Exchange Rate Dynamics

A new open economy macroeconomics perspective

Edited by Jean-Olivier Hairault and Thepthida Sopraseuth

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Exchange Rate Dynamics

Are exchange rates determined by economic fundamentals or are they a prey to random speculative forces? Some economists assert that economic theory has so far performed poorly in explaining the dramatic increase in exchange rate volatility in the recent floating rate period. This book argues that modern macroeconomic theory does provide guidelines for understanding exchange rate fluctuations.

Since the mid-1990s, there has been an outpouring of research that aims at laying new foundations for open-macroeconomic theory. The so-called "New Open Economy Macroeconomics" (NOEM) approach embeds microfounded behavior into dynamic general equilibrium models. This provides a rich framework for thinking about exchange rate behavior and lays the groundwork for credible policy evaluation. This book shows how the most recent analytical tools proposed in this literature improve our understanding of exchange rate fluctuations.

With contributions from an international array of thinkers, this impressive book shall interest both students and researchers involved with macroeconomics, money and banking, as well as all those interested in international finance, including financial institutions.

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Preface

Following Obstfeld and Rogoff's (1995) seminal paper, the last decade has seen an outpouring of research aimed at laying new foundations for open-macroeconomic theory. This "New Open Economy Macroeconomics" (NOEM) addresses the core international issues within microfounded general equilibrium models. The intertemporal nature of this approach allows the dynamic effects to be tracked while the presentation of explicit utility and profit maximization problems lays the groundwork for credible policy evaluation.

The salient feature of Obstfeld and Rogoff's (1995) influential paper lies in the attempt to bridge the gap between two strands of the international macroeconomic theory: the agent optimizing framework developed by the "intertemporal approach to the current account" (Frenkel and Razin, 1987) and the Mundell (1963)–Fleming (1962)–Dornbusch (1976) sticky-price setting. Nesting nominal rigidities and imperfect competition within microfounded dynamic general equilibrium models echoes the emergence of the "neo-classical synthesis" (Goodfriend and King, 1997) or the "neo-monetarism" (Kimball, 1995a) in closed-economy macroeconomics. Moreover, the NOEM partakes of the International Real Business Cycle literature (Backus *et al.*, 1994, 1995).

This theoretical framework has spurred a profusion of developments that allow us to revisit the major issues in international macroeconomics. Obstfeld and Rogoff (2000b) recall that the theory is challenged by six empirical puzzles. How can we rationalize the bias for home goods in households' preferences (the home bias in trade puzzle)? Can the high correlation between investment and saving be reconciled with capital mobility (Feldstein and Horioka, 1980)? Why do households not fully take advantage of the international portfolio diversification (the home bias portfolio puzzle and the low consumption correlations puzzle)? Why do deviations from purchasing power parity (PPP), captured by real exchange rate fluctuations, exhibit a very persistent behavior (the PPP puzzle)? Finally, the extreme exchange rate volatility has no corresponding counterpart in macroeconomic fundamentals (the exchange rate disconnect puzzle). The latter empirical observation leads Flood and Rose (1995) to assert that

> There is remarkably little evidence that macroeconomic variables have consistent strong effects on floating rates [. . .]. Such negative findings have led the profession to a certain degree of pessimism *vis-à-vis* the exchange rate research.

The role of economic fundamentals in explaining exchange rate behavior is undoubtedly controversial. This book intends to propose studies that rely on macroeconomic dynamic models to shed light on exchange rate dynamics. In the first part of the book, we focus, in particular, on the last two puzzles, namely the PPP puzzle and the exchange rate disconnect puzzle. In addition, since NOEM models are far more equipped than the traditional Mundell–Fleming–Dornbusch framework to analyze policy design, the second part of the book examines the impact of alternative exchange rate regimes and policy rules. This book illustrates how NOEM models revisit positive and normative issues that are currently at the heart of the international macroeconomic research.

Some papers (Lane, 2001; Sarno, 2001) have surveyed the recent developments in this literature. However, the book format gives an insight to the heart of the renewal of theoretical open macroeconomics by displaying a full presentation of the models, the analytical solutions and the quantitative implications of the mechanisms at work. This book describes the empirical and theoretical contribution of this "NOEM" to the understanding of exchange rate dynamics and economic policy. Our purpose is to improve our understanding of fluctuations in the exchange rate. Furthermore, we aim to shed light on the choice of exchange rate regimes and monetary policy design in open economies. The partition of the book mirrors this double issue. In Part I, Chapters 1–6 are all concerned with exchange rate volatility and persistence. We present models of the NOEM that examine essential features of exchange rate fluctuations. In Part II, Chapters 8–10 provide guidelines for thinking about the choice of exchange rate regimes and monetary policy. Each chapter is self-contained and can be used independently of the others.

More specifically, Chapter 1 returns to the original intent of Obstfeld and Rogoff's (1995) paper by examining how net foreign assets affect exchange rate dynamics. Michele Cavallo and Fabio Ghironi develop a two-country, flexible-price model of exchange rate determination with incomplete asset markets and stationary net foreign assets. They compare exchange rate dynamics in the traditional case of exogenous money supplies and under endogenous interest rate setting. The nominal exchange rate then depends on the stock of real net foreign assets in both cases. Thus, shocks that cause holdings of net foreign assets to change generate movements of the exchange rate over time. The exchange rate exhibits a unit root when central banks set interest rates to react to inflation. Endogenous monetary policy and asset dynamics have consequences for exchange rate overshooting while a persistent relative productivity shock results in delayed overshooting.

The course of the book then mimics the evolution of the literature by de-emphasizing the role of current account dynamics in accounting for exchange rate fluctuations. Chapter 2 revisits the exchange rate overshooting phenomenon put forward by Dornbusch (1976). Since the end of the fixed exchange rate period in 1971, nominal and real exchange rates of the G7-countries have become extremely volatile, while no corresponding changes have appeared in the distribution of macroeconomic fundamentals. In the spirit of Dornbusch (1976), with

Lise Patureau, we assess whether nominal exchange rate overshooting is responsible for the exchange rate disconnect puzzle. As long as uncovered interest rate parity holds, nominal exchange rate overshooting is linked to a persistent fall in the spread between domestic and foreign nominal interest rates. Given nominal price rigidity, the over-reaction of the nominal exchange rate then translates into an exacerbated response of the real exchange rate. We thus develop a limited participation model in a small open economy setting, with monopolistic competition and price sluggishness. Introducing adjustment costs on money holdings in the model substantially raises the magnitude of the overshooting dynamics and the theoretical nominal and real exchange rate volatilities. Overshooting indeed plays a key role in explaining a substantial part of the exchange rate disconnect puzzle.

While Chapter 2 explores the implication of price stickiness along with credit market frictions, Chapter 3 investigates the role of nominal wage rigidities in the understanding of exchange rate behavior. Steve Ambler and Emmanuel Hakizimana build a dynamic general equilibrium model of a semi-small open economy in which staggered wages are the only source of nominal rigidity. The model is capable of generating highly variable real and nominal exchange rates while predicting relative variabilities of prices and consumption that are broadly compatible with the data. The real and nominal exchange rates predicted by the model are both highly persistent and highly correlated with one another, as in the data.

In Chapter 4, we explore the exchange rate behavior by focusing on two competing explanations to the exchange rate disconnect puzzle. The first one relies on the failure of the law of one price among internationally traded goods. Firms tend to set prices in the buyer's currency (pricing-to-market, PTM) and do not adjust prices to changes in the nominal exchange rate (Betts and Devereux, 1996). This explanation to exchange rate volatility is based on the behavior of traded good prices. In contrast, according to Hau (2000), large nominal exchange rate fluctuations are attributable to the presence of non-traded goods. Chapter 4 proposes a unified theoretical framework including PTM behavior and non-tradables in a two-country sticky-price model. The purpose of this work is twofold. First, we shed light on the way PTM and non-tradables interact in the exchange rate determination. It is shown that, on the one hand, since PTM affects the behavior of tradable prices, local currency pricing matters especially when the share of tradables is not negligible, that is, the economy is open. On the other hand, the degree of openness does not matter if import prices do not respond to exchange rate changes because of PTM behavior. Second, the model helps determine which effect is likely to be the key ingredient to the high exchange rate volatility. Is PTM, more than non-tradables, responsible for the extreme exchange rate variability observed since the fall of the Bretton Woods system? This chapter reveals that the answer is a qualified yes.

In Chapter 5, Philippe Andrade aims at providing empirical evidence on the sources of real exchange rates fluctuations since the collapse of the Bretton Woods system. Structural economic a priori required by such an analysis is drawn from a theoretical framework which can match the long lasting PPP deviations observed in the data. More precisely, Chapter 5 relies on a two-country dynamic general equilibrium model with monopolistic firms which face translog households demand. The long-run properties of this model allow him to identify structural supply, demand and money supply shocks from the empirical study of a three-dimensional system composed of (the logarithm of) the output and price-level differentials between a home and a foreign country and their real exchange rate. He shows that the money supply shock has a non-significant effect (at the 20 percent level) on the real exchange rate after roughly 20 months, which mitigates the PPP puzzle. Indeed, once the real yen/dollar exchange rate data are corrected from their long-run components, (conditional) business-cycles frequencies PPP deviations after a monetary shock are much less persistent than has been previously documented.

In contrast to the previous chapters, Chapter 6 adopts a different approach to exchange rate dynamics by developing a theoretical framework deprived of any kind of market frictions. Fabrice Collard and Patrick Fève rely on real indeterminacy that generates self-fulfilling prophecies. They introduce habit persistence in consumption decisions in an open economy monetary model with a cash-in-advance constraint. They first show that high enough – but still reasonable – values for habit persistence yield indeterminate equilibria. They however establish that real indeterminacy is not *per se* sufficient to generate volatile and persistent fluctuations in exchange rate dynamics. The form of the beliefs matters. When beliefs are purely extrinsic, the nominal exchange rate essentially mimics the dynamics of money supply growth and never overshoots. Conversely, when beliefs are sufficiently positively correlated with money supply shock, the model is capable of generating overshooting and therefore volatility and persistence in exchange rate dynamics.

The second part of the book uses the general equilibrium frameworks developed in the previous chapters to provide guidelines for the choice of exchange rate regimes and monetary policies. In Chapter 7, Thepthida Sopraseuth documents business cycle properties across exchange rate regimes in order to identify the specific impact of exchange rate arrangements on macroeconomic fluctuations. She finds that the consequences of exchange rate arrangements are twofold. Business cycle properties confirm that the volatility puzzle uncovered by Baxter and Stockman (1989) and Flood and Rose (1995) is robust: nominal and real exchange rate volatilities are stabilized by the fixed exchange rate regime with no corresponding changes in the variability of the macroeconomic aggregates. There is no apparent systematic relationship between the exchange rate regime and the volatility of quantities. This conclusion applies to the Bretton Woods System as well as to the European exchange rate arrangement. The second empirical salient feature deals with interdependence. Her conclusion is consistent with Baxter and Stockman's (1989) conclusion about the lack of systematic relationship between the fall of the Bretton Woods System and international comovement. However, this feature is not a stylized fact since the analysis of EMS does not yield the same conclusion. Indeed, during the EMS period, EMS countries are more synchronized with the German cycle than with the US cycle. In that sense, since Germany can be considered as an "anchor" to participating countries, the EMS seems to favor a greater degree of synchronization among EMS countries.

In order to rationalize the empirical findings stressed in Chapter 7, Luca Dedola and Sylvain Leduc construct a general equilibrium model featuring nominal rigidities and deviations from the law of one price, due to firms pricing to market. In Chapter 8, they first document that this framework is consistent with an important business cycle finding: but for the real exchange rate, the currency regime does not affect the volatility of macroeconomic variables. They then explore the welfare cost of pegging the exchange rate and find that a flexible exchange-rate system is preferred to a currency peg. Their result is driven by the fact that, under the flexible exchange-rate system, the central bank, via its interest-rate policy, is able to dampen the movements in output and, therefore, the volatility of employment.

In Chapter 9, Tommaso Monacelli discusses the interest rate rule-based approach to the conduct of monetary policy and the exchange rate regime management in a small open economy. A tractable framework for the analysis of both the optimal policy design problem as well as of simple feedback rules is provided. The relative price channel is specific to the open economy dimension of monetary policy. As such, flexibility in the nominal exchange rate enhances this channel. He shows that the optimal policy under commitment, unlike the time consistent one, entails a stationary nominal exchange rate. Such a feature is shared by a regime of fixed exchange rates. He also shows that under certain conditions, fixed exchange rates can dominate the optimal discretionary policy when the economy is sufficiently open. Tommaso Monacelli also sheds light on a new type of trade-off that a small economy may face when choosing to participate to a currency area, namely a trade-off between the cost of relinquishing exchange rate flexibility and the benefit of designing a monetary regime which allows to implement in practice some of the features of the optimal commitment policy.

Finally, Chapter 10 is another illustration of how the NOEM framework allows monetary policy analysis. Matthieu Darracq-Pariès investigates the implications of different price setting rules for optimal monetary cooperation. He presents a two-country dynamic general equilibrium model with imperfect competition, nominal price rigidities in which the export prices can be denominated either in the producer currency (producer currency pricing, PCP) or in the consumer currency (local currency pricing, LCP). In addition, the model can account both for efficient and inefficient shocks. He first determines the optimal policy rule under alternative price setting. Under LCP, the monetary authorities should target the consumer price index. A pure CPI inflation targeting strategy implements the optimal outcome when shocks are efficient. An analogous result holds under PCP concerning the optimality of PPI inflation targeting. Furthermore, the optimal discretionary policy can be implemented by Taylor style reaction functions. Under LCP the monetary authority adjusts the national nominal interest rate to domestic expected CPI inflation rate with semi-elasticity above one. Under PCP, nominal interest rate is a function of both domestic and foreign PPI inflation rate with a weight higher than one on domestic inflation. Besides, a fixed exchange rate regime may be optimal under LCP in order to alleviate distortions associated with failures of the law of one price. Under PCP, a flexible exchange rate regime is optimal following efficient shocks. However, the presence of cost-push shocks implies some kind of exchange rate management. Finally, in contrast to Chapter 9, Chapter 10 adopts a two-country setting, which allows to gauge gains from cooperation. Such gains are more likely to arise in a model incorporating cost-push shocks and incomplete exchange rate pass-through. Matthieu Darracq-Pariès' results stress the importance of correctly modeling international price settings when studying monetary policy.

Obstfeld and Rogoff (1995) launched a renewed interest in international macroeconomics by providing a workhorse model for thinking about exchange rate dynamics and economic policies. This book overviews the recent developments in this literature, thereby showing how the NOEM perspective allows for a fruitful study of exchange rate dynamics and policy analysis.

Jean-Olivier Hairault and
Thepthida Sopraseuth

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Part I

Exchange rate volatility and persistence

1 Net foreign assets and exchange rate dynamics

The monetary model revisited

Michele Cavallo and Fabio Ghironi

1.1 Introduction

Exchange rate determination has been the "holy grail" of international finance and macroeconomics ever since the collapse of the Bretton Woods regime in 1971 and the ensuing period of high exchange rate volatility. The work by Obstfeld and Stockman (1985) is an excellent survey of models put forth in the 1970s and early 1980s. Of these, perhaps the most successful was Dornbusch's (1976) overshooting model, centered on the assumptions of uncovered interest parity (UIP) and sticky prices. Dornbusch clarified how exchange rate volatility was indeed consistent with rational behavior in the presence of sticky prices, which would cause the short-run response of the exchange rate to shocks to overshoot the new long-run equilibrium level.

Sadly for a generation of promising theoretical work, Meese and Rogoff (1983) documented evidence that the assumption that the exchange rate is simply described by a random walk process would perform better than the theoretical competitors at predicting the path of the exchange rate at business cycle frequencies. Since then, Meese and Rogoff's (1983) result has been among the major hurdles that theoretical work in search of the "exchange rate grail" has had to overcome. Another major stumbling bloc has been the evidence in favor of delayed overshooting in Clarida and Gali (1994) and Eichenbaum and Evans (1995). Dornbusch's overshooting model predicts that the exchange rate should overshoot its new long-run position on impact in response to a monetary shock. But empirical evidence suggested that overshooting actually takes place several periods after shocks, a finding that was interpreted as evidence against the importance of UIP in exchange rate determination.

Theoretical research on exchange rates developed renewed momentum with the publication of Obstfeld and Rogoff's (1995) seminal article, "Exchange Rate Dynamics Redux." There, Obstfeld and Rogoff put forth a fully microfounded, general equilibrium model of international interdependence and exchange rate determination with an explicit role for current account imbalances.[1] Nevertheless, the non-stationarity of the Redux model led most of the subsequent literature in the so-called "new open economy macroeconomics" to develop in different directions and "forget" the insights of the model on the dynamic relation between the exchange rate and net foreign asset accumulation by de-emphasizing the role of the latter.[2] (The assumption of purchasing power parity (PPP) was admittedly another weakness of the Obstfeld and Rogoff (1995) model on empirical grounds, addressed by several subsequent contributions. Yet, it was *not* PPP that motivated most scholars to de-emphasize the role of net foreign asset dynamics.)

US data show a growing and persistent current account deficit over the 1990s, that is, capital inflow and accumulation of a large foreign debt. During the same period, the dollar has appreciated steadily. It is a commonly held view that the advent of the "new economy" has been the most significant exogenous shock to affect the position of the US economy relative to the rest of the world in recent years. We can interpret this shock as a (persistent) favorable relative productivity shock. A story that one could tell about the behavior of the dollar and US net foreign assets in the 1990s is that the shock caused the United States to borrow from the rest of the world and the capital inflow generated exchange rate appreciation. This story could be reconciled with models of exchange rate determination developed in the 1970s and early 1980s.[3] If the shock is taken as permanent, the story can also be reconciled with Obstfeld and Rogoff's model. Nevertheless, the argument cannot be reconciled with the overwhelming majority of new generation models that followed.

We returned to the original intent of Obstfeld and Rogoff's work in Cavallo and Ghironi (2002). In that article, we developed a two-country model of exchange rate determination in which stationary net foreign asset dynamics play an explicit role. We dealt with indeterminacy of the steady state and non-stationarity of the original incomplete markets setup by adopting the overlapping generations framework illustrated in Ghironi (2000). If exogenous shocks are stationary, the departure from Ricardian equivalence generated by the birth of new households with no assets in all periods is sufficient to ensure existence of a determinate steady-state distribution of assets between countries and stationarity of real variables. Unexpected temporary shocks cause countries to run current account imbalances, which are re-absorbed over time as the world economy returns to the original steady state.[4]

In this chapter, we illustrate the model put forth in our previous article and compare its results for the traditional case in which monetary policy is conducted through exogenous changes in money supply and the case of endogenous interest rate setting. Exogenous monetary policy has been at the center of the traditional approach to exchange rate determination from the 1970s until very recently, including Obstfeld and Rogoff's Redux model. Yet, the publication of Taylor's (1993) seminal article has shifted the focus of research and the policy debate on endogenous monetary policy through interest rate setting. In an open economy world, this tends to de-emphasize the role of relative money demand in exchange rate determination and, as we argued and we shall review, has important consequences for the dynamics of the exchange rate implied by the model.

We focus on the case of flexible prices in this chapter. The reason is that the flexible price assumption allows us to solve the model analytically, delve into its mechanics, and discuss intuitions clearly. The main mechanisms of the model as far as the role of net foreign asset dynamics is concerned are unchanged with the introduction of price stickiness, and we refer to our 2002 article for that case. Given the focus on flexible price dynamics, we see this chapter as a revisitation of the traditional monetary model of exchange rate determination reviewed in Obstfeld and Stockman (1985) in the light of modern, microfounded international economics and the progress in understanding monetary policy of the last few years.

We start from the traditional setup of Obstfeld and Rogoff's Redux model in which monetary policy is conducted through exogenous changes in money supply in both countries. To facilitate comparison of results and the understanding of model dynamics in a simple case, we retain the PPP assumption. As in Obstfeld and Rogoff (1995), UIP emerges as the outcome of optimizing behavior in our setup. As standard in the literature, we show that the exchange rate can be expressed in terms of the present discounted value of fundamentals: relative money supply and the cross-country consumption differential. A higher consumption differential causes the exchange rate to appreciate by increasing the demand for home currency relative to foreign. We then show that the present discounted value of the consumption differential is, in turn, a function of the stock of net foreign assets entering the current period and of current relative productivity in the two countries.[5] Thus, when monetary policy is conducted through exogenous money injections, the exchange rate depends on the stock of net foreign assets through the effect of the latter on the consumption differential. Accumulation of net foreign assets has a positive effect on the expected relative consumption path and allows the home country to sustain higher consumption than foreign. Hence, the demand for home currency is above foreign, and the exchange rate appreciates. Conversely, a worsening of the relative asset position, that is, a capital inflow is associated with a depreciation. Therefore, the exogenous money supply monetary model cannot deliver the combination of capital inflow and appreciation often observed in the data in terms of a causal linkage from the net foreign asset position to the exchange rate. Also, unless monetary and productivity shocks are non-stationary, this version of the model cannot reproduce the unit root in exchange rate behavior found in Meese and Rogoff (1983).

The exchange rate appreciates in response to a favorable shock to home productivity, because the expected path of the consumption differential is positive in response to the shock, which raises the demand for home currency above foreign. Even if the relative productivity shock is transitory, the exchange rate returns slowly to its pre-shock level. Asset dynamics and their effects through the consumption differential and relative money demand keep the exchange rate stronger than its pre-shock level for several periods.

The exchange rate depreciates following a positive relative money supply shock. The channel is the traditional one through a decrease in the interest rate differential. Not surprisingly, the results after monetary shocks are as in the traditional flexible-price, monetary model of exchange rate determination of the 1970s. The reason is that the exchange rate is ultimately determined by the same ingredients as in the old-fashioned, non-microfounded setup: PPP, UIP, relative money demand, and the assumption about money supply.

When we formulate monetary policy in terms of interest rate feedback rules for the two countries, we assume that interest rates react to the deviations of consumption-based price index (CPI) inflation and GDP from their steady-state levels. Interest rates are also subject to exogenous shocks to allow for the possibility of exogenous changes in monetary policy. Our specification is consistent with Taylor (1993) and allows us to obtain a rich set of implications in a transparent setting.[6]

With endogenous interest rate setting, the solution for the nominal exchange rate exhibits a unit root, consistent with the empirical findings of Meese and Rogoff (1983). However, as in the case of exogenous monetary policy, today's exchange rate also depends on the stock of real net foreign assets accumulated in the previous period. The mechanism here is different though, owing to the fact that money demand plays no active role in exchange rate determination when interest rates are set endogenously. The intuition for the role of asset dynamics in this case is as follows: absence of unexploited arbitrage opportunities implies that UIP holds in our model: expected exchange rate depreciation equals the nominal interest rate differential. To the extent that interest rates react to variables that are affected by net foreign assets (namely GDP, through the wealth effect on labor supply), net foreign assets too affect the exchange rate. As in the previous case, the model implies that asset holdings help predict the nominal exchange rate. A key difference is that now, consistent with the evidence for the United States, *ceteris paribus*, a decrease in asset holdings – a current account deficit/capital inflow – generates an appreciation of the domestic currency for reasonable parameter values. Also, we show that the response of the exchange rate to shocks is more different from that of a simple random walk – the slower the convergence of net foreign assets to the steady state and the higher the degree of substitutability between domestic and foreign goods in consumption.

In this case, the exchange rate overshoots its new long-run level following a temporary (relative) productivity shock. If the shock is persistent, endogenous monetary policy and asset dynamics generate delayed overshooting. Endogenous monetary policy is responsible for exchange rate *undershooting* after persistent (relative) interest rate shocks. ("Persistent" does *not* mean "permanent" throughout the chapter. When we consider permanent shocks, we say so explicitly.)

Our results on exchange rate overshooting contrast with those of Obstfeld and Rogoff (1995), who obtain no overshooting following monetary and/or productivity shocks in their benchmark setup. We show that price stickiness is not necessary to generate overshooting once asset dynamics and endogenous monetary policy are accounted for. This brings a new perspective to bear on a topic that has been at the center of theoretical and empirical research on exchange rates since Dornbusch's (1976) seminal paper. Our model has the potential to reconcile the evidence in favor of delayed overshooting in Clarida and Gali (1994) and Eichenbaum and Evans (1995) with rational behavior and UIP.

As far as the empirical performance is concerned, the model with endogenous monetary policy delivers exchange rate appreciation following a favorable shock to relative productivity in an environment in which monetary policy obeys the Taylor principle. However, the model does not generate accumulation of net foreign debt following the shock. The reason is that consumption smoothing is the only motive for asset accumulation, and a favorable productivity shock induces home agents to lend rather than borrow to smooth the effect of the shock on consumption. We show in Cavallo and Ghironi (2002) that a sticky-price version of the model delivers debt accumulation and appreciation when the relative productivity shock is permanent. This is a consequence of slow terms of trade dynamics, which cause the short-run response of the GDP differential to the shock to be smaller than the long-run effect, thus motivating home agents to borrow rather than lend. Nevertheless, if one believes that the relative productivity shock of the 1990s has been persistent, but not permanent, the model can explain only part of the dynamics in US data. Along with price stickiness, inclusion of physical capital accumulation and PPP deviations appears a promising way of completing the theory illustrated here. On more rigorous grounds, the model with endogenous interest rate setting yields straightforward, empirically testable implications for exchange rate dynamics. The result that exchange rate dynamics may coincide with those of a random walk or be sufficiently close that the difference is hard to detect in short series is no longer an a-theoretical, data-driven finding. It emerges from a fully specified, microfounded, general equilibrium model if central banks do not react to GDP movements in interest rate setting or if substitutability between home and foreign goods is low. Whether this has brought us closer to finding the "exchange rate grail," only more empirical work on the longer series now available will tell.

The rest of the chapter is organized as follows. Section 1.2 presents the model. Section 1.3 illustrates the log-linear equations that determine domestic and foreign variables and presents the solution for real variables. Section 1.4 studies exchange rate determination when monetary policy is conducted through exogenous changes in money supply. Section 1.5 discusses the relation between net foreign assets and the exchange rate with endogenous interest rate setting. Section 1.6 concludes.

1.2 The model

The model is a monetary version of the setup in Ghironi (2000). The world consists of two countries, *home* and *foreign*. In each period t, the world economy is populated by a continuum of infinitely lived households between 0 and N_t^{W}. Each household consumes, supplies labor, and holds financial assets. As in Weil (1989), we assume that households are born on different dates *owning no assets*, but they own the present discounted value of their labor income.[7] The number of households in the home economy, N_t, grows over time at the exogenous rate $n > 0$, that is, $N_{t+1} = (1+n)N_t$. We normalize the size of a household to 1, so that the number of households alive at each point in time is the economy's population. Foreign population (N_t^*) grows at the same rate as home population. The world economy has existed since the infinite past. It is useful to normalize world population at time 0 to the continuum between 0 and 1, so that $N_0^{\mathrm{W}} = 1$.

A continuum of goods $i \in [0, 1]$ is produced in the world by monopolistically competitive, infinitely lived firms, each producing a single differentiated good. Firms have existed since the infinite past. At time 0, the number of goods that are supplied in the world economy is equal to the number of households. The latter grows over time, but the commodity space remains unchanged. Thus, as time goes by, the ownership of firms spreads across a larger number of households. Profits are distributed to consumers via dividends, and the structure of the market for each good is taken as given. We assume that the domestic economy produces goods in the interval $[0, a]$, which is also the size of the home population at time 0, whereas the foreign economy produces goods in the range $[a, 1]$.

The asset menu includes nominal bonds denominated in units of domestic and foreign currency, money balances, and shares in firms. Private agents in both countries trade the bonds domestically and internationally. Shares in home (foreign) firms and domestic (foreign) currency balances are held only by home (foreign) residents.

1.2.1 Households

Agents have perfect foresight, though they can be surprised by initial unexpected shocks. Consumers have identical preferences over a real consumption index (C), leisure (LE), and real money balances (M/P, where M denotes nominal money holdings and P is the consumption-based price index (CPI)). At any time t_0, the representative home consumer j born in period $\upsilon \in [-\infty, t_0]$ maximizes the intertemporal utility function

$$U_{t_0}^{\upsilon j} = \sum_{t=t_0}^{\infty} \beta^{t-t_0} \left[\rho \log C_t^{\upsilon j} + (1-\rho) \log \mathrm{LE}_t^{\upsilon j} + \chi \log \frac{M_t^{\upsilon j}}{P_t} \right], \tag{1.1}$$

with $0 < \rho < 1$.[8]

The consumption index for the representative domestic consumer is

$$C_t^{\upsilon j} = \left[a^{1/\omega} (C_{\mathrm{H}t}^{\upsilon j})^{(\omega-1)/\omega} + (1-a)^{1/\omega} (C_{\mathrm{F}t}^{\upsilon j})^{(\omega-1)/\omega} \right]^{\omega/(\omega-1)},$$

where $\omega > 0$ is the intratemporal elasticity of substitution between domestic and foreign goods. The consumption sub-indexes that aggregate individual domestic and foreign goods are, respectively:

$$C_{\mathrm{H}t}^{\upsilon j} = \left[\left(\frac{1}{a} \right)^{1/\theta} \int_0^a c_t^{\upsilon j}(i)^{(\theta-1)/\theta} \mathrm{d}i \right]^{\theta/(\theta-1)},$$

and

$$C_{\mathrm{F}t}^{\upsilon j} = \left[\left(\frac{1}{1-a} \right)^{1/\theta} \int_a^1 c_{*t}^{\upsilon j}(i)^{(\theta-1)/\theta} \mathrm{d}i \right]^{\theta/(\theta-1)},$$

where $c_{*t}^{vj}(i)$ denotes time t consumption of good i produced in the foreign country, and $\theta > 1$ is the elasticity of substitution between goods produced inside each country.

The CPI is

$$P_t = \left[aP_{Ht}^{1-\omega} + (1-a)P_{Ft}^{1-\omega}\right]^{1/(1-\omega)},$$

where P_H (P_F) is the price sub-index for home (foreign)-produced goods – both expressed in units of the home currency. Letting $p_t(i)$ be the home currency price of good i, we have

$$P_{Ht} = \left(\frac{1}{a}\int_0^a p_t(i)^{1-\theta}\,\mathrm{d}i\right)^{1/(1-\theta)}, \quad P_{Ft} = \left(\frac{1}{1-a}\int_a^1 p_t(i)^{1-\theta}\,\mathrm{d}i\right)^{1/(1-\theta)}.$$

We assume that there are no impediments to trade and that firms do not engage in local currency pricing (i.e. pricing in the currency of the economy where goods are sold). Hence, the law of one price holds for each individual good and $p_t(i) = \varepsilon_t p_t^*(i)$, where ε_t is the exchange rate (units of domestic currency per unit of foreign) and $p_t^*(i)$ is the foreign currency price of good i. This hypothesis and identical intratemporal consumer preferences across countries ensure that consumption-based PPP holds, that is, $P_t = \varepsilon_t P_t^*$.

Workers supply labor (L) in competitive labor markets. The total amount of time available in each period is normalized to 1, so that[9]

$$\mathrm{LE}_t^{vj} = 1 - L_t^{vj}. \tag{1.2}$$

The representative consumer enters a period holding nominal bonds, nominal money balances, and shares purchased in the previous period. She or he receives interest and dividends on these assets, may earn capital gains or incur losses on shares, earns labor income, is taxed, and consumes.

Denote the date t price (in units of domestic currency) of a claim to the representative domestic firm i's entire future profits (starting on date $t+1$) by V_t^i. Let x_{t+1}^{vji} be the share of the representative domestic firm i owned by the representative domestic consumer j born in period v at the end of period t. D_t^i denotes the nominal dividends firm i issues on date t. Then, letting A_{t+1}^{vj} (A_{t+1}^{*vj}) be the home consumer's holdings of domestic (foreign) currency denominated bonds entering time $t+1$, the period budget constraint expressed in units of domestic currency is

$$\begin{aligned} &A_{t+1}^{vj} + \varepsilon_t A_{t+1}^{*vj} + \int_0^a \left(V_t^i x_{t+1}^{vji} - V_{t-1}^i x_t^{vji}\right)\mathrm{d}i + M_t^{vj} \\ &\quad = (1+i_t)A_t^{vj} + \varepsilon_t\left(1+i_t^*\right)A_t^{*vj} + \int_0^a D_t^i x_t^{vji}\,\mathrm{d}i \\ &\qquad + \int_0^a \left(V_t^i - V_{t-1}^i\right)x_t^{vji}\,\mathrm{d}i + M_{t-1}^{vj} + W_t L_t^{vj} - P_t C_t^{vj} - P_t T_t^{v}, \end{aligned} \tag{1.3}$$