\ln\left(\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right) - \psi_{F^*}\frac{S_{\mathrm{t}}F^*_{\mathrm{t}+1}}{P_{\mathrm{t}}} \tag{3.41}$$

where $\psi_{F^*}\frac{S_{\mathrm{t}}F^*_{\mathrm{t}+1}}{P_{\mathrm{t}}}$ indicates bond-holding costs. If $\psi_{F^*} \to 0$, the limit of Eq. (3.41) is given by the standard UIP condition, which equates nominal interest-rate differentials between countries to expected variations in nominal exchange rates:

$$i_{\mathrm{t}} - i^*_{\mathrm{t}} \cong E_{\mathrm{t}}\ln\left(\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right)$$

Since we assume that $\psi_{F^*} > 0$, the standard UIP condition does not hold. But, deviations from UIP, arising from bond-holding costs, are insignificant, because ψ_{F^*} is calibrated to be very small. Therefore, in this log-linearized form, the path of the nominal exchange rate basically depends on the standard UIP condition (although not perfectly), and all domestic players make exchange rate forecasts based on the stable relationship between the nominal exchange rate and the nominal interest rate. Recent papers including Céspedes et al. (2002, 2004), Choi and Cook (2004), Cook (2004), Devereux et al. (2006), and Elekdağ and Tchakarov (2007) which incorporate balance sheet constraints coupled with foreign currency debt assume this stable relationship (log-linearizing their models, the dynamics of the nominal exchange rate basically depend on the standard UIP condition).[10]

However, as stressed by Kollmann (2005), Wollmershäuser (2006) and others, much of empirical work has failed to find reliable relationships between the exchange rate and the interest rate, especially the standard UIP condition. Motivated by the failure, this chapter assumes the stable relationship between the nominal exchange rate and the nominal interest rate is disturbed by an exogenous random shock. Specifically, following Kollmann (2002, 2004, 2005), it is assumed that a stationary exogenous stochastic random variable, φ_{t}, perturbs the households' Euler equation for foreign currency bonds (Eq. (3.8)):

$$1 = \varphi_{\mathrm{t}}\left[1 + \psi_{F^*}\frac{S_{\mathrm{t}}F^*_{\mathrm{t+1}}}{P_{\mathrm{t}}}\right]^{-1}\beta(1+i^*_{\mathrm{t}})E_{\mathrm{t}}\left\{\frac{C^{\sigma}_{\mathrm{t}}P_{\mathrm{t}}}{C^{\sigma}_{\mathrm{t+1}}P_{\mathrm{t+1}}}\frac{S_{\mathrm{t+1}}}{S_{\mathrm{t}}}\right\} \tag{3.42}$$

where the unconditional mean of φ_{t} is unity ($E\varphi_{\mathrm{t}} = 1$). Combining Eqs. (3.9) and (3.42) and taking a log linear approximation give

$$i_{\mathrm{t}} - i^*_{\mathrm{t}} \cong E_{\mathrm{t}}\ln\left(\frac{S_{\mathrm{t+1}}}{S_{\mathrm{t}}}\right) - \psi_{F^*}\frac{S_{\mathrm{t}}F^*_{\mathrm{t+1}}}{P_{\mathrm{t}}} + \ln(\varphi_{\mathrm{t}}) \tag{3.43}$$

Eq. (3.43) implies that φ_{t} could induce large deviations from standard UIP, depending on calibrations of φ_{t}. In line with Kollmann, we regard φ_{t} as a bias in the date *t* forecast of the date *t* +1 exchange rate, $S_{\mathrm{t+1}}$[11](we refer to φ_{t} as the 'forecast bias shock'[12]). We also assume that capitalists have the same forecast bias as households and that φ_{t} disturbs the optimal contract condition in the non-traded sector (Eq.

[10] Gertler et al. (2007) consider a random shock to the standard UIP condition. However, their analysis is based on a first-order approximation method, not using a second-order accurate welfare measure.

[11] Kollmann (2002, pp.1010) defines the biased exchange forecast as follows: 'Household beliefs at period *t* about the date *t* + 1 exchange rate ($S_{\mathrm{t+1}}$) are given by a probability density function (pdf), f^S_{t}, that differs from the true pdf, f_{t}, by a factor $1/\varphi_{\mathrm{t}}$: $f^S_{\mathrm{t}}(S_{\mathrm{t+1}}, \Psi) = \frac{f_{\mathrm{t}}\left(\frac{S_{\mathrm{t+1}}}{\varphi_{\mathrm{t}}}, \Psi\right)}{\varphi_{\mathrm{t}}}$, where Ψ is any other random variable'. We employ this definition in the present model.

[12] Kollmann (2002, 2004, 2005) calls the random variable the' UIP shock'. Batini et al. (2003), Cavoli (2009), Leitemo and and Söderström (2005), McCallum and Nelson (1999, 2000), Morón and Winkelried (2005), Wollmershäuser (2006), etc. also use this type of shock. They refer to it as the '(foreign exchange) risk premium (shock)'.

(3.30)):

$$E_{\mathrm{t}}\left[R_{KN\mathrm{t}+1}\left\{B(\overline{\omega}_{N\mathrm{t}+1})\frac{A^{'}(\overline{\omega}_{N\mathrm{t}+1})}{B^{'}(\overline{\omega}_{N\mathrm{t}+1})}-A(\overline{\omega}_{N\mathrm{t}+1})\right\}\right]$$

$$=\varphi_{\mathrm{t}}(1+i_{\mathrm{t}}^{*})E_{\mathrm{t}}\left[\frac{A^{'}(\overline{\omega}_{N\mathrm{t}+1})}{B^{'}(\overline{\omega}_{N\mathrm{t}+1})}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right] \tag{3.44}$$

The capitalists' forecast of the rate of exchange rate depreciation is subject to the same 'bias shock' as the households' forecast, that is, like households, the capitalists' forecast is $\varphi_{\mathrm{t}}\mathrm{E}_{\mathrm{t}}(\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}})$.

Similarly, the optimal financial contract condition in the export sector (Eq. (3.35)) is replaced with the following equation:

$$E_{\mathrm{t}}\left[R_{KX\mathrm{t}+1}\left\{B(\overline{\omega}_{X\mathrm{t}+1})\frac{A^{'}(\overline{\omega}_{X\mathrm{t}+1})}{B^{'}(\overline{\omega}_{X\mathrm{t}+1})}-A(\overline{\omega}_{X\mathrm{t}+1})\right\}\right]$$

$$=\varphi_{\mathrm{t}}(1+i_{\mathrm{t}}^{*})E_{\mathrm{t}}\left[\frac{A^{'}(\overline{\omega}_{X\mathrm{t}+1})}{B^{'}(\overline{\omega}_{X\mathrm{t}+1})}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right] \tag{3.45}$$

3.2.7. Monetary policy rules

The monetary authority manages a short-term nominal interest rate, i_{t}. A change in the interest rate has a direct effect on households' behaviour via Eq. (3.9). The interest rule takes the following simple form:

$$1+i_{\mathrm{t}}=\left(\frac{\pi_{N\mathrm{t}}}{\overline{\pi}_{N}}\right)^{\mu_{\pi N}}\left(\frac{\pi_{\mathrm{t}}}{\overline{\pi}}\right)^{\mu_{\pi}}\left(\frac{S_{t}}{\overline{S}}\right)^{\mu_{s}}(1+\overline{\iota}) \tag{3.46}$$

where $\pi_{N\mathrm{t}}=P_{N\mathrm{t}}/P_{N\mathrm{t}-1}$ and $\pi_{\mathrm{t}}=P_{\mathrm{t}}/P_{\mathrm{t}-1}$. $\overline{\pi}_{N}$ and $\overline{\pi}$ denote deterministic steady-state levels of domestic-inflation (non-traded goods inflation) and CPI inflation, respectively (throughout this paper, the term 'steady state' indicates the deterministic steady state). $\overline{S}$ is a nominal exchange rate target and $\overline{\iota}$ is a steady-state level of the short-term nominal interest rate. Here, $\bar{\pi}_N$, $\bar{\pi}$, and $\bar{S}$ are set to unity.

The monetary authority adjusts the short-term interest rate in response to domestic-inflation ($\pi_{N\mathrm{t}}$), CPI inflation (π_{t}) and the nominal exchange rate. $\mu_{\pi_N} \to \infty$ indicates that the central bank strictly targets the domestic-inflation rate (strict domestic-inflation targeting). $\mu_\pi \to \infty$ corresponds to strict CPI inflation targeting (the CPI rule). $\mu_S \to \infty$ means that the monetary authority implements a fixed exchange rate regime (a peg). Following Bergin et al. (2007), Devereux et al. (2006), Elekdağ and Tchakarov (2007), and Kollmann (2002, 2004), we assume that all monetary policy rules are completely credible.

3.2.8. Equilibrium

Recalling that foreign-bond-holding costs by households and monitoring costs by foreign lenders are denominated in the composite final good, the aggregate demand for non-traded goods is

$$Q_{\mathrm{t}}^{d} = a\left(\frac{P_{N\mathrm{t}}}{P_{\mathrm{t}}}\right)^{-\rho}\Big[C_{\mathrm{t}} + I_{N\mathrm{t}} + I_{X\mathrm{t}} + C_{\mathrm{t}}^{Ne} + C_{\mathrm{t}}^{Xe} + \frac{\psi_{F^*}}{2}\left(\frac{S_{\mathrm{t}}F_{\mathrm{t+1}}^{*}}{P_{\mathrm{t}}}\right)^{2} + \frac{\phi_{N\mathrm{t}}R_{KN\mathrm{t}}Q_{N\mathrm{t-1}}K_{N\mathrm{t}}}{P_{\mathrm{t}}} + \frac{\phi_{X\mathrm{t}}R_{KX\mathrm{t}}Q_{X\mathrm{t-1}}K_{X\mathrm{t}}}{P_{\mathrm{t}}}\Big] \tag{3.47}$$

The market clearing condition for non-traded goods is then

$$Y_{N\mathrm{t}} = K_{N\mathrm{t}}^{\alpha}(H_{N\mathrm{t}})^{(1-\alpha)\Omega}(H_{N\mathrm{t}}^{e})^{(1-\Omega)(1-\alpha)} = \xi_{\mathrm{t}}\, Q_{\mathrm{t}}^{d} \tag{3.48}$$

where $\xi_{\mathrm{t}} = \int_0^1 (\frac{P_{N\mathrm{t}}(i)}{P_{N\mathrm{t}}})^{-\lambda}\, di.$[13] Schmitt-Grohe and Uribe (2004a) refer to ξ_{t} as the resource costs, which represent an index of inefficient price dispersion across non-traded goods firms or output loss in the non-traded sector (if $\xi_{\mathrm{t}} > 1,\ Y_{N\mathrm{t}} > Q_{\mathrm{t}}^{d}$). Therefore, actual output (final output) in the non-traded sector is Q_{t}^{d} (we refer to Q_{t}^{d}

[13] See Appendix B.1. for the derivation of Eq. (3.48).

as 'actual output,' henceforth). In line with Schmitt-Grohe and Uribe (2004a), ξ_{t} can be rewritten as the following recursive form:

$$\xi_{\mathrm{t}} = (1-\kappa)\left(\frac{\widetilde{P_{N\mathrm{t}}}}{P_{N\mathrm{t}}}\right)^{-\lambda} + \kappa\left(\frac{P_{N\mathrm{t}-1}}{P_{N\mathrm{t}}}\right)^{-\lambda}\xi_{\mathrm{t}-1} \tag{3.49}$$

The labour market must also clear. Assuming that labour supply by capitalists is completely inelastic, or fixed at one for each sector,

$$H_{N\mathrm{t}} + H_{X\mathrm{t}} = H_{\mathrm{t}} \tag{3.50}$$

$$H_{N\mathrm{t}}^{e} = 1$$

$$H_{X\mathrm{t}}^{e} = 1$$

In addition, the market clearing condition for local currency bonds, B_{t}, must be satisfied, which means $B_{\mathrm{t}} = 0$ (it is assumed that foreigners do not hold local currency bonds B_{t}).

Finally, the exogenous variables, i_{t}^{*}, $P_{X\mathrm{t}}^{*}$, and φ_{t} are assumed to follow AR(1) processes:

$$i_{\mathrm{t}}^{*} = (1-\rho_i)i^{*} + \rho_i i_{\mathrm{t}-1}^{*} + \varepsilon_{i\mathrm{t}} \tag{3.51}$$

$$\ln\,(P_{X\mathrm{t}}^{*}) = \rho_X \ln\,(P_{X\mathrm{t}-1}^{*}) + \varepsilon_{X\mathrm{t}} \tag{3.52}$$

$$\ln(\varphi_{\mathrm{t}}) = \rho^{*}\ln(\varphi_{\mathrm{t}-1}) + \varepsilon_{\varphi\mathrm{t}} \tag{3.53}$$

where $\varepsilon_{i\mathrm{t}}$, $\varepsilon_{X\mathrm{t}}$, and $\varepsilon_{\varphi\mathrm{t}}$ are i.i.d. disturbances with standard deviations σ_i, σ_X, and σ^{*}, respectively.

Equilibrium is a set of 39 sequences (P_{t}, $P_{N\mathrm{t}}$, $\widetilde{P_{N\mathrm{t}}}$, $P_{M\mathrm{t}}$, $P_{X\mathrm{t}}$, C_{t}, C_{t}^{Ne}, C_{t}^{Xe}, W_{t}, $W_{N\mathrm{t}}^{e}$, $W_{X\mathrm{t}}^{e}$, H_{t}, $H_{N\mathrm{t}}$, $H_{X\mathrm{t}}$, S_{t}, Q_{t}^{d}, $Y_{X\mathrm{t}}$, $MC_{N\mathrm{t}}$, $I_{N\mathrm{t}}$, $I_{X\mathrm{t}}$, $Q_{N\mathrm{t}}$, $Q_{X\mathrm{t}}$, $R_{N\mathrm{t}}$, $R_{X\mathrm{t}}$, $R_{KN\mathrm{t}}^{G}$, $R_{KX\mathrm{t}}^{G}$, $R_{KN\mathrm{t}}$, $R_{KX\mathrm{t}}$, $\overline{\omega}_{N\mathrm{t}}$, $\overline{\omega}_{X\mathrm{t}}$, i_{t}, ξ_{t}, x_{t}^{1}, x_{t}^{2}, $K_{N\mathrm{t}}$, $K_{X\mathrm{t}}$, $Z_{N\mathrm{t}}$, $Z_{X\mathrm{t}}$, F_{t}^{*}), which satisfies Eqs. (3.4) – (3.7), (3.9), (3.11) – (3.18), (3.20) – (3.29), (3.31) - (3.34), (3.36) - (3.39), (3.42), and (3.44) – (3.50), given Eqs. (3.51) − (3.53). Here, $K_{N\mathrm{t}}$, $K_{X\mathrm{t}}$, $Z_{N\mathrm{t}}$, $Z_{X\mathrm{t}}$, and F_{t}^{*} are predetermined variables.

Imports ($T_{M\mathrm{t}}$) are given by

$$T_{M\mathrm{t}} = (1-a)\left(\frac{P_{M\mathrm{t}}}{P_{\mathrm{t}}}\right)^{-\rho} \left[C_{\mathrm{t}} + I_{N\mathrm{t}} + I_{X\mathrm{t}} + C_{\mathrm{t}}^{Ne} + C_{\mathrm{t}}^{Xe} + \frac{\psi_{F^*}}{2}\left(\frac{S_{\mathrm{t}}F_{\mathrm{t+1}}^*}{P_{\mathrm{t}}}\right)^2 + \frac{\phi_{N\mathrm{t}}R_{KN\mathrm{t}}Q_{N\mathrm{t-1}}K_{N\mathrm{t}}}{P_{\mathrm{t}}} + \frac{\phi_{X\mathrm{t}}R_{KX\mathrm{t}}Q_{X\mathrm{t-1}}K_{X\mathrm{t}}}{P_{\mathrm{t}}}\right]$$

3.2.9. Calibration

This subsection describes the parameters used in the baseline model, which are shown in Table 3.1. Most of the parameters are selected from the previous literature. Some parameters are calibrated to match Thai data.

3.2.9.1. Preferences

The quarterly discount factor β is set at 0.98, approximately in the middle between that of Devereux et al. (2006) and that of Uribe and Yue (2006). In line with much of the open economy macro-literature, the inverse of the inter-temporal elasticity of substitution (σ) is set equal to 2. Regarding the inverse of the elasticity of labour supply (ψ), the coefficient on labour in utility (η), and the elasticity of substitution between non-traded and imported goods in consumption (ρ), we set $\psi = \eta = \rho = 1$, following Devereux et al. (2006) and Elekdağ and Tchakarov (2007). In accordance with Devereux et al. (2006), the share of non-traded goods in the CPI (a) is set equal to 0.55, which implies that the steady-state share of non-traded goods in GDP is 52% - broadly consistent with Thai and Malaysian data.[14]

[14] Devereux et al. (2006) report that the average share of non-traded goods in total GDP in Thailand was 54% over the period 1980-1998 and the average share in Malaysia was similar to that of Thailand.

3.2.9.2. Technology and capital accumulation

The capital share of non-traded goods (α) and that of export goods (γ) are set at 0.3 and 0.7, respectively, following Devereux et al. (2006) who choose these two parameters on the basis of the findings of Cook and Devereux (2006) for Thailand and Malaysia. As in Devereux et al. (2006), the household-labour share, Ω, is set to 0.95. We set the quarterly capital depreciation rate, δ, to 0.025, which is within the range of the literature. In line with Devereux et al. (2006) and Elekdağ and Tchakarov (2007), the investment adjustment cost parameter, ψ_I, is chosen to be 12. Regarding the bond adjustment cost parameter, we follow Elekdağ and Tchakarov (2007) to set $\psi_{F^*} = 0.0019$.

The elasticity of substitution between differentiated non-traded goods, λ, is set at 11 so that the steady-state mark-up is 10%, which is used in much of the literature. We set the price stickiness parameter, κ, equal to 0.75, implying that the frequency of price adjustment is 4 quarters, the standard estimate used in the literature.

The parameters related to the capitalist sector are from Devereux et al. (2006). The monitoring cost parameter (μ) and the capitalists' saving rate (ν) are set at 0.2 and 0.94, respectively. The standard error of the idiosyncratic technology shock is chosen to be 0.5. Given the calibration, the steady-state leverage ratio (the average of the two sectors), $\frac{QK}{Z}$, is 1.59, which is approximately consistent with Devereux et al. (2006). The steady-state quarterly risk premium of the non-traded sector is 2.13%, whereas that of the export sector is 2.75%.

3.2.9.3. Calibration of the shocks

With respect to the foreign interest rate shock and the export price shock, we closely follow Elekdağ and Tchakarov (2007). The foreign interest rate shock is calibrated according to the quarterly U.S. 3-month CD rate covering the period from 1973:1 to

2010:2 (the raw series was obtained from the International Monetary Fund's IFS Database: series code 60LC.ZF CDS). The raw series is detrended using the Hodrick-Prescott filter (we set $\lambda = 1600$ for the smoothing parameter). We then fit Eq. (3.51) to the detrended data. The result is as follows:

$$i_t^* = \underset{(0.13)}{0.00002} + \underset{(16.24)}{0.8}\, i_{t-1}^* + \varepsilon_{it}, \quad \sigma_i = 0.0023, \quad \text{Adjusted } R^2 = 0.64$$

The figures in parentheses refer to the *t* ratio. ρ_i is exactly identical to the estimate of Elekdağ and Tchakarov (2007), but σ_i is slightly smaller than their estimate: $\sigma_i = 0.003$ in Elekdağ and Tchakarov. One of the reasons might be that they use the different sample period (1973 – 2004).

Quarterly Malaysian data for export prices (in terms of the U.S. dollar) are not available. Therefore, we use only quarterly Thai data for export prices (1990:4 – 2010:2) in order to calibrate the export price shock (the raw series was obtained from the IFS Database: series code 74...ZF). The raw series is seasonally adjusted using the U.S. Census Bureau and Department of Commerce's X-12 ARIMA method and then logged. The seasonally adjusted and logged data is detrended using the Hodrick-Prescott filter ($\lambda = 1600$ for the smoothing parameter). We fit Eq. (3.52) to the transformed data. The result is as follows (an intercept is included in the regression, but we do not report it in the result):

$$\ln P_{Xt}^* = \underset{(15.03)}{0.86} \ln P_{Xt-1}^* + \varepsilon_{Xt}, \quad \sigma_X = 0.019, \quad \text{Adjusted } R^2 = 0.74$$

The figure in parenthesis indicates the *t* ratio.

As we will discuss below, there is far less consensus on parameter estimates of the forecast bias shock, in particular which match data from EMCs. Thus, the parameters are inferred from industrialized country data from Kollmann (2005). Using quarterly data for the U.S. and a basket of France, Germany, and Italy (denoted EU3, henceforth) covering the period from 1973:1 to 1994:4 (the post Bretton Woods era), Kollmann estimates the parameters of Eq. (3.53).[15] He reports that $\rho^* = 0.5$ and $\sigma^* = 0.033$ (3.3%). We use the parameter estimates as reference values in the baseline model. In the sensitivity analysis section, we deal with alternative calibrations of ρ^* to investigate how the persistence of the forecast bias shock affects welfare.

3.2.10. Solution method and the welfare metric

A second-order approximation technique is used to solve the model numerically because the higher-order approximation is more suitable for welfare evaluations than a first-order approximation method.[16] Here, we employ the solution method of Schmitt-Grohe and Uribe (2004b).[17]

We use the same welfare-metric as in Chapter 2. As shown in Chapter 2, the total expected utility of the economy under fixed exchange rates can be written as:

$$V_s = E_0 \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \left(\frac{C_{s\mathrm{t}}^{1-\sigma}}{1-\sigma} - \eta \frac{H_{s\mathrm{t}}^{1+\psi}}{1+\psi} \right) + E_0 \sum_{\mathrm{t}=0}^{\infty} \beta^{\mathrm{t}} \nu^{\mathrm{t}} \left(C_{s\mathrm{t}}^{Ne} + C_{s\mathrm{t}}^{Xe} \right) \tag{3.54}$$

where the subscript *s* indicates a fixed exchange rate regime. We assume that the discount factor is the same for households and capitalists.

---

15 Let $\ln(\varphi_{\mathrm{t}}') \equiv i_{\mathrm{t}} - i_{\mathrm{t}}^* - \ln\left(\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right)$. Kollmann (2005) regresses $\ln(\varphi_{\mathrm{t}}')$ on (i) lags 1 - 4 of $\ln(\varphi_{\mathrm{t}}')$ and (ii) the nominal interest rates and the detrended GDP of US and EU 3 at *t*, ..., *t* – 4. Then, he estimates Eq. (3.53) using the fitted $\ln(\varphi_{\mathrm{t}}')$ series (note that $\ln(\varphi_{\mathrm{t}}) \cong E_{\mathrm{t}} \ln(\varphi_{\mathrm{t}}')$ since ψ_{F^*} is very small).

16 Also see Section 3.1.

17 We use the Matlab codes of Schmitt-Grohe and Uribe, which are available at the following: URL:http://www.econ.upenn.edu/~uribe/2nd_order.htm

Then, using (i) the permanent consumption and labour effort of households (C_s and H_s) and (ii) the permanent consumption of capitalists in the non-traded and export sectors (C_s^{Ne} and C_s^{Xe}) under the fixed exchange rate regime[18], Eq. (3.54) can be rewritten as:

$$V_s = \frac{C_s^{1-\sigma}}{(1-\sigma)(1-\beta)} - \eta \frac{H_s^{1+\psi}}{(1+\psi)(1-\beta)} + \frac{(C_s^{Ne} + C_s^{Xe})}{(1-\beta\nu)}$$

Similarly, the total expected utility under flexible exchange rates can be written as:

$$V_f = \frac{C_f^{1-\sigma}}{(1-\sigma)(1-\beta)} - \eta \frac{H_f^{1+\psi}}{(1+\psi)(1-\beta)} + \frac{(C_f^{Ne} + C_f^{Xe})}{(1-\beta\nu)}$$

where the subscript *f* indicates a flexible exchange rate regime.

Characterizing ϵ as the fraction of permanent consumption required to achieve the same expected utility or to make households and capitalists indifferent between the peg and the float, ϵ is implicitly defined as

$$\frac{[(1-\epsilon)C_s]^{1-\sigma}}{(1-\sigma)(1-\beta)} - \eta \frac{H_s^{1+\psi}}{(1+\psi)(1-\beta)} + \frac{(1-\epsilon)(C_s^{Ne} + C_s^{Xe})}{(1-\beta\nu)} = V_f$$

In other words, the value of ϵ represents the *consumption cost* of shift from the fixed exchange rate regime to the flexible exchange rate regime. If a value of ϵ is positive, it indicates that the fixed exchange rate regime is welfare-superior to the flexible exchange rate regime, and vice versa.

3.3. Welfare evaluations

This section provides the welfare results of our baseline model. First, we consider the case where the economy is subject to the *two* simultaneous shocks (foreign interest

[18] See Chapter 2 (subsection 2.2.9.) for more details.

rate and export price shocks). Second, we deal with the case where the economy faces the *three* simultaneous shocks (these two shocks and the forecast bias shock), and see how the forecast bias shock affects welfare under floating exchange rates.

Since CPI inflation targeting is practically used in all inflation-targeting countries, this chapter mainly focuses on the CPI rule (strict CPI inflation targeting), which corresponds to the interest rule when $\mu_\pi \to \infty$ in Eq. (3.46). As indicated by Svensson (2000), all inflation-targeting countries target the inflation rate of the CPI or the index related to the CPI (e.g., the core consumer price index). None of them implements domestic-inflation targeting. We briefly consider domestic-inflation targeting in the sensitivity analysis section.

3.3.1. Exchange rate forecasts under the peg

For simplicity, the peg is assumed to completely eliminate biases in exchange rate forecasts. In other words, biased exchange rate forecasts apply under flexible exchange rates, not under fixed exchange rates. Kollmann (2005) estimates the parameters of Eq. (3.53) using quarterly data for the U.S. and EU3 and compares the parameter estimates in the Bretton Woods (BW) era (1959:1 – 1970:4) with those in the post-BW era (1973:1 - 1994:4). He reports that the autocorrelation (ρ^*) and the standard deviation (σ^*) of the forecast bias shock are 0.24 and 0.0058, respectively, in the BW era and that the autocorrelation (ρ^*) is 0.5 and the standard deviation (σ^*) is 0.033 in the post-BW era (also see subsection 3.2.9.3.). The evidence suggests that forecast bias shocks would be more persistent and far more volatile under flexible exchange rates than under fixed exchange rates or that deviations from UIP are much smaller under fixed exchange rates (biased and irrational exchange rate forecasts are less likely to be made under fixed exchange rates). Taking into account the empirical evidence, this chapter simply assumes that there is no bias in exchange rate forecasts under the peg, namely the standard deviation of the forecast bias shock, σ^*, is set at zero.[19]

Based on the above findings, the models of Kollmann (2002, 2004) assume that a peg completely eliminates biases in exchange rate forecasts. Kollmann (2002, pp.1006; 2004, pp.298-299) argues that 'under a (credible) peg [a monetary union] there is much less [no] scope for irrational exchange rate forecasts (than under a float)'.

3.3.2. Impulse responses to a forecast bias shock under the CPI rule

Before moving on to the welfare results, we now briefly consider how forecast bias shocks are propagated in the economy.[20] Figure 3.1 displays the dynamic responses of some macroeconomic aggregates to a 1% positive forecast bias shock in period 1 under the CPI rule (recall that the peg is assumed to completely eliminate biases in exchange rate forecasts. Figure 3.1 thus depicts the dynamic responses only under the CPI rule). In the figure, the horizontal axis shows time. Total real net worth indicates an aggregate of real net worth in each sector. Total investment and capitalist consumption also represent the sum of investment in each sector and the sum of capitalist consumption in each sector, respectively. The responses of the macroeconomic aggregates are computed using the baseline parameter values and shown as percentage deviations from their deterministic steady-state values (see subsection 3.3.3.1. for the definition of the 'percentage deviation from steady-state'). They are all expressed in per cent (i.e. they are multiplied by 100).

The forecast bias shock induces an immediate depreciation of the nominal exchange rate. As shown in Eqs. (3.32), (3.33), (3.37), and (3.38), the exchange rate

[19] We may relax the above assumption as follows: the persistence and the volatility of the forecast bias shock ($\rho^*$and σ^*) are much lower under fixed exchange rates than under floating exchange rates, e.g. $\rho^* = 0.24$ and $\sigma^* = 0.0058$ under fixed exchange rates, whereas $\rho^* = 0.5$ and $\sigma^* = 0.033$ under flexible exchange rates (in Kollmann (2005), this modified assumption is used). The main message of this chapter would hold when we use this modified assumption.

[20] We also examined how the economy responds to foreign interest rate shocks and to export price shocks. Dynamic responses to these two shocks are nearly identical to those in Devereux et al. (2006, Fig. 3 and Fig. 6). Therefore, we do not report the cases.

depreciation then reduces capitalist consumption and their real net worth, which causes a fall in total investment – which implies that the effective cost of foreign borrowing rises owing to balance sheet deterioration. The forecast bias shock also lowers household consumption and consequently total absorption, which leads to a fall in actual output in the non-traded sector (demand for non-traded goods). On the other hand, traded output rises owing to the exchange rate depreciation. Employment falls in response to the forecast bias shock.

3.3.3. Welfare evaluations of the peg and the CPI rule

3.3.3.1. Results for simulations with the two simultaneous shocks (shocks to $\boldsymbol{i^*}$, $\boldsymbol{P_X^*}$)

First, we consider the case where the economy is subject to both the foreign interest rate shock (i^*) and the export price shock (P_X^*) simultaneously, that is, the case where the economy is not exposed to the forecast bias shock (there is no bias in exchange rate forecasts both under the peg and under the CPI rule). As discussed in subsection 3.2.6., in this case, the dynamics of the nominal exchange rate basically depend on the standard UIP condition (when log-linearizing the model).

The results are reported in columns [1] and [2] of Table 3.2. Column [1] considers the peg, while column [2] pertains to the CPI rule. In the table, the consumption cost represents the welfare metric (see subsection 3.2.10.). Z_N/P indicates real net worth in the non-traded sector, whereas Z_X/P represents that in the export sector. *NFA* is the net foreign asset position, divided by the deterministic steady-state value of nominal GDP ($NFA_t = F_{t+1}^*/Y$, where Y is the deterministic steady-state value of nominal GDP). rp_N and rp_X are risk premiums in the non-traded and export sectors, respectively :

$$rp_{Nt} = \left(\frac{A'(\bar{\omega}_{Nt})}{B'(\bar{\omega}_{Nt})}\right) \Big/ \left[B(\bar{\omega}_{Nt})\frac{A'(\bar{\omega}_{Nt})}{B'(\bar{\omega}_{Nt})} - A(\bar{\omega}_{Nt})\right]$$

$$rp_{X\mathrm{t}} = \left(\frac{A'(\bar{\omega}_{X\mathrm{t}})}{B'(\bar{\omega}_{X\mathrm{t}})}\right) \Big/ \left[B(\bar{\omega}_{X\mathrm{t}})\frac{A'(\bar{\omega}_{X\mathrm{t}})}{B'(\bar{\omega}_{X\mathrm{t}})} - A(\bar{\omega}_{X\mathrm{t}})\right]$$

The other variables correspond to those in the text. The mean of *NFA* is defined as the difference from its deterministic steady-state value. The means and standard deviations of the other variables refer to percentage deviations from their deterministic steady-state values ($\hat{x}_{\mathrm{t}} = \frac{(x_{\mathrm{t}} - x)}{x}$ denotes the percentage deviation of a variable x_{t} from its deterministic steady-state value, where *x* is its deterministic steady-state value). All statistics and the consumption cost are measured in per cent, that is, they are multiplied by 100.

Columns [1] and [2] show that the CPI rule welfare-dominates the peg: the consumption cost is −0.16 %. This mainly reflects the fact that average household consumption is lower and average labour supply is higher under the peg relative to the CPI rule ($\mathrm{E}\widehat{C_{\mathrm{t}}}$= −0.21% and $\mathrm{E}\widehat{H_{\mathrm{t}}}$ = 0.10% under the peg, whereas $\mathrm{E}\widehat{C_{\mathrm{t}}}$= −0.10% and $\mathrm{E}\widehat{H_{\mathrm{t}}}$ = 0.03% under the CPI rule). The lower consumption under the peg appears to be due to the fact that average actual output in the non-traded sector is lower under the peg than under the CPI rule ($\mathrm{E}\widehat{Q_{\mathrm{t}}^{d}}$= −0.30% under the peg, while $\mathrm{E}\widehat{Q_{\mathrm{t}}^{d}}$= −0.15% under the CPI rule). The main reason for the lower output is that resource costs are higher under the peg relative to the CPI rule ($\mathrm{E}\widehat{\xi_{\mathrm{t}}}$=0.23% under the peg, whereas $\mathrm{E}\widehat{\xi_{\mathrm{t}}}$=0.09% under the CPI rule).[21] As discussed in subsection 3.2.8., resource costs represent inefficient price dispersion across non-traded goods firms, that is, output loss in the non-traded sector (see Eq. (3.48)). Since by design the peg acts so as to stabilize the nominal exchange rate completely and not to directly respond to non-traded goods prices, the peg generates higher resource costs or the peg generates larger output loss than the CPI rule. The result is broadly consistent with that of the Devereux et al. (2006) model which does not incorporate the forecast bias shock.[22]

[21] Note that $\mathrm{E}\widehat{Y_{N\mathrm{t}}}$ is the same for both regimes.
[22] See Chapter 2 (subsection 2.3.2.) for more details.

Since the model assumes the stable relationship between the nominal exchange rate and the nominal interest rate, the predicted standard deviation of the nominal exchange rate (*S*) under the CPI rule is extremely low. The standard deviation is 1.94% (column [2]), which is much smaller than that seen in historical data (e.g., Kollmann (2005) reports that the estimated standard deviation of the nominal exchange rate between the U.S. and EU3 in the post-BW era was 8.75%). This implies that the impact of exchange rate volatility on balance sheets could be underestimated in this economy. Below, we examine how the results would change when we introduce the forecast bias shock under the float.

3.3.3.2. *Results for simulations with the three simultaneous shocks (shocks to i^*, P_X^*, φ)*

Next, we deal with the case where the economy is subject to (i) the foreign interest rate shock, i^*, (ii) the export price shock, P_X^*, and (iii) the forecast bias shock, φ, simultaneously (the forecast bias shock applies under the CPI rule, not under the peg). As explained in subsection 3.2.6., forecast bias shocks induce departures from standard UIP (in the log-linearized model).

Columns [1] and [3] of Table 3.2 report the results of our baseline model. Column [3] pertains to the CPI rule with the three simultaneous shocks (the autocorrelation of the forecast bias shock, ρ^*, is 0.5). We now focus on the standard deviations of the variables. Columns [1] and [3] show that all the standard deviations are higher under the CPI rule than under the peg. Of special interest here is the standard deviation of the nominal exchange rate, *S*, under the CPI rule. The standard deviation of *S* under the CPI rule is 4.4 % (column [3]), which is much higher than that in the economy subjected to the two simultaneous shocks (the foreign interest and export price shocks). As mentioned above, with the two simultaneous shocks, the standard deviation of *S* under the CPI rule is 1.94 % (column [2]), which is roughly two-fifth of that in the baseline model. This implies that forecast bias shocks are the chief source of exchange rate variability.[23] As we will see in the sensitivity analysis section, exchange rates become more volatile as the persistence of the forecast bias shock increases.

The baseline model predicts that the peg delivers higher welfare than the CPI rule: the consumption cost is 0.78%. This reflects the fact that the average levels of household consumption and capitalist consumption are lower with the CPI rule relative to the peg ($\mathrm{E}\widehat{C}_{\mathrm{t}}= -0.49\%$, $\mathrm{E}\widehat{C_{\mathrm{t}}^{Ne}} = -0.86\%$, and $\mathrm{E}\widehat{C_{\mathrm{t}}^{Xe}} = -2.40\%$ under the CPI rule, whereas $\mathrm{E}\widehat{C}_{\mathrm{t}}= -0.21\%$, $\mathrm{E}\widehat{C_{\mathrm{t}}^{Ne}} = -0.21\%$, and $\mathrm{E}\widehat{C_{\mathrm{t}}^{Xe}} = -0.33\%$ under the peg). The lower consumption under the CPI rule is mainly accounted for by the following two factors. First, since forecast bias shocks generate relatively high exchange rate volatility, balance sheet deterioration is much more serious under the CPI rule than under the peg – the forecast bias shocks thus have a more adverse effect on the average level of capitalist consumption under the CPI rule. This can be seen when comparing the average levels of real net worth in the non-traded and export sectors ($\mathrm{E}\,\widehat{Z_{N\mathrm{t}}/P_{\mathrm{t}}}$ and $\mathrm{E}\,\widehat{Z_{X\mathrm{t}}/P_{\mathrm{t}}}$) under the peg (column [1]) to those under the CPI rule (column [3]). They are much lower under the CPI rule than under the peg.

Second, the average level of actual output in the non-traded sector is far lower with the CPI rule than under the peg ($\mathrm{E}\widehat{Q_{\mathrm{t}}^{d}}= -0.95\%$ under the CPI rule, while $\mathrm{E}\widehat{Q_{\mathrm{t}}^{d}}= -0.30\%$ under the peg) – average household consumption is thus lower under the CPI rule relative to the peg. There are two main reasons for the lower output under the CPI rule. One of the reasons is that resource costs are higher - output loss in the non-traded sector is larger - under the CPI rule, compared to the peg ($\mathrm{E}\widehat{\xi}_{\mathrm{t}}$=0.48% under the CPI rule, whereas $\mathrm{E}\widehat{\xi}_{\mathrm{t}}$=0.23% under the peg). Under the CPI rule, price dispersion across non-traded goods firms increases with exchange rate volatility, thereby raising resource costs relative to the peg. Another reason is that, under the

[23] Under our baseline parameterization, the standard deviation of the nominal exchange rate (*S*) under strict domestic-inflation targeting is 7.0% (not shown in Table 3.2.). As discussed above (Note 2), in Devereux et al. (2006), the predicted standard deviations of *S* under the CPI rule and under strict domestic-inflation targeting are 1.8% and 3.4%, respectively. Compared to their model, the present baseline model generates somewhat realistic exchange rate volatility.

CPI rule, Y_N falls much more than under the peg[24], since foreign borrowing costs are higher under the CPI rule (the higher borrowing costs are due to the fact that balance sheet deterioration is much more severe under the CPI rule). We observe that, under columns [1] and [3], $\mathrm{E}\widehat{Y_{Nt}}$ is lower under the CPI rule relative to the peg and that the average risk premium of the non-traded sector is higher with the CPI rule ($\mathrm{E}\widehat{Y_{Nt}}$ = −0.46% and $\mathrm{E}\widehat{rp_{Nt}}$= 0.16% under the CPI rule, while $\mathrm{E}\widehat{Y_{Nt}}$ = −0.07% and $\mathrm{E}\widehat{rp_{Nt}}$= 0.04% under the peg).[25] The above result is precisely the inverse of that found in the previous subsection and indicates that forecast bias shocks have substantial consequences for welfare.

We also notice that households under the CPI rule hold a larger stock of net foreign assets (*NFA*): the average net foreign asset position is 22.31% under the CPI rule, whereas that is 1.25% under the peg. As indicated by Kollmann (2002) and Elekdağ and Tchakarov (2007), in models with imperfect risk sharing (as assumed here), the average net foreign asset position has significant impacts on household welfare. In their models, uncertainty induces households to increase their net foreign assets, which raises households' wealth and provides protection against expected declines in consumption. Bergin et al. (2007) and Elekdağ and Tchakarov (2007) refer to this foreign asset holdings as 'precautionary saving.' Nevertheless, this baseline model predicts that households under the CPI rule reduce the average level of consumption relative to the peg. As discussed above, the CPI rule generates (i) more serious balance sheet deterioration and (ii) larger output loss, thereby lowering consumption relative to the peg. This implies that, under the CPI rule, these two negative effects overwhelm the benefits of precautionary saving.

---

[24] Y_N is defined as non-traded output which does not exclude output loss, that is, $Y_N = K_N^{\alpha}(H_N)^{(1-\alpha)\Omega}(H_N^e)^{(1-\Omega)(1-\alpha)}$

[25] Eq. (3.48) implies that:

	the decline in actual output in the non-traded sector	=	the decline in Y_N	+	output loss
e.g., under the CPI rule (column [3]),	−0.95%	=	−0.46%		−0.48%

3.4. Sensitivity analysis

This section performs four kinds of simulations in order to check the sensitivity of the baseline model to alternative calibrations. First, this section considers alternative calibrations of the persistence parameter of the forecast bias shock. Second, we compare the peg with strict domestic-inflation targeting in terms of welfare. Third, we deal with two other flexible exchange rate regimes. More specifically, we compare the peg to two types of Taylor rules. Fourth, we consider an alternative choice of the price stickiness parameter. In addition, we compare exchange rate regimes *with* and *without* balance sheet constraints in order to investigate whether and how the presence of these constraints affects the choice of exchange rate regime. We briefly explore each of these experiments in turn.

3.4.1. The persistence of the forecast bias shock

Initially, we investigate alternative choices of the persistence parameter of the forecast bias shock, ρ^*. The objective of this subsection is to see whether the results of the baseline model are sensitive to the choice of the forecast-bias-shock parameter. As discussed in the previous section, forecast bias shocks have significant effects on the welfare ranking of the peg versus the CPI rule. It is thus important to investigate whether and how the parameter value of ρ^* affects the results of the baseline model.

As for the parameter estimate of ρ^* in Eq. (3.53), empirical results are mixed. According to the literature survey conducted by Wollmershäuser (2006), the estimated values of ρ^* range widely from 0.261 to 0.8 (the estimates are mainly based on data for UK or other industrialized countries).[26] Given the survey, there seems no standard value, in particular, which matches data from EMCs. In this experiment, we

[26] Wollmershäuser (2006) deals with parameter estimates based on both annual data and quarterly data. Here, we focus on the parameter estimates based on quarterly data, since our interest is to calibrate the shocks using quarterly data.

fix the volatility of the forecast bias shock, σ^*, at 0.033 (3.3%, the baseline value) and allow ρ^* to vary within a range from 0.2 to 0.8 on the basis of the survey by Wollmershäuser (2006).

The results are depicted in Fig. 3.2. The vertical axis refers to the consumption cost, ϵ , which is expressed in per cent (that is, it is multiplied by 100). The horizontal axis represents the persistence of the forecast bias shock, ρ^*. The figure shows that the consumption cost exceeds zero within the range from 0.2 to 0.8. This suggests that the peg is welfare-superior to the CPI rule under plausible calibrations of the persistence parameter.

In addition, the figure indicates that, as ρ^* rises, the welfare difference between the two regimes becomes larger – the peg becomes more desirable. The main reason for this is as follows: with a growing persistence (ρ^*), exchange rate volatility increases and the impact of exchange rate fluctuations on balance sheets becomes greater under the CPI rule. Moreover, output loss in the non-traded sector increases (resource costs rise) and actual output in the non-traded sector falls steeply under the CPI rule. As a result, under the CPI rule consumption declines, and the relative difference between consumption in each regime increases – which widens the welfare difference between the two regimes (recall that the persistence does not affect consumption under the peg, since the peg is assumed to completely eliminate biases in exchange rate forecasts).

This can be confirmed when comparing means and standard deviations under column [3] with those under column [4] of Table 3.2. Column [3] pertains to the CPI rule when $\rho^* = 0.5$ (the baseline model), whereas column [4] considers the CPI rule when $\rho^* = 0.8$. Notice that, when ρ^* rises from 0.5 to 0.8, the standard deviation of the nominal exchange rate increases from 4.4% to 9.76% - which indicates that, as ρ^* rises, nominal exchange rate volatility increases. Interestingly, this predicted standard deviation (9.76%) is roughly similar to the estimate for U.S. and EU3 reported by Kollmann (2005): the estimated standard deviation of the nominal exchange rate between the U.S. and EU3 during 1973:1-1994:4 was 8.75%.

Also notice that, when ρ^* rises from 0.5 to 0.8, the average levels of household consumption and capitalist consumption decline dramatically (E$\widehat{C_{\mathrm{t}}}$:−0.49%→−2.82%, E$\widehat{C_{\mathrm{t}}^{Ne}}$: −0.86%→−4.02%, and E$\widehat{C_{\mathrm{t}}^{Xe}}$: −2.40%→−10.96%). This reflects the fact that (i) the average levels of real net worth in the non-traded and export sectors (E $\widehat{Z_{N\mathrm{t}}/P_{\mathrm{t}}}$ and E $\widehat{Z_{X\mathrm{t}}/P_{\mathrm{t}}}$) fall from −0.85% to −3.99% and from −2.40% to −10.95%, respectively; (ii) average resource costs (E$\widehat{\xi_{\mathrm{t}}}$) rise from 0.48% to 2.65%; (iii) the average risk premium in the non-traded sector (E$\widehat{rp_{N\mathrm{t}}}$) increases from 0.16% to 0.75%; and (iv) average actual output in the non-traded sector (E$\widehat{Q_{\mathrm{t}}^{d}}$) declines from −0.95% to −4.53%, when ρ^* rises from 0.5 to 0.8.[27]

When ρ^*= 0.8 (nominal exchange rate volatility is 9.76%), the consumption cost is 5.50% - which is equivalent to 5.50% of permanent consumption. This implies that, when exchange rates are highly volatile, the welfare difference is very large in magnitude. This result contrasts with that of Devereux et al. (2006), which shows that the welfare-difference between fixed and flexible exchange rate regimes is very small. For example, their model predicts that the consumption cost is 0.08% when the CPI rule welfare-dominates the peg under full exchange rate pass-through. In our view, this is due to the fact that their model assumes the stable relationship between the nominal exchange rate and the nominal interest rate and generates extremely low exchange rate volatility.

We now briefly review parameter estimates of σ^* (the standard deviation of the forecast bias innovation, $\varepsilon_{\varphi\mathrm{t}}$). As is the case for ρ^*, parameter estimates of σ^* range widely. For example, Taylor (1993) reports that the estimates of σ^* for the U.S. and other G7 countries range from 3.7 % (the U.S. dollar/Canadian dollar) to

[27] Besides, when ρ^* rises from 0.5 to 0.8, average labour effort (E$\widehat{H_t}$) increases from −0.06% (column [3]) to 0.62 % (column [4] of Table 3.2.). This is another reason why the welfare difference becomes wide.

10.1% (the U.S. dollar/deutsche mark). Taking into account a line of empirical evidence that EMCs tend to be more vulnerable to shocks, especially to volatile capital flows, than industrialized countries (e.g., Schaechter et al., 2000), σ^* could be greater than or equal to the Taylor's estimates (3.7% $\sim$ 10.1%).[28] Devereux (2002) argues that 'the estimate of Kollmann (σ^*= 3.3%) is likely to represent a lower bound on the volatility of UIP shocks relevant to EMCs, given their much higher exposure to volatile capital flows.' Since it is obvious that a higher value of σ^* makes the peg more desirable, we do not deal with alternative calibrations of σ^* (as σ^* rises, exchange rate volatility increases).

3.4.2. Strict domestic-inflation targeting

We now compare the peg with strict domestic-inflation targeting in terms of welfare. Strict domestic-inflation targeting corresponds to the interest rule when $\mu_{\pi_N} \rightarrow \infty$ in Eq. (3.46). This subsection conducts the same simulation as in the previous subsection.

The results are summarized in Fig. 3.3. Figure 3.3 plots the consumption cost when comparing the peg with strict domestic-inflation targeting (the dashed line) and that when comparing the peg with the CPI rule (the solid line). This figure indicates that, when $\rho^* < 0.68$, strict domestic-inflation targeting welfare-dominates the peg and that strict domestic-inflation targeting outperforms the CPI rule. The intuition for the results is as follows: strict domestic-inflation targeting entails perfect stabilization of non-traded goods inflation, which completely eliminates inefficient price dispersion across non-traded goods firms, that is, output loss in the non-traded sector ($\mathrm{E}\widehat{\xi}_t$=0). This thus helps to prevent potentially large declines in consumption ('stabilization effects'), thereby yielding higher welfare under strict domestic-inflation targeting when $\rho^* < 0.68$ (recall that, under the CPI rule, inefficient price dispersion is one of the

[28] McCallum and Nelson (1999, 2000) choose σ^* to be 4.0% on the basis of the study by Taylor (1993).

main reasons for the decline in consumption). This also gives us an explanation about why strict domestic-inflation targeting has better welfare properties than the CPI rule. On the other hand, when $\rho^* > 0.68$ (exchange rate volatility is high), the peg is welfare-superior to strict domestic-inflation targeting. This is mainly because adverse balance sheet effects overwhelm the benefits of stabilization effects.

When $\rho^* = 0.68$ (welfare is the same for both regimes), the standard deviation of the nominal exchange rate *under strict domestic-inflation targeting* is 10.25 %. This implies that highly volatile exchange rates are required for the superiority of the peg over strict domestic-inflation targeting, compared to the case where the peg welfare-dominates the CPI rule (for example, when $\rho^* = 0.2$, the standard deviation of the nominal exchange rate *under the CPI rule* is 3.18%: not shown in Table 3.2).[29]

3.4.3. Taylor rules

Next, we consider two more flexible exchange rate regimes. More specifically, we compare the peg with two types of Taylor rules. First, we analyze a classic Taylor rule which has the parameters $\mu_\pi = 1.5$, $\mu_Y = 0.5$, and $\mu_s = 0$ in the following form:

$$i_{\mathrm{t}} = \bar{\imath} + \mu_\pi \frac{(\pi_{\mathrm{t}} - \bar{\pi})}{\bar{\pi}} + \mu_Y \frac{(Y_{N\mathrm{t}} - \bar{Y}_N)}{\bar{Y}_N} + \mu_s \ln\left(\frac{S_{\mathrm{t}}}{S_{\mathrm{t}-1}}\right) \tag{3.55}$$

where $\bar{Y}_N$ is a deterministic steady-state level of non-traded output.[30] Second, we examine an augmented Taylor rule whereby the central bank sets $\mu_\pi = 1.5$, $\mu_Y = 0.5$, and $\mu_s = 0.5$ in Eq. (3.55).[31] The augmented Taylor rule indicates that the monetary

[29] Generally, strict domestic-inflation targeting tends to generate more volatile exchange rates than strict CPI inflation targeting (the CPI rule). Strict domestic-inflation targeting makes the best use of exchange rate fluctuations in order to stabilize non-traded goods prices. On the other hand, the CPI rule has to care about exchange rate fluctuations, since the CPI consists of both non-traded goods prices and imported goods prices.

[30] Strictly speaking, real output (real GDP) should be incorporated into the Taylor rule. However, the rule incorporating real GDP performs much worse than the interest rule as described by Eq. (3.55). Therefore, we report the results when using Eq. (3.55).

[31] We may use optimally calibrated parameters. For example, μ_π, μ_Y, and μ_s are set to the

authority responds directly to nominal exchange rate depreciation. This subsection performs the same simulations as in subsection 3.4.1.

Figure 3.4 presents the results of the simulations. The solid line describes the consumption cost when comparing the peg with the CPI rule, whereas the chained line [the dashed line] represents that when comparing the peg with the classic Taylor rule [the augmented Taylor rule]. The figure illustrates that, when the persistence of the forecast bias shock, ρ^*, is relatively high (or exchange rate volatility is relatively high), the peg is better than the classic Taylor rule in terms of welfare (once ρ^* exceeds 0.42, the peg welfare-dominates the classic Taylor rule). In the comparison of the peg relative to the augmented Taylor rule, after ρ^* goes beyond 0.23, the peg welfare-dominates the augmented Taylor rule.

The figure also shows that the classic Taylor rule performs much better than the CPI rule. Since the classic Taylor rule reacts directly to non–traded output fluctuations (μ_Y =0.5), the classic Taylor rule generates higher non-traded output than the CPI rule, thereby raising consumption relative to the CPI rule. This implies that monetary policy rules which react directly to output could generate a bigger improvement in performance than those that do not respond directly to output. Moreover, the figure indicates that the classic Taylor rule outperforms the augmented Taylor rule. This is mainly because the augmented Taylor rule generates higher resource costs than the classic Taylor rule. Therefore, the augmented Taylor rule reduces consumption, compared to the classic Taylor rule. This suggests that adding the exchange rate into the Taylor rule might increase resource costs and reduce welfare.

(*footnote continued*)
values which maximize the conditional expectation of life time utility. Here, following Elekdağ and Tchakarov (2007), we use the standard parameter values.

3.4.4. Price stickiness

We now consider an alternative calibration of the price stickiness parameter (κ). As discussed above, price stickiness in the non-traded sector induces output loss and has significant consequences for consumption. Under the CPI rule with forecast bias shocks, price dispersion across non-traded goods firms increases with exchange rate volatility, thereby lowing consumption relative to the peg. The experiments so far have calibrated κ to the standard estimate used in the literature, that is, κ has been fixed at 0.75, which implies that the average price adjustment interval is 4 quarters. We now choose a lower value of κ and set it at 0.5, implying that the average price adjustment period is 2 quarters. The objective here is to see whether the peg welfare-dominates the CPI rule when the degree of nominal price rigidity is lower than the standard estimate used in the literature. This section conducts the same simulation as in subsection 3.4.1.

The results are depicted in Fig. 3.5. This figure shows that the peg has better welfare properties than the CPI rule and that the consumption cost increases with ρ^*. The results indicate that, even if the average price adjustment interval shortens from 4 quarters to 2 quarters, the main message of subsection 3.4.1. holds. Comparing the consumption cost when $\kappa = 0.75$ (the baseline value) with that when $\kappa = 0.5$, as expected, the former is greater than the latter. This implies that the degree of nominal price rigidity affects the welfare difference of the two regimes and that the peg becomes more desirable, the higher the degree of nominal price rigidity.

3.4.5. No financing constraint case

The simulations thus far have focused on the economy *with* balance sheet constraints. Finally, we compare it to the economy *without* balance sheet constraints in order to investigate whether and how the presence of these constraints affects the welfare assessment of exchange rate regimes. We briefly describe the model *without* balance sheet constraints in Appendix B.2. The model assumes that there are no capitalists and households accumulate physical capital without any financing constraints on investment. As in the economy *with* balance sheet constraints, we assume that the forecast bias shock applies under flexible exchange rates, not under fixed exchange rates. Here, we compare the peg to two types of flexible exchange rate regimes: the CPI rule and strict domestic-inflation targeting.

The results are depicted in Fig. 3.6. The solid line represents the consumption cost for the economy *with* balance sheet constraints, whereas the dashed line does that for the economy *without* balance sheet constraints. The top panel of Fig. 3.6 compares the peg with the CPI rule. It shows that the same conclusion holds even when balance sheet constraints are not present: in the economy *without* balance sheet constraints, the peg welfare-dominates the CPI rule under plausible calibrations of ρ^*. However, the welfare difference between the two regimes is much greater in the economy *with* financing constraints than in the economy *without* these constraints. When the value of ρ^* is low, the welfare difference between the two regimes is very small in the economy *without* financing constraints (e.g., the consumption cost is 0.06% when $\rho^* = 0.35$). As discussed in subsection 3.3.3.2., in the economy *with* balance sheet constraints, the CPI rule generates (i) more serious balance sheet deterioration and (ii) larger output loss in the non-traded sector, thereby lowering consumption relative to the peg. On the other hand, in the economy *without* financing constraints, the CPI rule yields output loss in the non-traded sector, but does not generate balance sheet deterioration. Therefore, the consumption cost is much higher in the economy *with* financing constraints. Our results indicate that, although the presence of balance sheet constraints does not alter the welfare ranking of the two regimes, it affects the welfare difference between the two regimes, that is, it increases the welfare difference between both regimes.

The bottom panel of Fig. 3.6 plots the consumption cost when comparing the peg to strict domestic-inflation targeting. It shows that, in the economy *without* balance sheet constraints, strict domestic-inflation targeting is welfare-superior to the peg for variations of ρ^* between 0.2 and 0.8. In addition, with a growing ρ^*, the welfare difference between both regimes becomes larger - strict domestic-inflation targeting becomes more desirable. The results contrast with that found in the economy *with* balance sheet constraints (see subsection 3.4.2.). There are two main reasons for the results. First, as discussed above, strict domestic-inflation targeting entails perfect stabilization of non-traded goods inflation, which completely eliminates output loss in the non-traded sector and thus helps to prevent potentially large declines in consumption ('stabilization effects'). Another reason is that households under strict domestic-inflation targeting hold more foreign currency bonds in contrast to the peg and their stock of foreign currency bonds increases as ρ^* rises. That is, they increase the stock of 'precautionary savings.'[32] In the economy *without* balance sheet constraints, these two effects work in conjunction, generating higher welfare under strict domestic-inflation targeting. Similarly, in the economy *with* balance sheet constraints, strict domestic-inflation targeting completely eliminates output loss in the non-traded sector and households under this regime hold a larger stock of foreign currency bonds (compared to the peg). However, when exchange rate volatility is high ($\rho^* > 0.68$), the benefits of both stabilization effects and precautionary saving are more than offset by adverse balance sheet effects, thereby reducing welfare relative to the peg. Our results reveal that the presence of balance sheet constraints alters the welfare ranking of the two regimes in the case of high exchange rate volatility.

When comparing strict domestic-inflation targeting with the CPI rule in the economy *without* balance sheet constraints, Fig. 3.6 shows that the former outperforms the latter, as in the economy *with* balance sheet constraints. As mentioned above, this is because strict domestic-inflation targeting completely eliminates inefficient price dispersion across non-traded goods firms. Average foreign assets under the CPI rule are about as high as under strict domestic-inflation targeting. However, under the CPI rule, the benefits of precautionary saving are more than offset by output loss due to

[32] See subsection 3.3.3.2. for 'precautionary saving.'

inefficient price dispersion, thereby lowering consumption (and welfare) relative to strict domestic-inflation targeting.

3.5. Conclusions

This chapter investigates what type of exchange rate regime is more desirable when there are financial market imperfections in EMCs. This is accomplished through a welfare-based comparison of a fixed exchange rate regime with several types of flexible exchange rate regimes in the context of a dynamic stochastic general equilibrium small open economy model which includes some characteristics of EMCs such as balance sheet effects in combination with foreign currency debt and vulnerabilities to external shocks (foreign interest rate and export price shocks).

This chapter extends the model of Chapter 2 to examine how the degree of exchange rate volatility affects balance sheets and welfare. The main feature of the extended model is to introduce an exogenous shock to the UIP condition *under flexible exchange rates*, which allows the model to generate more realistic exchange rate volatility. The second-order approximation method is used to solve the model and to conduct a rigorous welfare evaluation of exchange rate regimes.

This chapter finds that the peg is welfare-superior to the strict CPI inflation targeting regime (the CPI rule) under plausible calibrations of exchange rate volatility. In addition, as exchange rate volatility increases, the welfare difference between the two regimes becomes wider (the peg becomes more attractive). Our results also show that whether the peg is welfare-superior to the strict domestic-inflation targeting regime or not depends on the degree of exchange rate volatility - the peg is more desirable in welfare terms when exchange rate volatility is high. Our results provide one explanation for the widespread adoption of currency pegs by emerging market countries which suffer from excessively volatile exchange rates.

Chapter 4

Conclusions

The objective of this thesis has been to study what type of exchange rate regime is more desirable in welfare terms when there are balance sheet constraints in emerging market countries (EMCs). This was accomplished through a rigorous welfare-based comparison of fixed and flexible exchange rate regimes in the context of different dynamic stochastic general equilibrium small open economy models which incorporate balance sheet effects coupled with foreign currency debt. More specifically, this thesis investigated whether and how (i) the level of foreign currency debt and (ii) the degree of exchange rate volatility affect balance sheets and welfare under different exchange rate regimes.

Little work in the existing literature has addressed these two questions. Most of the previous studies have not investigated the welfare implications of various debt levels under different exchange rate regimes. Thus, they have not provided clear answers to the question of what type of exchange rate regime is more suitable for EMCs when the level of foreign currency debt is low or high. Regarding the second question, since they assume a stable relationship between the nominal exchange rate and the nominal interest rate, their models generate extremely low exchange rate volatility. Therefore, they might understate balance sheet effects and tend to underestimate balance sheet vulnerabilities. In other words, they have not investigated how highly volatile exchange rates affect balance sheets and welfare. This thesis aimed to fill the gap in the literature.

Chapter 4: Conclusions

Chapter 2 highlighted the effects of debt levels on balance sheets and welfare. We evaluated the welfare properties of fixed and flexible exchange rate regimes by employing a two-sector (non-traded and export sectors) model, which assumes staggered price setting in the non-traded sector. Although Calvo and Reinhart (2002) argue that many monetary authorities in EMCs are reluctant to allow their currencies to float freely owing to balance sheet vulnerabilities, we found that the float welfare-dominates the peg for a broad range of debt levels. In addition, as the level of foreign currency debt rises, the welfare difference between the two regimes becomes larger – the float becomes more desirable. Since by design the peg acts so as to contain exchange rate fluctuations completely and not to react directly to domestic-inflation (non-traded goods inflation), the peg generates more volatile domestic-inflation and hence higher price adjustment costs in the non-traded sector than the float. As discussed in Chapter 2., the price adjustment cost induces output loss and reduces final-output in the non-traded sector. Therefore, the peg yields lower final-output than the float – which lowers consumption (and welfare) relative to the float. In order to check the sensitivity of the results, we conducted different robustness experiments and similar results were obtained.

We also found that the degree of exchange rate pass-through has no effect on the welfare ranking of the two exchange rate regimes. However, our results showed that the degree of exchange rate pass-through affects the welfare difference between the two regimes: the welfare difference between the two regimes is larger under low exchange rate pass-through than under full pass-through. This suggests that flexible exchange rates are more attractive in terms of welfare, the slower exchange rate pass-through. Further, the two-sector model offered a useful insight into the behaviour of the non-traded and export sectors. It showed that, with a large stock of foreign currency debt, the economic slowdown becomes more severe in the export sector than in the non-traded sector.

In Chapter 3, we extended the model of Chapter 2 to examine how the degree of exchange rate volatility affects balance sheets and welfare. The main feature of the extended model was to introduce an exogenous shock to the UIP (uncovered interest parity) condition *under flexible exchange rates*, which allows the model to generate more realistic exchange rate volatility. On the other hand, we assumed that *under fixed exchange rates* the shock does not apply. Using the extended model, we evaluated the welfare implications of the peg and several types of flexible exchange rate regimes (the strict CPI inflation targeting regime, the strict domestic-inflation targeting regime, etc.).

The results were basically consistent with the 'Fear of Floating' view. We found that the peg welfare-dominates the strict CPI-inflation targeting regime under plausible calibrations of exchange rate volatility. In addition, we showed that, when exchange rates are highly volatile, the welfare difference between the two regimes is very large in magnitude, which presents a convincing rationale for choosing the peg. This result contrasts with those of previous studies. For example, Devereux et al. (2006) report that the welfare difference between fixed and flexible exchange rate regimes is very small even in the presence of balance sheet effects and foreign currency debt. In our view, this is due to the fact that their model assumes a stable relationship between the nominal interest rate and the nominal exchange rate and generates extremely low exchange rate volatility. We also found that whether the peg is welfare-superior to the strict domestic-inflation targeting regime or not depends on the degree of exchange rate volatility – the peg is more desirable in welfare terms when exchange rate volatility is high.

Moreover, our model showed that the presence of balance sheet constraints is very important for the welfare assessment of exchange rate regimes. When comparing the peg with strict CPI inflation targeting, we found that the presence of balance sheet constraints affects the welfare difference across the two regimes - that is, it increases the welfare difference between the two regimes -, although the presence of these constraints does not alter the welfare ranking of the two regimes (the peg is welfare-superior to strict CPI inflation targeting in the economy *with* and *without* balance sheet constraints). In the comparison of the peg relative to strict domestic-inflation targeting, our results revealed that the presence of balance sheet constraints alters the welfare ranking of the two regimes when exchange rate volatility is high. In the economy *without* balance sheet constraints, strict domestic-inflation targeting welfare-dominates the peg under plausible calibrations of exchange rate volatility, whereas in the economy *with* balance sheet constraints the peg welfare-dominates strict domestic-inflation targeting when exchange rates are highly volatile (as mentioned above).

In the light of these findings, we argue that

(i) floating exchange rates could be more desirable, the higher the level of foreign currency debt, and that

(ii) fixed exchange rates could be more desirable, the higher exchange rate volatility.

Interestingly, the former contrasts with the 'Fear of Floating' view. The 'Fear of Floating' view argues that the higher the level of foreign currency debt, the greater the impacts of exchange rate fluctuations on balance sheets become, thus making flexible exchange rates less desirable. This is because, with a large amount of foreign currency debt, even a small exchange rate depreciation could inflate debt servicing costs, which could reduce firms' net worth, thereby increasing balance sheet vulnerabilities. However, our findings do not support this argument.

This thesis has focused only on the appropriate choice of exchange rate regime: which exchange rate regime is more desirable, fixed exchange rates or floating exchange rates? A possible extension of this thesis is to investigate whether monetary authorities in EMCs should add the exchange rate into the monetary policy rule, e.g. a classic Taylor rule, when they implement *a flexible exchange rate regime*. Although we briefly discussed this topic in Chapter 3, it would be possible to perform a more thorough welfare evaluation of monetary policy rules under flexible exchange rates.

In Chapter 3, we restricted our attention to the standard parameter values of Taylor rules. Such an extension could also allow for optimally calibrated policy parameters: the coefficients of Taylor rules are set to the values which maximize the conditional expectation of life time utility. This would further enhance our understanding of the role of the exchange rate in monetary policy rules for EMCs.

Appendix: Tables

Table 2.1: Parameter calibration

Symbol	Value	Description
σ	2	Inverse of the inter-temporal elasticity of substitution
β	0.985	Quarterly discount factor
ρ	1	Elasticity of substitution between non-traded goods and import goods in consumption
λ	11	Elasticity of substitution between varieties (same across the sectors)
η	1.0	Coefficient on labor in utility
ψ	1.0	Inverse of the elasticity of labor supply
γ	0.7	Share of capital in the export sector
α	0.3	Share of capital in the non-traded sector
δ	0.025	Quarterly rate of capital depreciation
a	0.55	Share of non-traded goods in the CPI
ψ_{P_N}	120	Price adjustment cost parameter in the non-traded sector
ψ_{P_M}	0 or 120	Price adjustment cost parameter in the import sector ($\psi_{P_M} = 0$ under full pass-through, while $\psi_{P_M} = 120$ under delayed pass-through)
ψ_I	12	Investment adjustment cost parameter
ψ_D	0.0007	Foreign borrowing cost parameter
μ	0.2	Coefficient of the monitoring cost for foreign lenders
Ω	0.95	Household labor share
ρ_{i^*}	0.46	Autocorrelation of the foreign interest rate shock
ρ_X	0.77	Autocorrelation of the export price shock
σ_{i^*}	0.012	Standard deviation of the foreign interest rate shock
σ_X	0.013	Standard deviation of the export price shock

Source: Devereux et al. (2006).

Table 2.2: Welfare evaluations

Regime	Original calibration Full Pass-through ($\psi_{P_M} = 0$)		Baseline experiment Full Pass-through ($\psi_{P_M} = 0$)		Baseline experiment Delayed Pass-through ($\psi_{P_M} = 120$)	
	FLOAT [1]	PEG [2]	FLOAT [3]	PEG [4]	FLOAT [5]	PEG [6]
Debt- to- net worth ratio (%)	62.25	62.25	200.0	200.0	200.0	200.0
Total expected utility	-28.892	-28.926	-35.701	-35.885	-35.599	-35.885
of which household	(-43.131)	(-43.175)	(-44.218)	(-44.415)	(-44.096)	(-44.415)
Consumption cost (ϵ, %)	−	0.0769	−	0.4642	−	0.7223
Means (%)						
C	-0.26	-0.32	-2.49	-2.83	-2.23	-2.83
H	0.18	0.27	1.37	1.71	1.21	1.71
H_N	0.12	0.20	1.35	1.66	1.24	1.66
H_X	0.35	0.46	1.41	1.82	1.14	1.82
D	-0.03	0.00	-1.85	-1.80	-2.32	-1.80
Real wage (*W*/*P*)	-0.32	-0.35	-3.58	-3.89	-3.28	-3.89
Y_N	-0.16	-0.12	-1.81	-1.87	-1.61	-1.87
Y_X	-0.16	-0.10	-3.06	-2.89	-3.06	-2.89
K_N	-0.74	-0.75	-8.80	-9.61	-7.98	-9.61
K_X	-0.34	-0.28	-4.83	-4.73	-4.73	-4.73
rp_N	0.10	0.11	0.82	0.92	0.75	0.92
rp_X	0.05	0.04	0.29	0.28	0.30	0.28
Real exchange rate (*S*/*P*)	0.06	0.04	0.50	0.32	0.66	0.32
ξ_N	0.14	0.36	0.45	1.19	0.12	1.19
ξ_M	−	−	−	−	0.19	0.00

Table 2.2 (continued)

Regime	Original calibration Full Pass-through ($\psi_{P_M} = 0$)		Baseline experiment Full Pass-through ($\psi_{P_M} = 0$)		Baseline experiment Delayed Pass-through ($\psi_{P_M} = 120$)	
	FLOAT [1]	PEG [2]	FLOAT [3]	PEG [4]	FLOAT [5]	PEG [6]
Standard deviations (%)						
C	1.45	1.53	2.23	2.35	2.09	2.35
H	1.26	1.51	2.58	3.14	1.97	3.14
H_N	2.55	3.22	5.83	7.14	3.99	7.14
H_X	4.81	5.14	8.16	8.88	7.84	8.88
D	18.16	17.42	31.64	30.43	38.28	30.43
Real wage (W/P)	2.80	3.31	4.59	5.53	2.83	5.53
Y_N	1.84	2.30	4.10	5.00	2.85	5.00
Y_X	1.17	1.27	2.00	2.23	1.98	2.23
K_N	3.04	3.33	5.27	5.81	4.40	5.81
K_X	0.89	0.99	1.67	1.85	0.89	1.85
rp_N	0.83	0.88	2.92	3.10	2.79	3.10
rp_X	0.56	0.55	1.85	1.80	1.90	1.80
Real exchange rate (S/P)	1.52	1.34	2.50	2.16	3.89	2.16
S	1.77	0.00	2.71	0.00	3.88	0.00
π_N	0.51	0.82	0.92	1.49	0.48	1.49

Source: Author's calculations. *Notes*: 'FLOAT' and 'PEG' represent strict CPI inflation targeting and the fixed exchange rate regime, respectively. Columns [1] and [2] pertain to the case with a debt-to-net worth ratio of 62% under *full pass-through*, which is consistent with the calibration of Devereux et al. (2006). Columns [3] and [4] correspond to the case with a debt- to- net worth ratio of 200% under *full pass-through*, while columns [5] and [6] correspond to the case with a debt-to-net worth ratio of 200% under *delayed pass-through*. The tabulated variables coincide with those in the text and Appendix A.3. ξ_N and ξ_M refer to differences from their deterministic steady-state values. The other variables are defined as percentage deviations from their deterministic steady-state values. All statistics and the consumption cost are expressed in per cent, that is, they are multiplied by 100.

Table 3.1: Parameter calibration (Baseline parameter values)

Symbol	Value	Description
β	0.98	Quarterly discount factor – the quarterly real interest rate is thus $(1-\beta)/\beta$
σ	2	Inverse of the inter-temporal elasticity of substitution
η	1.0	Coefficient on labor in utility
ψ	1.0	Inverse of the elasticity of labor supply
ρ	1.0	Elasticity of substitution between non-traded and imported goods in consumption
a	0.55	Share of non-traded goods in the CPI
α	0.3	Share of capital in the non-traded sector
γ	0.7	Share of capital in the export sector
Ω	0.95	Household-labor share
δ	0.025	Quarterly rate of capital depreciation
ψ_I	12	Investment adjustment cost parameter
ψ_{F^*}	0.0019	Bond adjustment cost parameter
λ	11	Elasticity of substitution between varieties
κ	0.75	Price stickiness parameter
μ	0.2	Coefficient of the monitoring cost for foreign lenders
ν	0.94	Capitalists' saving rate
σ_ω	0.5	Standard error of the idiosyncratic technology shock of capitalists
ρ_i	0.8	Autocorrelation of the foreign interest rate shock
ρ_X	0.86	Autocorrelation of the export price shock
ρ^*	0.5	Autocorrelation of the forecast bias shock
σ_i	0.0023	Standard deviation of the foreign interest rate shock
σ_X	0.019	Standard deviation of the export price shock
σ^*	0.033	Standard deviation of the forecast bias shock

Source: Author's calculations.

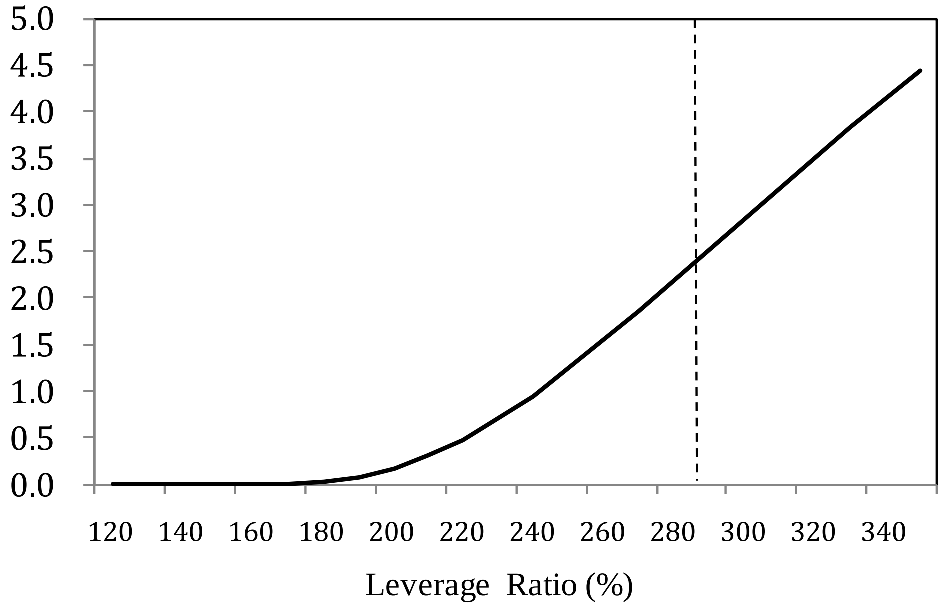
Table 3.2: Welfare evaluations

Regime	Without φ		With φ	
	Shocks to i^*, P_X^*		Shocks to i^*, P_X^*, φ	
	PEG	CPI rule	CPI rule	CPI rule
			$\rho^* = 0.5$	$\rho^* = 0.8$
	[1]	[2]	[3]	[4]
Total expected utility (a + b)	−17.258	−17.199	−17.551	−19.392
(a) Households	−32.424	−32.383	−32.473	−33.280
(b) Capitalists	15.166	15.184	14.922	13.888
Consumption cost (ϵ, %)	−	−0.1591	0.7772	5.5012
Means (%)				
C	-0.21	-0.10	-0.49	-2.82
H	0.10	0.03	-0.06	0.62
Y_N	-0.07	-0.07	-0.46	-1.88
Y_X	-0.27	-0.23	-1.99	-9.39
Q^d	-0.30	-0.15	-0.95	-4.53
K_N	-0.40	-0.28	-1.17	-6.77
K_X	-0.39	-0.30	-2.58	-12.43
Imports	-0.09	-0.03	-0.85	-4.22
rp_N	0.04	0.02	0.16	0.75
rp_X	0.02	0.01	0.11	0.40
Z_N/P	-0.20	-0.09	-0.85	-3.99
Z_X/P	-0.33	-0.21	-2.40	-10.95
C^{Ne}	-0.21	-0.09	-0.86	-4.02
C^{Xe}	-0.33	-0.21	-2.40	-10.96
Real exchange rate (*S/P*)	-0.06	-0.01	0.08	0.58
NFA	1.25	1.29	22.31	103.23
ξ	0.23	0.09	0.48	2.65
Standard deviations (%)				
C	1.59	1.51	3.22	8.18
H	1.91	1.64	2.57	5.48
Y_N	2.09	1.62	5.15	9.40
Y_X	1.33	1.27	3.68	8.79
K_N	2.64	2.26	2.87	6.22
K_X	1.59	1.48	1.87	4.46
C^{Ne}	7.28	6.27	12.21	28.09
C^{Xe}	4.39	4.31	8.65	17.81
S	0.00	1.94	4.40	9.76
Real exchange rate (*S/P*)	1.61	1.79	2.32	5.81
π_N	0.59	0.36	0.86	2.01

Source: Author's calculations. *Notes*: 'PEG' and 'CPI rule' represent the fixed exchange rate regime and the strict CPI inflation targeting regime, respectively. Columns [1] and [2] correspond to the case without the forecast bias shock (φ). Columns [3] and [4] pertain to the CPI rules when $\rho^* = 0.5$ and when $\rho^* = 0.8$, respectively. The tabulated variables coincide with those in the text. All statistics and the consumption cost are expressed in percent (that is, they are multiplied by 100).

Appendix: Figures

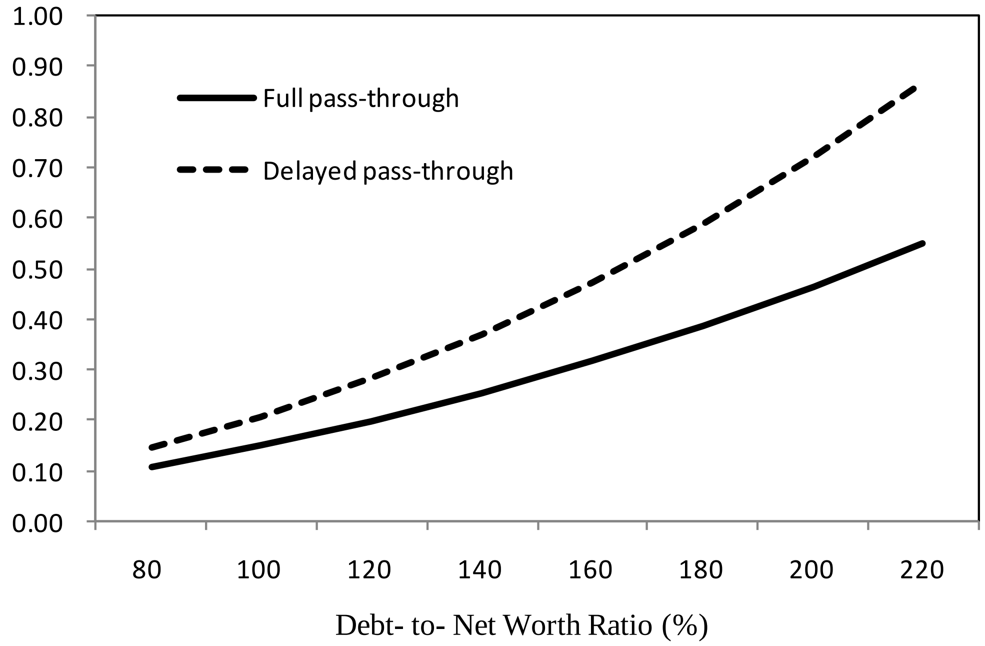
Figure 2.1: Relation between the Risk Premium and the Leverage Ratio



Source: Author's calculations.

Notes: The vertical axis shows the quarterly risk premium (%). Figure 2.1 coincides with the case when the standard error of the productivity shock (σ_ω) is set at 0.217. The dashed line indicates a leverage ratio of 290%, which corresponds to a deterministic steady-state debt-to-net worth ratio of 200% in the baseline experiment.

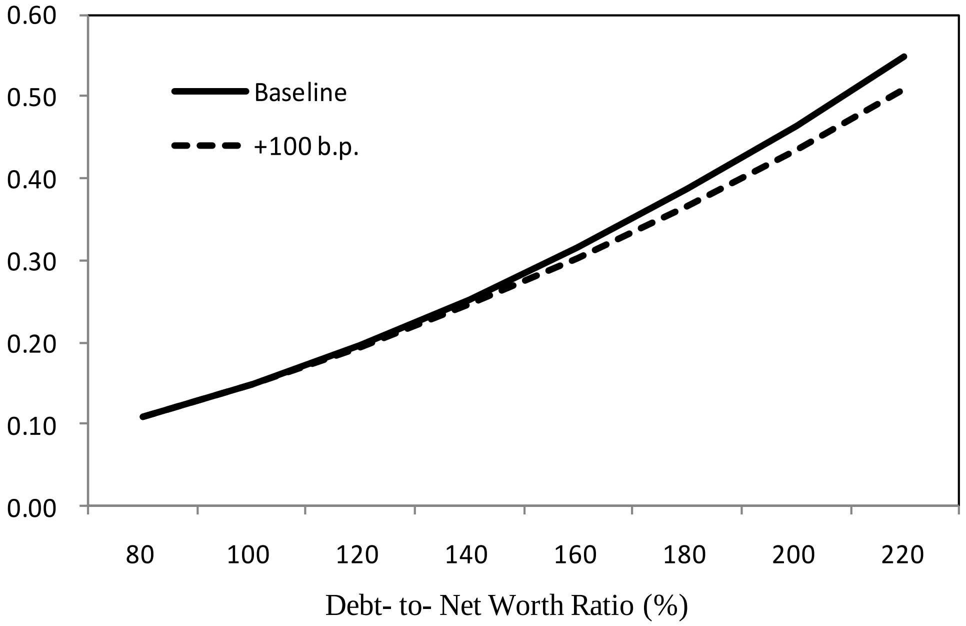
Figure 2.2: Welfare Evaluations (Baseline Experiment)



Source: Author's calculations.

Notes: The vertical axis shows the consumption cost, ϵ (ϵ is expressed in per cent, that is, it is multiplied by 100). A positive value of ϵ indicates that the flexible exchange rate regime is welfare-superior to the fixed exchange rate regime. The solid line describes the consumption cost under full exchange rate pass-through, while the dashed line represents that under low pass-through.

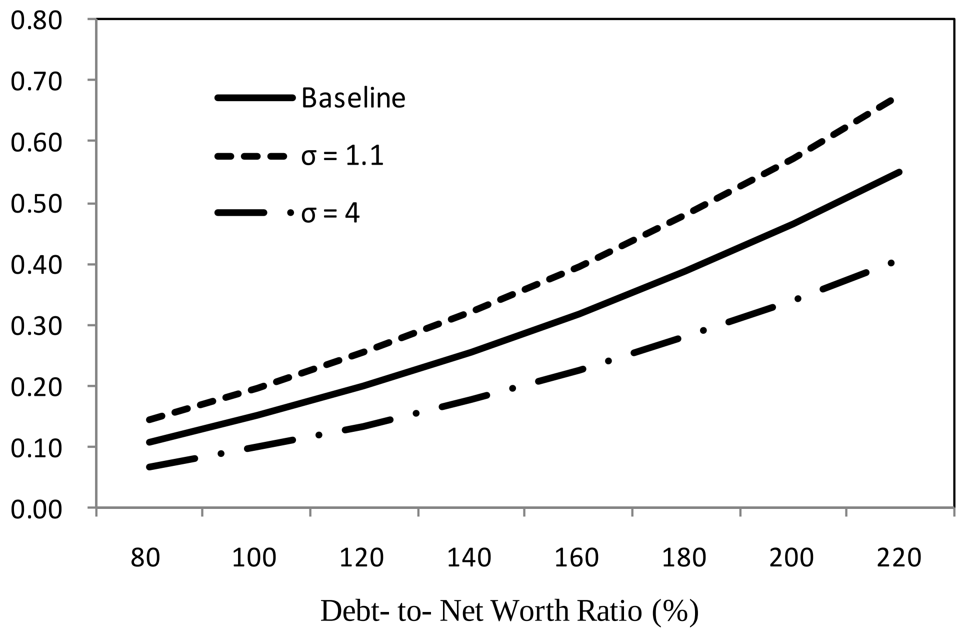
Figure 2.3: Welfare Evaluations
(Robustness to the Steady-State Risk Premium)



Source: Author's calculations.

Notes: The vertical axis shows the consumption cost, ϵ (ϵ is expressed in per cent, that is, it is multiplied by 100). A positive value of ϵ indicates that the flexible exchange rate regime is welfare-superior to the fixed exchange rate regime. The solid line describes the consumption cost in the baseline experiment. The dashed line represents the consumption cost when the deterministic steady-state risk premiums are increased to the baseline values plus 100 basis points.

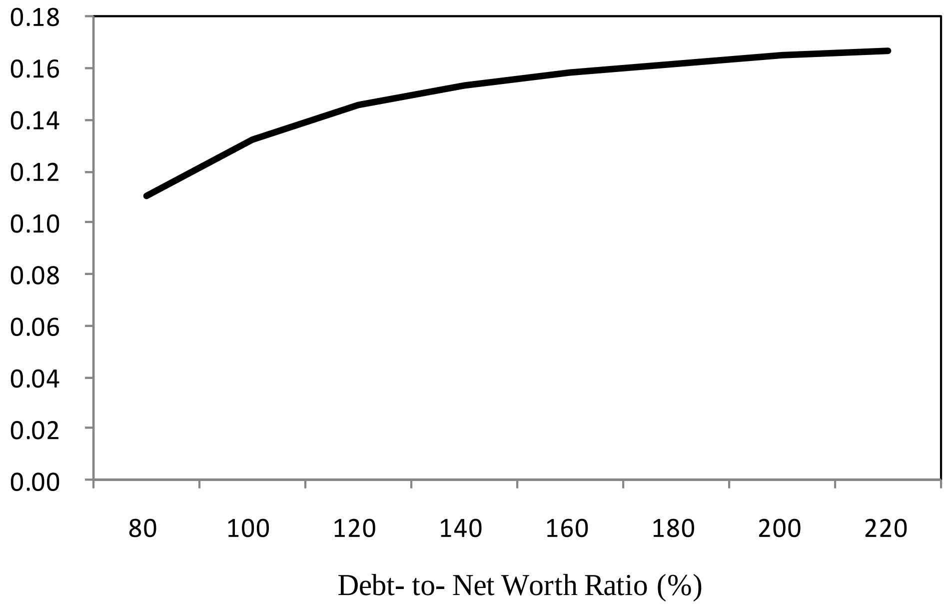
Figure 2.4: Welfare Evaluations
(Robustness to Alternative Calibrations for σ)



Source: Author's calculations.

Notes: σ is the inverse of the inter-temporal elasticity of substitution. The vertical axis shows the consumption cost, ϵ (ϵ is expressed in per cent, that is, it is multiplied by 100). A positive value of ϵ indicates that the flexible exchange rate regime is welfare-superior to the fixed exchange rate regime. The solid line describes the consumption cost in the baseline experiment ($\sigma = 2$). The dashed line represents the consumption cost when $\sigma = 1.1$, while the chained line indicates that when $\sigma = 4$.

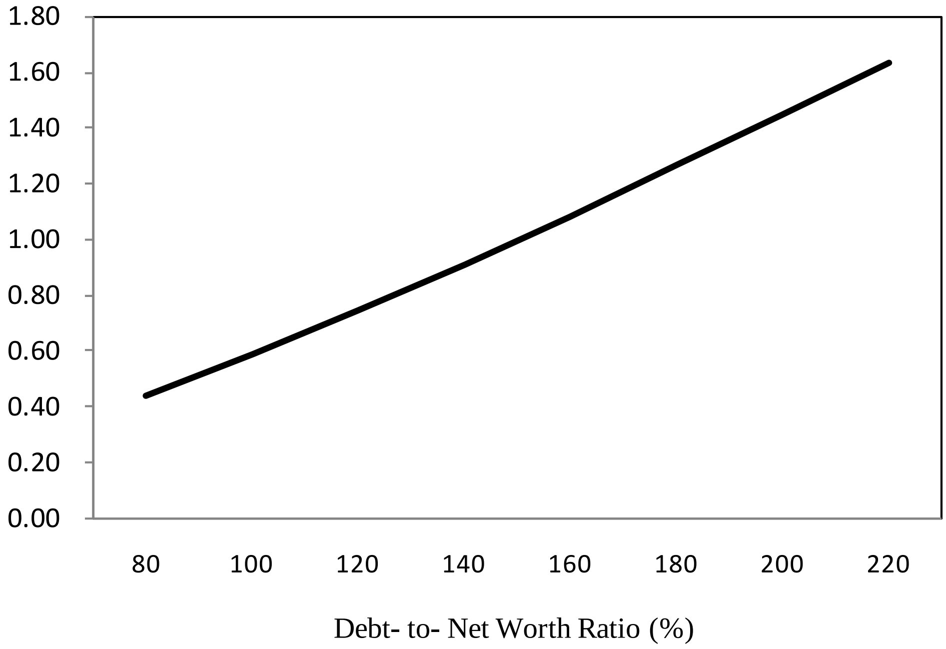
Figure 2.5: Welfare Evaluations (Robustness to an Alternative Method to Calibrate the Debt-to-Net Worth Ratio)



Source: Author's calculations.

Notes: The vertical axis shows the consumption cost, ϵ (ϵ is expressed in per cent, that is, it is multiplied by 100). A positive value of ϵ indicates that the flexible exchange rate regime is welfare-superior to the fixed exchange rate regime.

Figure 2.6: Welfare Evaluations
(Robustness to an Alternative Risk Premium Specification)



Source: Author's calculations.

Notes: The vertical axis shows the consumption cost, ϵ (ϵ is expressed in per cent, that is, it is multiplied by 100). A positive value of ϵ indicates that the flexible exchange rate regime is welfare-superior to the fixed exchange rate regime.

Figure 3.1: Impulse response to a 1% forecast bias shock under the CPI rule (expressed in %)

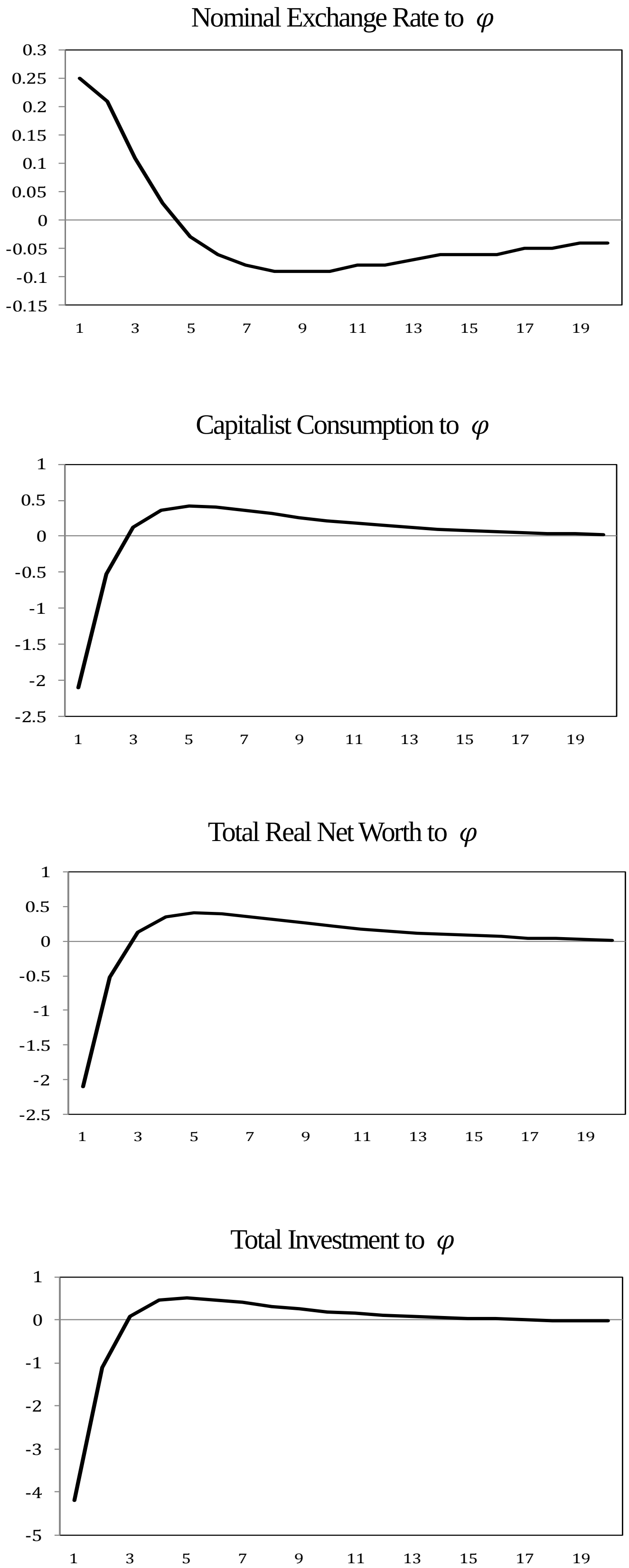
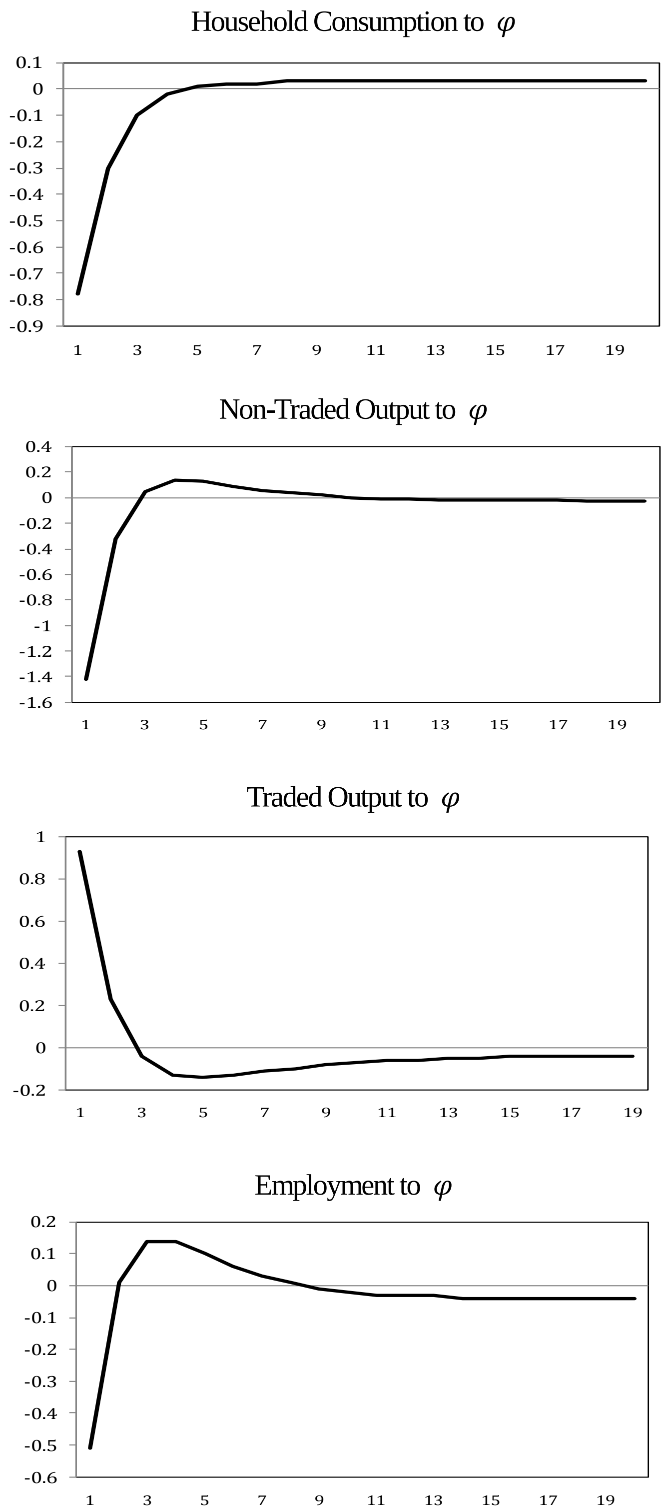


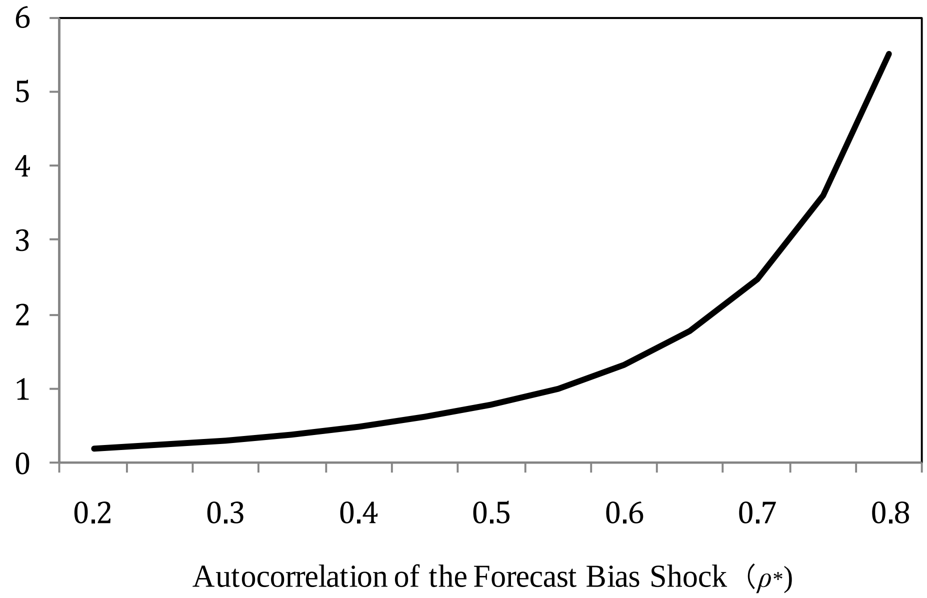
Figure 3.1 (continued)



Source: Author's calculations. *Notes:* Figure 3.1 depicts the dynamic responses of some macroeconomic aggregates to a 1% positive forecast bias shock in period 1 under the CPI rule (the baseline parameter values used). The horizontal axis shows time. φ denotes the forecast bias shock. The responses of the macroeconomic aggregates are shown as percentage deviations from their deterministic steady-state values. They are all expressed in per cent.

Figure 3.2: Sensitivity Analysis (Alternative Calibrations for ρ^*)

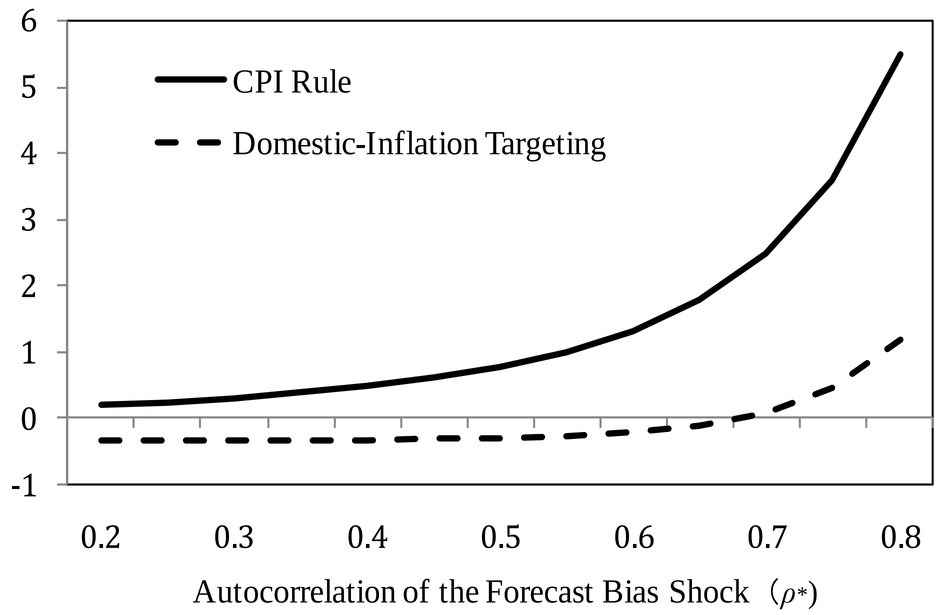
PEG versus CPI rule



Source: Author’s calculations.
Notes: Figure 3.2 shows the welfare comparison of the peg with the CPI rule. The horizontal axis represents the autocorrelation coefficient of the forecast bias shock, ρ^*. The vertical axis shows the consumption cost, ϵ, which is multiplied by 100 (i.e. expressed in per cent). A positive value of ϵ indicates that the peg is welfare-superior to the CPI rule, and vice versa.

Figure 3.3: Sensitivity Analysis (Alternative Calibrations for ρ^*)

PEG versus Strict Domestic-Inflation Targeting & CPI rule

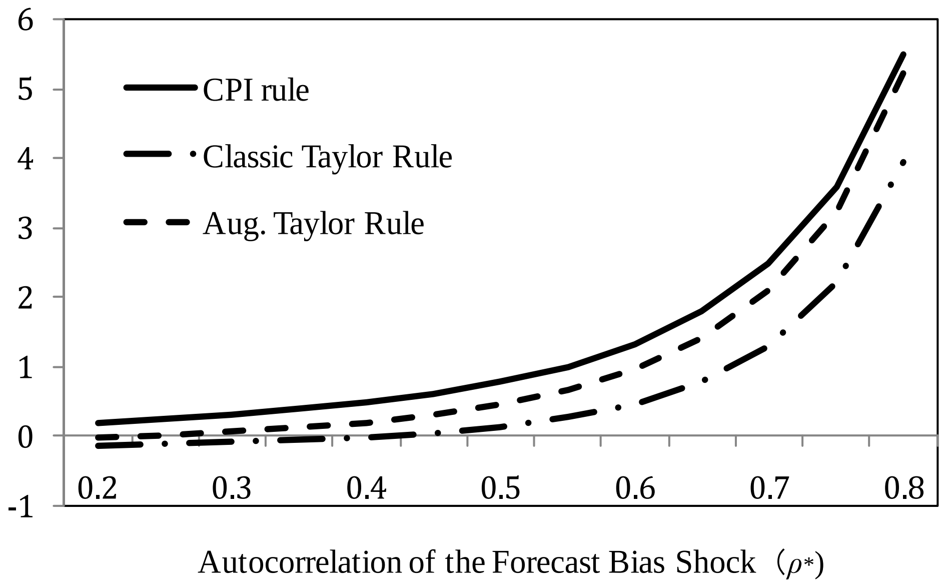


Source: Author's calculations.

Notes: Figure 3.3 shows the welfare comparison of the peg with two flexible exchange rate regimes (strict domestic-inflation targeting and the CPI rule). The horizontal axis represents the autocorrelation coefficient of the forecast bias shock, ρ^*. The vertical axis shows the consumption cost, ϵ, which is multiplied by 100 (i.e. expressed in per cent). A positive value of ϵ indicates that the peg is welfare-superior to strict domestic-inflation targeting (or the CPI rule), and vice versa. The solid line describes the consumption cost when comparing the peg with the CPI rule, whereas the dashed line represents that when comparing the peg with strict domestic-inflation targeting.

Figure 3.4: Sensitivity Analysis (Alternative Calibrations for ρ^*)

PEG versus { **Classic Taylor Rule**, **Augmented Taylor Rule**, **CPI rule** }



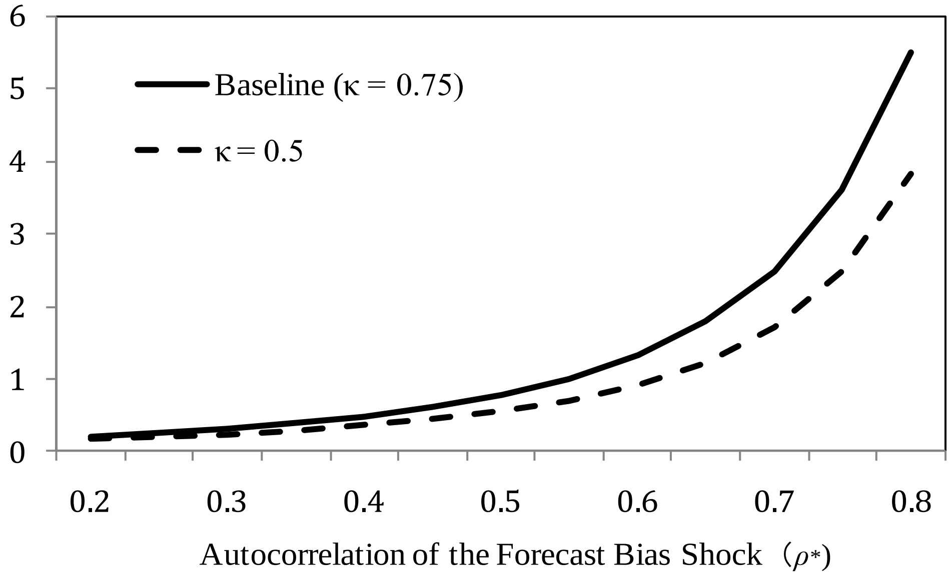
Source: Author's calculations.

Notes: Figure 3.4 shows the welfare comparison of the peg with three flexible exchange rate regimes (the classic Taylor, augmented Taylor and CPI rules). The horizontal axis represents the autocorrelation coefficient of the forecast bias shock, ρ^*. The vertical axis shows the consumption cost, ϵ, which is multiplied by 100 (i.e. expressed in per cent). A positive value of ϵ indicates that the peg is welfare-superior to the float, and vice versa. The solid line describes the consumption cost when comparing the peg with the CPI rule, whereas the chained line [the dashed line] represents the consumption cost when comparing the peg with the classic Taylor rule [the augmented Taylor rule].

Figure 3.5: Sensitivity Analysis

(Alternative Calibrations for ρ^* and κ)

PEG versus CPI rule



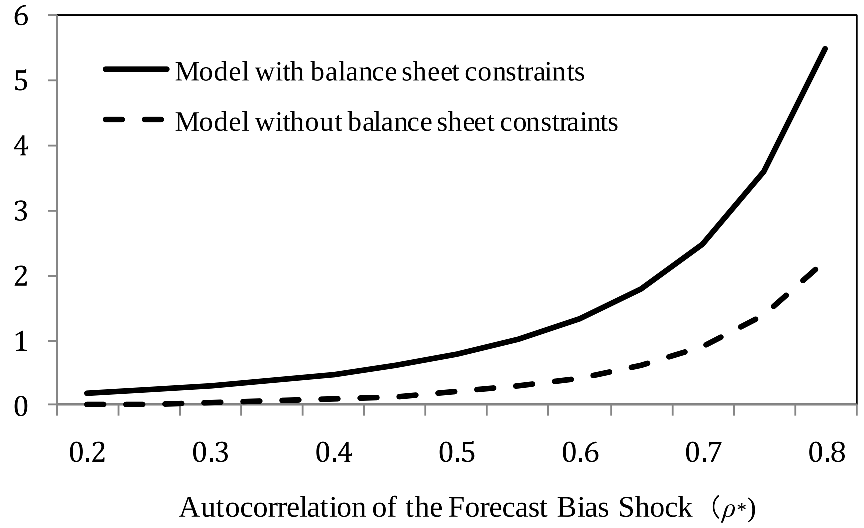
Source: Author's calculations.

Notes: κ denotes the price stickiness parameter. Figure 3.5 shows the welfare comparison of the peg with the CPI rule. The horizontal axis represents the autocorrelation coefficient of the forecast bias shock, ρ^*. The vertical axis shows the consumption cost, ϵ, which is multiplied by 100 (i.e. expressed in per cent). A positive value of ϵ indicates that the peg is welfare-superior to the CPI rule, and vice versa. The solid line describes the consumption cost when using the baseline value ($\kappa = 0.75$), whereas the dashed line indicates the consumption cost when $\kappa = 0.5$.

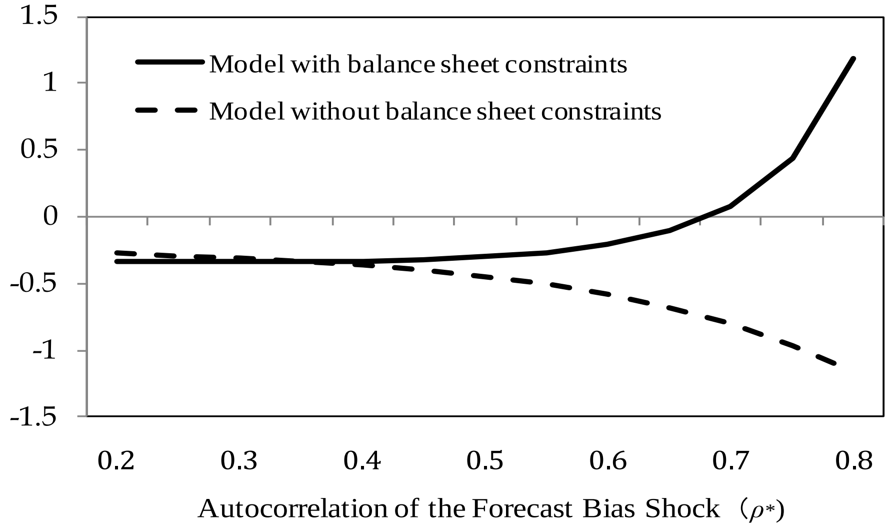
Figure 3.6: Sensitivity Analysis (Alternative Calibrations for ρ^*)

Economies with and without balance sheet constraints

(i) PEG versus CPI rule



(ii) PEG versus Strict Domestic-Inflation Targeting



Source: Author's calculations.

Figure 3.6 compares the economy *with* balance sheet constraints (the solid line) to that *without* these constraints (the dashed line). The horizontal axis represents the autocorrelation coefficient of the forecast bias shock, ρ^*. The vertical axis shows the consumption cost, ϵ, which is multiplied by 100 (i.e. expressed in per cent). A positive value of ϵ indicates that the peg is welfare-superior to the float, and vice versa. The top panel compares the peg with the CPI rule, whereas the bottom panel compares the peg to strict domestic-inflation targeting.

Appendix A

Appendix to Chapter 2

A.1. The optimal financial contract

In this section, we focus on the derivation of the optimal financial contract condition in the non-traded sector.[1] The optimal contract in the export sector is described in a similar way.

There is a continuum of measure 1 of capitalists in the non-traded sector. At the end of period *t*, capitalist *i* invests $K_{N\mathrm{t}+1}^{i}$ units in his project. He finances the project partially with his net worth, $Z_{N\mathrm{t}+1}^{i}$, and partially with the loan from the foreign lender, $(Q_{N\mathrm{t}}K_{N\mathrm{t}+1}^{i} - Z_{N\mathrm{t}+1}^{i})/S_{\mathrm{t}}$, where $Q_{N\mathrm{t}}$ denotes the unit price of capital and S_{t} is the nominal exchange rate. The project is subject to an idiosyncratic productivity shock $\omega^{i} \in (0, \infty)$, where $\ln(\omega^{i}) \sim N(-\frac{\sigma_{\omega}^{2}}{2}, \sigma_{\omega}^{2})$ with $E(\omega) = 1$ and the pdf of ω^{i} is given by $f(\omega^{i})$. The total value of the project is thus $\omega^{i}R_{KN\mathrm{t}+1}Q_{N\mathrm{t}}K_{N\mathrm{t}+1}^{i}$, where $R_{KN\mathrm{t}+1}$ is the real return of capital investment. After his investment decision, the capitalist can observe ω^{i} without any costs, while the foreign lender has to pay monitoring costs, μ times the value of the project ($\mu\omega^{i}R_{KN\mathrm{t}+1}Q_{N\mathrm{t}}K_{N\mathrm{t}+1}^{i}$), in order to observe ω^{i}. The model assumes that capitalists and foreign lenders are risk neutral.

[1] Appendix A.1. and A.2. are mainly based on the appendixes of Bernanke et al. (1999) and of Devereux et al. (2006).

Under the conditions, the optimal contract is stipulated as follows: if $\omega^{\,i}$ is greater than a cutoff value $\overline{\omega}^{i}_{N\mathrm{t}+1}$ ($\omega^{\,i} > \overline{\omega}^{i}_{N\mathrm{t}+1}$), the capitalist pays a fixed amount $\overline{\omega}^{i}_{N\mathrm{t}+1} R_{KN\mathrm{t}+1} Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1}$ to the foreign lender and receives the residual amount, $(\omega^{\,i} - \overline{\omega}^{i}_{N\mathrm{t}+1}) R_{KN\mathrm{t}+1} Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1}$. On the other hand, if $\omega^{\,i} < \overline{\omega}^{i}_{N\mathrm{t}+1}$, the capitalist receives nothing and the foreign lender monitors the project and seizes the total proceeds net of monitoring costs. The expected yield to the capitalist is thus

$$R_{KN\mathrm{t}+1} Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1} [\int_{\overline{\omega}^{i}_{N\mathrm{t}+1}}^{\infty} \omega^{\,i} f(\omega^{\,i}) d\omega^{\,i} - \overline{\omega}^{i}_{N\mathrm{t}+1} \int_{\overline{\omega}^{i}_{N\mathrm{t}+1}}^{\infty} f(\omega^{\,i}) d\omega^{\,i}]$$
$$\equiv R_{KN\mathrm{t}+1} Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1} A(\overline{\omega}^{i}_{N\mathrm{t}+1})$$

where $A(\overline{\omega}^{i}_{N\mathrm{t}+1})$ is the expected share of the return on capital going to the capitalist. The expected return to the foreign lender is written as:

$$R_{KN\mathrm{t}+1} Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1} [\overline{\omega}^{i}_{N\mathrm{t}+1} \int_{\overline{\omega}^{i}_{N\mathrm{t}+1}}^{\infty} f(\omega^{\,i}) d\omega^{\,i} + (1-\mu) \int_{0}^{\overline{\omega}^{i}_{N\mathrm{t}+1}} \omega^{\,i} f(\omega^{\,i}) d\omega^{\,i}]$$
$$= R_{KN\mathrm{t}+1} Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1} \left[\overline{\omega}^{i}_{N\mathrm{t}+1} \int_{\overline{\omega}^{i}_{N\mathrm{t}+1}}^{\infty} f(\omega^{\,i}) d\omega^{\,i} + \int_{0}^{\overline{\omega}^{i}_{N\mathrm{t}+1}} \omega^{\,i} f(\omega^{\,i}) d\omega^{\,i} - \phi^{i}_{N\mathrm{t}+1} \right]$$
$$\equiv R_{KN\mathrm{t}+1} Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1} B(\overline{\omega}^{i}_{N\mathrm{t}+1})$$

where $B(\overline{\omega}^{i}_{N\mathrm{t}+1})$ is the expected share of the return on capital going to the foreign lender. $\phi^{i}_{N\mathrm{t}+1} = \mu \int_{0}^{\overline{\omega}^{i}_{N\mathrm{t}+1}} \omega^{\,i} f(\omega^{\,i}) d\omega^{\,i}$ represents the expected fraction of the return on capital that is used up in monitoring. Total expected monitoring costs are thus $\phi^{i}_{N\mathrm{t}+1} R_{KN\mathrm{t}+1} Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1}$. Since the expected return to the foreign lender needs be at least equal to the opportunity cost of his funds, the participation constraint for the foreign lender is given by

$$R_{KN\mathrm{t}+1} Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1} B(\overline{\omega}^{i}_{N\mathrm{t}+1}) = (1 + i^{*}_{\mathrm{t}+1})(Q_{N\mathrm{t}} K^{i}_{N\mathrm{t}+1} - Z^{i}_{N\mathrm{t}+1}) \frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}} \qquad \text{(A.1)}$$

The left hand side of (A.1) indicates the expected return on the investment, whereas the right hand side does the opportunity cost of the loan, $(Q_{N\mathrm{t}}K_{N\mathrm{t}+1}^{i} - Z_{N\mathrm{t}+1}^{i})/S_{\mathrm{t}}$, in terms of local currency. $1 + i_{\mathrm{t}+1}^{*}$ represents the risk-free rate.

The optimal contracting problem is to choose the cutoff value $\bar{\omega}_{N\mathrm{t}+1}^{i}$ and $K_{N\mathrm{t}+1}^{i}$ in order to maximize the expected return to the capitalist

$$E_{\mathrm{t}}[R_{KN\mathrm{t}+1}Q_{N\mathrm{t}}K_{N\mathrm{t}+1}^{i}\,A(\,\bar{\omega}_{N\mathrm{t}+1}^{i})]$$

subject to the participation constraint (A.1).

As stressed by Bernanke et al. (1999), when there is aggregate uncertainty, $\bar{\omega}_{N\mathrm{t}+1}^{i}$ will basically depend on the ex post realization of $R_{KN\mathrm{t}+1}$, which makes the loan contract structure complicated because the capitalist has to decide the cutoff value $\bar{\omega}_{N\mathrm{t}+1}^{i}$ before the realization of $R_{KN\mathrm{t}+1}$. In order to make the contract structure simpler, we assume that risk-neutral capitalists bear all the aggregate risk, following Bernanke et al. (1999) and Devereux et al. (2006).[2] So $\bar{\omega}_{N\mathrm{t}+1}^{i}$ will be contingent on the realized aggregate state and the participation constraint will hold with equality at every possible state ex post.

The first order conditions are then

$$E_{t}[R_{KN\mathrm{t}+1}Q_{N\mathrm{t}}\,A(\bar{\omega}_{N\mathrm{t}+1}^{i})]$$
$$+E_{\mathrm{t}}\left\{\lambda_{\mathrm{t}+1}\left[R_{KN\mathrm{t}+1}Q_{N\mathrm{t}}B(\bar{\omega}_{N\mathrm{t}+1}^{i}) - (1 + i_{\mathrm{t}+1}^{*})Q_{N\mathrm{t}}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right]\right\} = 0 \qquad (\mathrm{A}.2)$$

$$\lambda_{\mathrm{t}+1}(\theta) = -\left[\frac{\pi(\theta)A'(\bar{\omega}_{N\mathrm{t}+1}^{i}(\theta))}{B'(\bar{\omega}_{N\mathrm{t}+1}^{i}(\theta))}\right] \qquad (\mathrm{A}.3)$$

where $\theta \in \Theta$ denotes a state of the world, $\pi(\theta)$ is the probability of state θ and $\lambda_{\mathrm{t}+1}$ is the Lagrange multiplier. Substituting (A.3) into (A.2) yields

[2] In Céspedes et al. (2004), it is assumed that the threshold $\bar{\omega}_{N\mathrm{t}+1}^{i}$ does not depend on aggregate risk.

$$E_{\mathrm{t}}\left[R_{KN\mathrm{t}+1}\left\{B\left(\overline{\omega}_{N\mathrm{t}+1}^{i}\right)\frac{A'\left(\overline{\omega}_{N\mathrm{t}+1}^{i}\right)}{B'\left(\overline{\omega}_{N\mathrm{t}+1}^{i}\right)}-A\left(\overline{\omega}_{N\mathrm{t}+1}^{i}\right)\right\}\right]$$
$$=E_{\mathrm{t}}\left[\frac{A'(\overline{\omega}_{N\mathrm{t}+1}^{i})}{B'(\overline{\omega}_{N\mathrm{t}+1}^{i})}(1+i_{\mathrm{t}+1}^{*})\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right] \tag{A.4}$$

Rearranging (A.4) gives

$$\frac{E_{\mathrm{t}}\left[R_{KN\mathrm{t}+1}\left\{B\left(\overline{\omega}_{N\mathrm{t}+1}^{i}\right)\frac{A'\left(\overline{\omega}_{N\mathrm{t}+1}^{i}\right)}{B'\left(\overline{\omega}_{N\mathrm{t}+1}^{i}\right)}-A\left(\overline{\omega}_{N\mathrm{t}+1}^{i}\right)\right\}\right]}{E_{\mathrm{t}}\left[\frac{A'(\overline{\omega}_{N\mathrm{t}+1}^{i})}{B'(\overline{\omega}_{N\mathrm{t}+1}^{i})}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right]}=(1+i_{\mathrm{t}+1}^{*})$$

Since ω^{i} is i.i.d. across capitalists, the financial contract is the same for every capitalist. We thus drop the superscript *i*.

$$\frac{E_{\mathrm{t}}\left[R_{KN\mathrm{t}+1}\left\{B(\overline{\omega}_{N\mathrm{t}+1})\frac{A'(\overline{\omega}_{N\mathrm{t}+1})}{B'(\overline{\omega}_{N\mathrm{t}+1})}-A(\overline{\omega}_{N\mathrm{t}+1})\right\}\right]}{E_{\mathrm{t}}\left[\frac{A'(\overline{\omega}_{N\mathrm{t}+1})}{B'(\overline{\omega}_{N\mathrm{t}+1})}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right]}=(1+i_{\mathrm{t}+1}^{*}) \tag{A.5}$$

(A.5) corresponds to Eq. (26) in Chapter 2.

A.2. Derivation of $A(\cdot)$, $B(\cdot)$, ϕ, $A'(\cdot)$, and $B'(\cdot)$

We assume that $\ln(\omega) \sim N\left(-\frac{\sigma_{\omega}^{2}}{2},\ \sigma_{\omega}^{2}\right)$ where σ_{ω} is the standard error of the productivity shock. Then, we have

$$\mathrm{E}(\omega)=\int_{0}^{\infty}\omega f(\omega)d\omega=1$$

where $f(\omega)$ denotes the pdf of ω given by

$$f(\omega)=\frac{1}{\sigma_{\omega}\omega\sqrt{2\pi}}\exp\left\{-\frac{\left(\ln(\omega)+\frac{\sigma_{\omega}^{2}}{2}\right)^{2}}{2\sigma_{\omega}^{2}}\right\}$$

As shown in subsection 2.2.5. (Chapter 2), the expected share of the return on capital going to capitalists, $A(\bar{\omega})$, is given by

$$A(\bar{\omega}) = \int_{\bar{\omega}}^{\infty} \omega f(\omega) d\omega - \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega$$

The first term on the right hand side is then

$$\int_{\bar{\omega}}^{\infty} \omega f(\omega) d\omega = \int_{\bar{\omega}}^{\infty} \omega \frac{1}{\sigma_\omega \omega \sqrt{2\pi}} \exp\left\{ -\frac{\left(\ln(\omega) + \frac{\sigma_\omega^2}{2} \right)^2}{2\sigma_\omega^2} \right\} d\omega \qquad (A.6)$$

Let $y = \ln(\omega)$. Using the fact that $\frac{d\omega}{dy} = \omega = \exp(y)$, we can rewrite (A.6) as follows:

$$\begin{aligned}
\int_{\bar{\omega}}^{\infty} \omega f(\omega) d\omega &= \int_{\ln(\bar{\omega})}^{\infty} \frac{1}{\sigma_\omega \sqrt{2\pi}} \exp\left\{ -\frac{\left(y + \frac{\sigma_\omega^2}{2} \right)^2}{2\sigma_\omega^2} \right\} \left(\frac{d\omega}{dy}\right) dy \\
&= \int_{\ln(\bar{\omega})}^{\infty} \frac{1}{\sigma_\omega \sqrt{2\pi}} \exp\left\{ -\frac{\left(y + \frac{\sigma_\omega^2}{2} \right)^2}{2\sigma_\omega^2} \right\} \exp(y) dy \\
&= \int_{\ln(\bar{\omega})}^{\infty} \frac{1}{\sigma_\omega \sqrt{2\pi}} \exp\left\{ -\frac{\left(y - \frac{\sigma_\omega^2}{2} \right)^2}{2\sigma_\omega^2} \right\} dy \\
&= \frac{1}{\sqrt{\pi}} \int_{\frac{\ln(\bar{\omega}) - 0.5\sigma_\omega^2}{\sqrt{2}\sigma_\omega}}^{\infty} \exp\left\{ -\frac{\left(y - \frac{\sigma_\omega^2}{2} \right)^2}{2\sigma_\omega^2} \right\} d\left(\frac{y - \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega} \right) \\
&= \frac{1}{2} erfc\left(\frac{\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega} \right) \qquad (A.7)
\end{aligned}$$

where $erfc(\cdot)$ is the complementary error function defined as

$$erfc(z) = \frac{2}{\sqrt{\pi}} \int_{z}^{\infty} e^{-t^2} dt$$

Analogously, the second term on the right hand side can be expressed as

$$\bar{\omega}\int_{\bar{\omega}}^{\infty} f(\omega)d\omega = \bar{\omega}\int_{\bar{\omega}}^{\infty} \frac{1}{\sigma_\omega \omega\sqrt{2\pi}} \exp\left\{-\frac{\left(\ln(\omega)+\frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\} d\omega$$

$$= \bar{\omega}\int_{\ln(\bar{\omega})}^{\infty} \frac{1}{\sigma_\omega \omega\sqrt{2\pi}} \exp\left\{-\frac{\left(y+\frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\} \left(\frac{d\omega}{dy}\right) dy$$

$$= \bar{\omega}\int_{\ln(\bar{\omega})}^{\infty} \frac{1}{\sigma_\omega \sqrt{2\pi}} \exp\left\{-\frac{\left(y+\frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\} dy$$

$$= \frac{\bar{\omega}}{\sqrt{\pi}}\int_{\frac{\ln(\bar{\omega})+0.5\sigma_\omega^2}{\sqrt{2}\sigma_\omega}}^{\infty} \exp\left\{-\frac{\left(y+\frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\} d\left(\frac{y+\frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right)$$

$$= \frac{\bar{\omega}}{2} erfc\left(\frac{\ln(\bar{\omega})+\frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right) \qquad (A.8)$$

From (A.7) and (A.8), we obtain

$$A(\bar{\omega}) = \frac{1}{2} erfc\left(\frac{\ln(\bar{\omega})-\sigma_\omega^2/2}{\sqrt{2}\sigma_\omega}\right) - \frac{\bar{\omega}}{2} erfc\left(\frac{\ln(\bar{\omega})+\sigma_\omega^2/2}{\sqrt{2}\sigma_\omega}\right) \qquad (A.9)$$

Using (A.7), we can write ϕ (the expected fraction of the return on capital that is used up in monitoring) as:

$$\phi = \mu\int_0^{\bar{\omega}} \omega f(\omega)d\omega$$

$$= \frac{\mu}{\sqrt{\pi}}\int_{-\infty}^{\frac{\ln(\bar{\omega})-0.5\sigma_\omega^2}{\sqrt{2}\sigma_\omega}} \exp\left\{-\frac{\left(y-\frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\} d\left(\frac{y-\frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right)$$

$$= \frac{\mu}{2}\left(1+erf\left(\frac{\ln(\bar{\omega})-\sigma_\omega^2/2}{\sqrt{2}\sigma_\omega}\right)\right)$$

where $erf(\cdot)$ is the error function defined as

$$erf(z) = \frac{2}{\sqrt{\pi}}\int_0^z e^{-t^2}dt$$

Since $A(\bar{\omega}) + B(\bar{\omega}) + \phi = 1$, the expected share of the return on capital going to the foreign lender ($B(\bar{\omega})$) is given by

$$B(\bar{\omega}) = 1 - A(\bar{\omega}) - \phi \tag{A.10}$$

Differentiating (A.9) with respect to $\bar{\omega}$ yields

$$A'(\bar{\omega}) = -\frac{1}{\sigma_\omega\sqrt{2\pi}}\left[\frac{1}{\bar{\omega}}\exp\left\{-\frac{\left(\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\} - \exp\left\{-\frac{\left(\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\}\right]$$
$$-\frac{1}{2}erfc\left(\frac{\ln(\bar{\omega}) + \sigma_\omega^2/2}{\sqrt{2}\sigma_\omega}\right)$$

Here, we can show that

$$\frac{1}{\bar{\omega}}\exp\left\{-\frac{\left(\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\} = \exp\left[-\ln(\bar{\omega})\right]\exp\left\{-\frac{\left(\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\}$$
$$= \exp\left\{-\frac{\left(\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2}\right)^2}{2\sigma_\omega^2}\right\}$$

Therefore, we obtain

$$A'(\bar{\omega}) = -\frac{1}{2}erfc\left(\frac{\ln(\bar{\omega}) + \sigma_\omega^2/2}{\sqrt{2}\sigma_\omega}\right)$$

Finally, we know from (A.10) that:

$$B(\bar{\omega}) = 1 - A(\bar{\omega}) - \phi$$

$$= 1 - A(\bar{\omega}) - \mu \int_0^{\bar{\omega}} \omega f(\omega) d\omega$$

Differentiating this equation with respect to $\bar{\omega}$, we get

$$B'(\bar{\omega}) = -A'(\bar{\omega}) - \frac{\mu}{\sqrt{2\pi}\sigma_\omega} \exp\left(-\frac{(\ln(\bar{\omega}) + \sigma_\omega^2/2)^2}{2\sigma_\omega^2}\right)$$

A.3. Capitalists in the export sector

Let the subscript X denote the export sector. Eqs. (A.11) - (A.12) describe the optimal financial contract condition and the foreign lenders' participation constraint in the export sector, respectively:

$$\frac{E_{\mathrm{t}}\left[R_{KX\mathrm{t}+1}\left\{B(\bar{\omega}_{X\mathrm{t}+1})\frac{A'(\bar{\omega}_{X\mathrm{t}+1})}{B'(\bar{\omega}_{X\mathrm{t}+1})} - A(\bar{\omega}_{X\mathrm{t}+1})\right\}\right]}{E_{\mathrm{t}}\left[\frac{A'(\bar{\omega}_{X\mathrm{t}+1})}{B'(\bar{\omega}_{X\mathrm{t}+1})}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right]} = (1 + i_{\mathrm{t}+1}^*) \qquad (\mathrm{A}.11)$$

$$R_{KX\mathrm{t}} Q_{X\mathrm{t}-1} K_{X\mathrm{t}} B(\bar{\omega}_{X\mathrm{t}}) = (1 + i_{\mathrm{t}}^*) S_{\mathrm{t}} D_{X\mathrm{t}}^{\mathrm{e}} \qquad (\mathrm{A}.12)$$

where $D_{X\mathrm{t}}^{\mathrm{e}}$ is the amount borrowed abroad at the end of period *t*-1:

$$D_{X\mathrm{t}}^{\mathrm{e}} = \left(\frac{1}{S_{\mathrm{t}-1}}\right)(Q_{X\mathrm{t}-1} K_{X\mathrm{t}} - Z_{X\mathrm{t}})$$

The consumption of capitalists, C_{t}^{Xe}, and their net worth, $Z_{X\mathrm{t}+1}$, are given by

$$P_{\mathrm{t}} C_{\mathrm{t}}^{Xe} = (1 - \nu) R_{KX\mathrm{t}} Q_{X\mathrm{t}-1} K_{X\mathrm{t}} A(\bar{\omega}_{X\mathrm{t}}), \text{and} \qquad (\mathrm{A}.13)$$

$$Z_{X\mathrm{t}+1} = \nu R_{KX\mathrm{t}} Q_{X\mathrm{t}-1} K_{X\mathrm{t}} A(\bar{\omega}_{X\mathrm{t}}) + W_{X\mathrm{t}}^{e}, \text{respectively.} \qquad (\mathrm{A}.14)$$

It is assumed that C_{t}^{Xe} comprises the same mix as the household's consumption basket.

Finally, the real gross return on capital in the export sector, $R_{KX\mathrm{t}+1}$, is expressed as

$$R_{KX\mathrm{t}+1} = \frac{R_{X\mathrm{t}+1} + R^{G}_{KX\mathrm{t}+1} + Q_{X\mathrm{t}+1}(1-\delta)}{Q_{X\mathrm{t}}} \qquad (\mathrm{A}.15)$$

Appendix B

Appendix to Chapter 3

B.1. Derivation of Eq. (3.48)

Let $Y_{N\mathrm{t}}(i)$

$$= F_N[K_{N\mathrm{t}}(i), H_{N\mathrm{t}}(i), H^e_{N\mathrm{t}}(i)] \quad = K_{N\mathrm{t}}(i)^{\alpha} H_{N\mathrm{t}}(i)^{(1-\alpha)\Omega} (H^e_{N\mathrm{t}}(i))^{(1-\Omega)(1-\alpha)}.$$

It is assumed that firm *i* must meet all demand at the posted price (see subsection 3.2.3). The assumption means that supply must equal demand at the firm level:

$$F_N[K_{N\mathrm{t}}(i), H_{N\mathrm{t}}(i), H^e_{N\mathrm{t}}(i)] = \quad Q^d_{\mathrm{t}}\left(\frac{P_{N\mathrm{t}}(i)}{P_{N\mathrm{t}}}\right)^{-\lambda}$$

Recall that $F_N(\cdot)$ is homogeneous of degree one and that the household-labour capital ratio and the capitalist-labour capital ratio are identical across firms (see Eqs. (3.12) – (3.13)). Integrating over all firms yields

$$K_{N\mathrm{t}}\, F_N\left(1, \frac{H_{N\mathrm{t}}}{K_{N\mathrm{t}}}, \frac{H^e_{N\mathrm{t}}}{K_{N\mathrm{t}}}\right) = \; Q^d_{\mathrm{t}} \int_0^1 \left(\frac{P_{N\mathrm{t}}(i)}{P_{N\mathrm{t}}}\right)^{-\lambda} di$$

where $K_{N\mathrm{t}} \equiv \int_0^1 K_{N\mathrm{t}}(i)\, di$, $H_{N\mathrm{t}} \equiv \int_0^1 H_{N\mathrm{t}}(i)\, di$, and $H^e_{N\mathrm{t}} \equiv \int_0^1 H^e_{N\mathrm{t}}(i)\, di$. This equation corresponds to Eq. (3.48).

B.2. The economy without balance sheet constraints

In this section, we list the equilibrium conditions of the model without balance sheet constraints. The model is mainly based on both that of Bergin et al. (2007) and that of Devereux et al. (2006). The model assumes that there are no capitalists and households accumulate physical capital without any financing constraints on investment. The model equations are identical to those of the model with balance sheet constraints, with the exceptions of the representative consumer's budget constraint (B.1); the Euler equations for the determination of capital in the two sectors (B.5 and B.6); the production technologies in the two sectors (B.15 and B.26); the optimality conditions for production firms (B.11, B.12, B.13 and B.14); no equations related to capitalists (the absence of capitalist consumption, their net worth, and the risk premium). As in the economy *with* balance sheet constraints, the forecast bias shock applies under flexible exchange rates, not under fixed exchange rates. The equilibrium conditions of the model are described as follows:

$$\begin{aligned} &P_{\mathrm{t}}C_{\mathrm{t}} + Q_{N\mathrm{t}}[K_{N\mathrm{t}+1} - (1-\delta)K_{N\mathrm{t}}] + Q_{X\mathrm{t}}[K_{X\mathrm{t}+1} - (1-\delta)K_{X\mathrm{t}}] \\ &= W_{\mathrm{t}}H_{\mathrm{t}} + \int_0^1 \pi_t^N(i)di - S_{\mathrm{t}}F_{\mathrm{t}+1}^* - B_{\mathrm{t}+1} - P_{\mathrm{t}}\frac{\psi_{F^*}}{2}\left(\frac{S_{\mathrm{t}}F_{\mathrm{t}+1}^*}{P_{\mathrm{t}}}\right)^2 + (1+i_{\mathrm{t}-1}^*)S_{\mathrm{t}}F_{\mathrm{t}}^* \\ &\quad +(1+i_{\mathrm{t}-1})B_{\mathrm{t}} + R_{N\mathrm{t}}K_{N\mathrm{t}} + R_{X\mathrm{t}}K_{X\mathrm{t}} + R_{KN\mathrm{t}}^G K_{N\mathrm{t}} + R_{KX\mathrm{t}}^G K_{X\mathrm{t}} \end{aligned} \qquad (\mathrm{B.1})$$

$$W_{\mathrm{t}} = \eta H_{\mathrm{t}}^{\psi} P_{\mathrm{t}} C_{\mathrm{t}}^{\sigma} \qquad (\mathrm{B.2})$$

$$1 = \varphi_{\mathrm{t}}\left[1 + \psi_{F^*}\frac{S_{\mathrm{t}}F_{\mathrm{t}+1}^*}{P_{\mathrm{t}}}\right]^{-1}\beta(1+i_{\mathrm{t}}^*)E_{\mathrm{t}}\left\{\frac{C_{\mathrm{t}}^{\sigma}P_{\mathrm{t}}}{C_{\mathrm{t}+1}^{\sigma}P_{\mathrm{t}+1}}\frac{S_{\mathrm{t}+1}}{S_{\mathrm{t}}}\right\} \qquad (\mathrm{B.3})$$

$$1 = \beta(1+i_{\mathrm{t}})E_{\mathrm{t}}\left\{\frac{C_{\mathrm{t}}^{\sigma}P_{\mathrm{t}}}{C_{\mathrm{t}+1}^{\sigma}P_{\mathrm{t}+1}}\right\} \qquad (\mathrm{B.4})$$

$$\beta E_{\mathrm{t}}\left[\frac{R_{KN\mathrm{t}+1}}{C_{\mathrm{t}+1}^{\sigma}P_{\mathrm{t}+1}}\right] = \frac{1}{C_{\mathrm{t}}^{\sigma}P_{\mathrm{t}}} \qquad (\mathrm{B.5})$$

$$\beta E_{\mathrm{t}}\left[\frac{R_{KX\mathrm{t}+1}}{C_{\mathrm{t}+1}^{\sigma}P_{\mathrm{t}+1}}\right]=\frac{1}{C_{\mathrm{t}}^{\sigma}P_{\mathrm{t}}} \tag{B.6}$$

$$R_{KN\mathrm{t}+1}=\frac{R_{N\mathrm{t}+1}+R_{KN\mathrm{t}+1}^{G}+Q_{N\mathrm{t}+1}(1-\delta)}{Q_{N\mathrm{t}}} \tag{B.7}$$

$$R_{KX\mathrm{t}+1}=\frac{R_{X\mathrm{t}+1}+R_{KX\mathrm{t}+1}^{G}+Q_{X\mathrm{t}+1}(1-\delta)}{Q_{X\mathrm{t}}} \tag{B.8}$$

$$P_{\mathrm{t}}=(a\,P_{N\mathrm{t}}^{1-\rho}+\,(1-a)\,P_{M\mathrm{t}}^{1-\rho})^{\frac{1}{1-\rho}} \tag{B.9}$$

$$P_{M\mathrm{t}}=S_{\mathrm{t}}\,P_{M\mathrm{t}}^{*} \tag{B.10}$$

$$MC_{N\mathrm{t}}=\frac{R_{N\mathrm{t}}^{\alpha}\,W_{\mathrm{t}}^{(1-\alpha)}}{\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}} \tag{B.11}$$

$$\frac{H_{N\mathrm{t}}}{K_{N\mathrm{t}}}=\frac{R_{N\mathrm{t}}(1-\alpha)}{\alpha W_{\mathrm{t}}} \tag{B.12}$$

$$W_{\mathrm{t}}=P_{X\mathrm{t}}(1-\gamma)\frac{Y_{X\mathrm{t}}}{H_{X\mathrm{t}}} \tag{B.13}$$

$$R_{X\mathrm{t}}=P_{X\mathrm{t}}\gamma\,\frac{Y_{X\mathrm{t}}}{K_{X\mathrm{t}}} \tag{B.14}$$

$$Y_{X\mathrm{t}}={K_{X\mathrm{t}}}^{\gamma}{H_{X\mathrm{t}}}^{(1-\gamma)} \tag{B.15}$$

$$P_{X\mathrm{t}}=S_{\mathrm{t}}P_{X\mathrm{t}}^{*} \tag{B.16}$$

$$\widetilde{P_{Nt}} = \frac{\lambda}{\lambda - 1} \frac{\sum_{\tau=0}^{\tau=\infty} \kappa^{\tau} E_t \Xi_{\mathrm{t,t+\tau}} MC_{N\mathrm{t}+\tau}}{\sum_{\tau=0}^{\tau=\infty} \kappa^{\tau} E_t \Xi_{\mathrm{t,t+\tau}}} \tag{B.17}$$

where $\Xi_{\mathrm{t,t+\tau}} = \beta^{\tau} \frac{C_{\mathrm{t}}^{\sigma} P_{\mathrm{t}}}{C_{\mathrm{t+\tau}}^{\sigma} P_{\mathrm{t+\tau}}} Q_{\mathrm{t+\tau}}^{d} (P_{N\mathrm{t}+\tau})^{\lambda}$

$${P_{N\mathrm{t}}}^{1-\lambda} = \kappa {P_{N\mathrm{t}-1}}^{1-\lambda} + (1-\kappa) \widetilde{P_{N\mathrm{t}}}^{1-\lambda} \tag{B.18}$$

$$Q_{N\mathrm{t}} = \frac{P_{\mathrm{t}}}{1 - \psi_I (\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta)} \tag{B.19}$$

$$R_{KN\mathrm{t}}^{G} = Q_{Nt} \left[\psi_I (\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta) \frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \frac{\psi_I}{2} \left(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta \right)^2 \right] \tag{B.20}$$

$$Q_{X\mathrm{t}} = \frac{P_{\mathrm{t}}}{1 - \psi_I (\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta)} \tag{B.21}$$

$$R_{KX\mathrm{t}}^{G} = Q_{Xt} \left[\psi_I (\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta) \frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \frac{\psi_I}{2} \left(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta \right)^2 \right] \tag{B.22}$$

$$K_{N\mathrm{t}+1} = \left[\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \frac{\psi_I}{2} \left(\frac{I_{N\mathrm{t}}}{K_{N\mathrm{t}}} - \delta \right)^2 \right] K_{N\mathrm{t}} + (1-\delta) K_{N\mathrm{t}} \tag{B.23}$$

$$K_{X\mathrm{t}+1} = \left[\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \frac{\psi_I}{2} \left(\frac{I_{X\mathrm{t}}}{K_{X\mathrm{t}}} - \delta \right)^2 \right] K_{X\mathrm{t}} + (1-\delta) K_{X\mathrm{t}} \tag{B.24}$$

$$Q_{\mathrm{t}}^{d} = a \left(\frac{P_{N\mathrm{t}}}{P_{\mathrm{t}}} \right)^{-\rho} \left[C_{\mathrm{t}} + I_{N\mathrm{t}} + I_{X\mathrm{t}} + \frac{\psi_{F^*}}{2} \left(\frac{S_{\mathrm{t}} F_{\mathrm{t+1}}^{*}}{P_{\mathrm{t}}} \right)^2 \right] \tag{B.25}$$

$$Y_{N\mathrm{t}} = {K_{N\mathrm{t}}}^{\alpha} {H_{N\mathrm{t}}}^{(1-\alpha)} = \xi_{\mathrm{t}} Q_{\mathrm{t}}^{d} \tag{B.26}$$

where $\xi_{\mathrm{t}} = \int_0^1 (\frac{P_{N\mathrm{t}}(i)}{P_{N\mathrm{t}}})^{-\lambda}\, di$

$$H_{N\mathrm{t}} + H_{X\mathrm{t}} = H_{\mathrm{t}} \tag{B.27}$$

$$i_{\mathrm{t}}^{*} = (1-\rho_i)i^{*} + \rho_i i_{\mathrm{t}-1}^{*} + \varepsilon_{i\mathrm{t}} \tag{B.28}$$

$$\ln\,(P_{X\mathrm{t}}^{*}) = \rho_X \ln\,(P_{X\mathrm{t}-1}^{*}) + \varepsilon_{X\mathrm{t}} \tag{B.29}$$

$$\ln(\varphi_{\mathrm{t}}) = \rho^{*}\ln(\varphi_{\mathrm{t}-1}) + \varepsilon_{\varphi\mathrm{t}} \tag{B.30}$$

$$1 + i_{\mathrm{t}} = \left(\frac{\pi_{N\mathrm{t}}}{\bar{\pi}_N}\right)^{\mu_{\pi_N}} \left(\frac{\pi_{\mathrm{t}}}{\bar{\pi}}\right)^{\mu_\pi} \left(\frac{S_t}{\bar{S}}\right)^{\mu_S} (1+\bar{\imath}) \tag{B.31}$$

References

Batini, N., Harison, R. and Millard, S. P., 2003. "Monetary Policy Rules for an Open Economy," *Journal of Economic Dynamics & Control*, 27, pp.2059-2094.

Bergin, P. R., Shin, H.-C., and Tchakarov, I., 2007. "Does Exchange Rate Variability Matter for Welfare? A Quantitative Investigation of Stabilization Policies," *European Economic Review*, 51, pp. 1041-1058.

Bernanke, B., Gertler, M. and Gilchrist, S., 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework," *Handbook of Macroeconomics*, edited by Taylor, J. and M. Woodford, pp. 1341-1393, North-Holland.

Calvo, G. A., 1983. "Staggered Prices in a Utility Maximizing Framework," *Journal of Monetary Economics*, 12, pp. 383-398.

Calvo, G. A. and Reinhart, C. M., 2002. "Fear of Floating," *Quarterly Journal of Economics*, 117 (2), pp. 379-408. ("Fear of Floating," *NBER Working Paper*, No. 7993, November, 2000)

Carlstrom, C. T. and Fuerst, T. S., 1997. "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review*, 87(5), pp. 893-910.

Cavoli, T., 2009. "Is fear of Floating Justified? The East Asia Experience," *Journal of Policy Modeling*, 31, pp. 1-16.

References

Céspedes, L. F., Chang, R. and Velasco, A., 2002. "Dollarization of Liabilities, Net Worth Effects, and Optimal Monetary Policy," *Preventing Currency Crises in Emerging Markets*, edited by Edwards, S. and J. A. Frankel, NBER, pp. 559-600.

Céspedes, L. F., Chang, R. and Velasco, A., 2004. "Balance Sheets and Exchange Rate Policy," *American Economic Review*, 94 (4), pp. 1183-1193. ("Balance Sheets and Exchange Rate Policy," *NBER Working Paper*, No. 7840, August, 2000)

Choi, W. G. and Cook, D., 2004. "Liability Dollarization and the Bank Balance Sheet Chanel," *Journal of International Economics*, 64, pp. 247-275.

Cook, D., 2004. "Monetary Policy in Emerging Markets: Can Liability Dollarization Explain Contractionary Devaluations?," *Journal of Monetary Economics*, 51, pp. 1155-1181.

Cook, D. and Devereux, M.B., 2006. "Accounting for the East Asian Crisis: A Quantitative Model of Capital Outflows in Small Open Economies," *Journal of Money, Credit, and Banking*, 38 (3), pp. 721-749.

Devereux, M.B., 2002. "Monetary Policy Strategies for Emerging Market Countries: The Case of the East European Accession Countries," University of British Columbia, February. Available at the following URL: http://faculty.arts.ubc.ca/mdevereux/devereuxestonia.pdf

Devereux, M.B., Lane, P. R. and Xu, J., 2006. "Exchange Rates and Monetary Policy in Emerging Market Economies," *Economic Journal*, 116, pp. 478-506.

Dixit, A. K., and Stiglitz, J. E., 1977. "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67 (3), pp. 297-308.

References

Edwards, S., 2006. “The Relationship between Exchange Rates and Inflation Targeting Revisited, ” *NBER Working Paper*, No. 12163, April.

Elekdağ, S. and Tchakarov, I., 2007. “Balance Sheets, Exchange Rate Policy, and Welfare,” *Journal of Economic Dynamics & Control*, 31, pp. 3986-4015.

Gertler, M., Gilchrist, S. and Natalucci, F., 2007. “External Constraints on Monetary Policy and the Financial Accelerator,” *Journal of Money, Credit and Banking*, 39 (2–3), pp. 295-330.

Ho, C. and McCauley, R. N., 2003. “Living with Flexible Exchange Rates: Issues and Recent Experience in Inflation Targeting Emerging Market Economies,” *BIS Working Papers*, No. 130, February.

Kollmann, R., 2002. “Monetary Policy Rules in the Open Economy: Effects on Welfare and Business Cycles,” *Journal of Monetary Economics*, 49, pp. 989-1015.

Kollmann, R., 2004. “Welfare Effects of a Monetary Union: The Role of Trade Openness,” *Journal of the European Economic Association*, 2 (2-3), pp. 289-301.

Kollmann, R., 2005. “Macroeconomic Effects of Nominal Exchange Rate Regimes: New Insights into the Role of Price Dynamics,” *Journal of International Money and Finance*, 24, pp. 275-292.

Leitemo, K. and Söderström, U., 2005. “Simple Monetary Policy Rules and Exchange Rate Uncertainty,” *Journal of International Money and Finance*, 24, pp. 481-507.

McCallum, B.T. and Nelson, E., 1999. “Nominal Income Targeting in an

Open-Economy Optimizing Model," *Journal of Monetary Economics*, 43, pp. 553-578.

McCallum, B.T. and Nelson, E., 2000. "Monetary Policy for an Open Economy: An Alternative Framework with Optimizing Agents and Sticky Prices," *Oxford Review of Economic Policy*, 16 (4), pp. 74-91.

Morón, E. and Winkelried, D., 2005. "Monetary Policy rules for Financially Vulnerable Economies," *Journal of Development Economics*, 76, pp. 23-51.

Ravenna, F. and Natalucci, F., 2008. "Monetary Policy Choices in Emerging Market Economies: The Case of High Productivity Growth," *Journal of Money, Credit and Banking*, 40 (2-3), pp. 243-271.

Rotemberg, J., 1982. "Monopolistic Price Adjustment and Aggregate Output," *Review of Economic Studies*, 49, pp. 517-531.

Schaechter, A., Stone, M. R. and Zelmer, M., 2000. "Adopting Inflation Targeting: Practical Issues for Emerging Market Countries," *IMF Occasional Paper*, No. 202, International Monetary Fund.

Schmitt-Grohe, S. and Uribe, M., 2004a. "Optimal Simple and Implementable Monetary and Fiscal Rules," *NBER Working Paper*, No. 10253, January.

Schmitt-Grohe, S. and Uribe, M., 2004b. "Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function," *Journal of Economic Dynamics & Control*, 28, pp. 755-775.

Svensson, L. E.O., 2000. "Open-Economy Inflation Targeting," *Journal of International Economics*, 50, pp. 155-183.

References

Taylor, J. B., 1993. *Macroeconomic Policy in a World Economy: From Econometric Design to Practical Operation*, W.W. Norton, New York.

Taylor, J. B., 2001. “The Role of the Exchange Rate in Monetary-Policy Rules,” *American Economic Review*, 91 (2), pp.263-267.

Uribe, M. and Yue, V. Z., 2006. “Country Spreads and Emerging Countries: Who drives Whom?,” *Journal of International Economics*, 69, pp. 6-36.

Wollmershäuser, T., 2006. “Should Central Banks React to Exchange Rate Movements? An Analysis of the Robustness of Simple Policy Rules under Exchange Rate Uncertainty,” *Journal of Macroeconomics*, 28, pp.493-519.

Yun, T., 1996. “ Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles,” *Journal of Monetary Economics*, 37, pp. 345-370.