Chapter VIII

The Nominal Exchange Rate

VIII.1 Introduction and Overview

Given the theoretical framework we presented in the past chapters, it is surprising how much attention both academics and the general public devote to fluctuations of the nominal exchange rate: with perfect foresight and completely flexible prices, nominal magnitudes should be irrelevant for the development of macroeconomic aggregates and individual income levels. Income, consumption, investment, the current account etc. would be exclusively determined by economic fundamentals – preferences, technologies, factor endowments – as well as the institutional environment.

However, once we depart from the assumptions of perfect foresight and frictionless price adjustment, it becomes evident why considerable intellectual and financial resources are devoted to the analysis of nominal exchange rates. First, the evolution of nominal exchange rates is decisive for the valuation of assets that are denominated in foreign currency, and it therefore plays a crucial role for agents' international portfolio decisions. Moreover, if goods prices are slow to react, fluctuations of the nominal exchange rate entail variations in the terms of trade and the real exchange rate. As we saw in Chapter VII, this has important consequences for resource allocation and economic performance.

In this chapter, we will consider the mechanisms that determine the level and evolution of the nominal exchange rate. We will start with the observation that the nominal exchange rate – as the relative price of a currency in terms of another currency – reflects supply and demand on the ***foreign exchange (forex) market***. Supply and demand partly result from goods and services transactions, e.g. from the demand of domestic importers who have to pay bills in foreign currency. However, what matters much more is the situation on international financial markets, i.e. the demand for foreign currency that reflects the demand for foreign assets.[1] This is illustrated by Figure 8.1, which gives the evolution

[1] The distinction between foreign exchange markets and asset markets is somewhat artificial since the largest part of foreign exchange transactions amounts to an exchange of deposits among banks. Hence, by acquiring foreign currency, market participants also acquire a foreign asset. From a conceptual perspective, however, this distinction has some advantages, and we will therefore adopt it for the rest of this chapter.

of the daily (!) trading volume on international foreign exchange markets. To be sure, the global volume of goods and services trade also increased substantially since the early 1990s, and amounted to 23,260 billion US dollars in 2013 (World Bank, 2015). However, the total trading volume on foreign exchange markets dwarfs the volume that would be justified by goods and services trade alone.

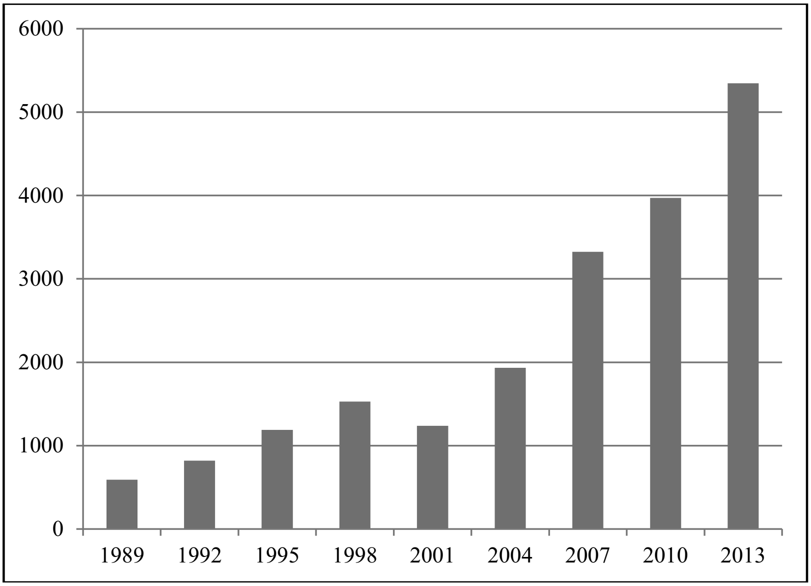


Figure 8.1: Daily turnover on international foreign exchange markets (in billions of US dollars). Source: Bank for International Settlements (2013).

The fact that supply and demand on foreign exchange markets predominantly mirror developments on international financial markets implies that the exchange rate crucially depends on market participants' expectations about its future value. In fact, the prominent role of expectations is the central feature of the ***asset market approach*** to the analysis of exchange rates, which will guide our analysis throughout this chapter.

Of course, supply and demand do not only depend on the decisions of private agents, but also on the type and volume of public intervention. For this reason, we start this chapter by briefly describing the mechanics and implications of different ***exchange rate regimes***. In Section VIII.3, we will introduce the ***interest rate parity conditions*** that link international interest rate differentials and market participants' exchange rate expectations. The ***uncovered interest rate***

parity condition is a central ingredient of the ***monetary exchange rate model***, which we will present in Section VIII.4. The key insight conveyed by this model is that today's exchange rate does not just depend on observable magnitudes – in particular, money supply and income levels – but also on individuals' expectations about the future evolution of these variables.

The monetary model of the exchange rate is based on the assumption that goods prices are perfectly flexible. The Dornbusch model, which was developed by the economist Rüdiger Dornbusch, and which we will present in Section VIII.5, drops this assumption and demonstrates that changes in monetary policy may result in an ***overshooting*** of the exchange rate – i.e. in seemingly "excessive" fluctuations, which do not originate in irrational behavior, but in the different speed of adjustment of goods prices and exchange rates.

In Section VIII.6, finally, we will drop the assumption that securities which are denominated in different currencies are perfect substitutes. Imperfect substitutability implies that individuals keep holding domestic-currency assets even if the expected return is smaller than the expected return on foreign-currency assets. The ***portfolio balance approach*** illustrates how, in such a framework, changes of supply and demand conditions on the markets for domestic and foreign securities determine the exchange rate. As we will show, this model has important implications for the analysis of ***foreign exchange interventions***, i.e. central banks' attempts to influence exchange rates by buying and selling currency in forex markets.

VIII.2 Exchange Rate Regimes

VIII.2.1 Motivation

The evolution of the nominal exchange rate crucially depends on the ***exchange rate regime***: with a perfectly ***flexible exchange rate***, the relative price of a currency depends on the supply and demand of private agents. Public institutions – in particular, central banks – do not try to influence this price. In the opposite case of a ***fixed exchange rate***, monetary authorities announce an ***exchange rate target*** – the "***parity***" – and commit to ***intervene*** on foreign exchange markets whenever market forces move the exchange rate too far away from the announced peg.[2] Figure 8.2 shows the nominal exchange rate of the (British) Pound sterling (GBP) against the US dollar (USD) between 1957 and 2015. It is easy to see that this variable remained at a constant level for most of the 1950s

[2] Exchange rate economics abounds with synonyms: a flexible exchange rate is sometimes called a "***floating exchange rate***" or a "***float***", while the term "***peg***" is sometimes used instead of parity.

and 1960s. Afterwards, the time series is characterized by substantial volatility. This evolution mirrors the transition from a fixed to a flexible exchange rate of the Pound sterling vis-à-vis the US dollar, which took place in the early 1970s.

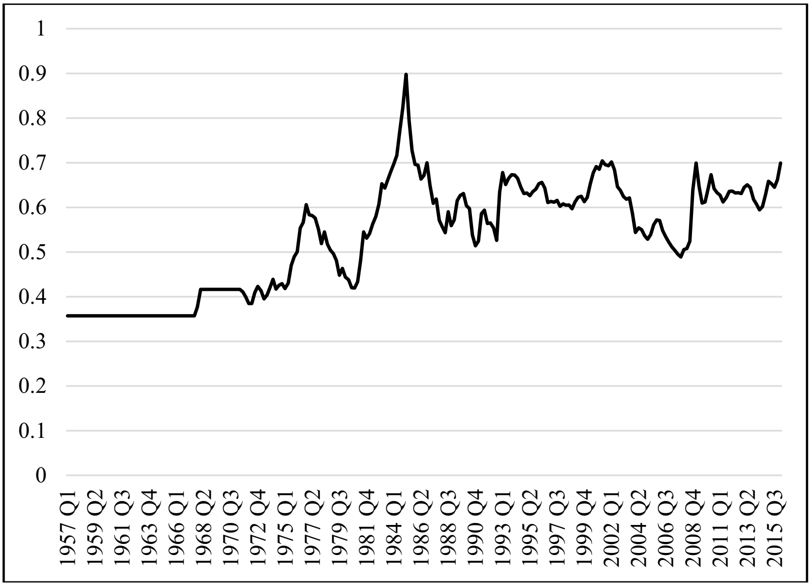


Figure 8.2: The nominal USD/GBP exchange rate (Pound sterling per US dollar). Source: IMF (International Financial Statistics).

Between the two extreme cases of a completely flexible and a completely fixed exchange rate, there are various "intermediate" regimes, which differ with respect to the intensity of public intervention, the specific description of the exchange rate target, and the costs of abandoning the announced target. We will return to these distinctions in the last part of this section. Before, however, it is important to describe the mechanics of a fixed exchange rate regime and to highlight the implications of such a regime for the evolution of the domestic money supply.

VIII.2.2 Exchange Rate Regimes and the Central Bank's Foreign Reserves

In Chapter II, we stated that, ex post, the balance of payments is always *in equilibrium*. The argument we brought forward to support this statement ran as follows: a surplus of the current and capital accounts has to be mirrored by a financial account surplus of identical size since, roughly speaking, a surplus of goods and services exports over goods and services imports is associated with an increase of net claims – the difference between assets and liabilities – towards the rest of the world.[3] Distinguishing between the change of the central bank's foreign exchange reserves from the start of period t to the start of period t+1 $\left(\Delta R_{t+1}\right)$ and the remaining ("non-reserves") part of the financial account $\left(FA_t^{NR}\right)$, we can rewrite the equation introduced in Chapter II:

$$(8.1) \qquad CA_t + KA_t - FA_t^{NR} = \Delta R_{t+1}$$

This equation can also be interpreted as a characterization of equilibrium on foreign exchange markets: *foreigners'* purchases of domestic goods and services as well as their purchases of domestic securities – with the latter being recorded as an increase of domestic liabilities in the financial account – result in a *demand* for domestic currency.[4] By contrast, *domestic agents'* purchases of foreign goods and services as well as their purchases of foreign securities – recorded as an increase of domestic assets in the financial account – result in demand for foreign currency and a *supply* of domestic currency. The central banks' activities are shown separately: if the domestic central bank buys assets denominated in foreign currency, its foreign exchange reserves increase $\left(\Delta R_{t+1} > 0\right)$. By contrast, a sale of assets denominated in foreign currency results in a decrease of foreign exchange reserves $\left(\Delta R_{t+1} < 0\right)$.

Ex post, equation (8.1) always holds. However, it crucially depends on the strategy of the central bank whether foreign exchange market equilibrium is associated with a change in foreign reserves. In particular, it hinges on the choice of the exchange rate regime: if the exchange rate is completely flexible, the central bank has no mandate to influence the supply of domestic currency through interventions. In this case, foreign exchange reserves remain constant $\left(\Delta R_{t+1} = 0\right)$, and the nominal exchange rate emerges as the price which equates supply and demand on forex markets.

If, by contrast, the exchange rate is fixed, and the officially announced parity differs from the exchange rate that emerges as a market equilibrium, the domestic central bank has to intervene to sustain (or "defend") the peg. If $CA_t + KA_t - FA_t^{NR} < 0$, there is an excess supply of domestic currency: domestic net demand for foreign currency – emerging, e.g., from a deficit of the combined current and capital accounts – is not matched by foreigners' net demand for domestic currency that is needed, e.g., to purchase domestic securities. In order

[3] This exposition, which downplays the fact that the current account is *not* identical with net exports of goods and services, and which ignores the role of capital account transactions, is chosen for simplicity.

[4] For the time being, we assume that foreign securities are denominated in foreign currency while domestic securities are denominated in domestic currency. As we will see in later chapters, this need not be the case, with domestic institutions sometimes selling securities that are denominated in foreign currency.

to sustain the peg, the domestic central bank has to increase the supply of foreign currency and increase the demand for domestic currency. This is realized by selling foreign currency-denominated securities, which, in turn, is reflected by a decline in foreign exchange reserves, i.e. $\Delta R_{t+1} < 0$. By contrast, an excess demand for domestic currency occurs if $CA_t + KA_t - FA_t^{NR} > 0$. In this case, the central bank intervenes to increase the demand for foreign currency and the supply of domestic currency. As a consequence, foreign exchange reserves increase, i.e. $\Delta R_{t+1} > 0$. An important lesson emerges: the crucial feature of a fixed exchange rate regime is that, at a given parity, changes of foreign exchange reserves result endogenously from an excess supply or demand of the domestic currency on foreign exchange markets.[5]

Box 8.1: TARGET2 Balances and the European Debt Crisis

In the previous paragraphs, we have so far argued that the foreign reserves of a country's central bank decrease whenever $CA_t + KA_t - FA_t^{NR} < 0$ – a situation that may emerge, e.g., because agents on the international capital market are unwilling to finance a country's current account deficit by purchasing its assets. In a world in which countries have different currencies, such a situation cannot be sustained forever: once the central bank's reserves are depleted the country is forced to abandon the peg, and the resulting depreciation of the currency contributes to reaching a new equilibrium. But what happens if countries share the *same* currency? Being a member of a currency union does not guarantee that $CA_t + KA_t = FA_t^{NR}$ and, in the absence of foreign reserves, it is not obvious who steps in if there is a discrepancy between the combined current and capital account balances and the non-reserve part of the financial account.

It turned out that this was exactly the situation faced by some member countries of the Euro area in the years after 2010: following their access to the European Monetary Union in 1999, the international capital market had stood ready to finance growing current account deficits in these countries, and large volumes of assets had crossed intra-European borders. However, in the wake of the Global Financial Crisis that unfolded in 2008, it became increasingly hard for countries like Greece, Ireland, Italy, Portugal and Spain – the so-called GIIPS countries – to attract foreign capital. These

[5] Our presentation is based on the notion that both monetary policy and exchange rate policy are in the hands of the central bank. While this is the case for many economies, there are some notable exceptions – e.g. the United States, where the department of the treasury is responsible for foreign exchange interventions (see Svensson 2003:157). In what follows, we will assume that the central bank and the treasury perfectly coordinate their activities, such that this institutional detail can be ignored.

countries were members of the Euro area, hence neither the selling of foreign reserves nor a depreciation of the currency was an option. Since current account deficits did not vanish immediately, there had to be some other mechanism that replaced the missing adjustment of foreign reserves. It turned out that this mechanism was the Trans-European Automated Real-Time Gross Settlement Express Transfer – in short: TARGET – system. This system had originally been set up as a clearing mechanism for cross-border payments within the Euro area, and the original TARGET version had been replaced by **TARGET2** in 2007.

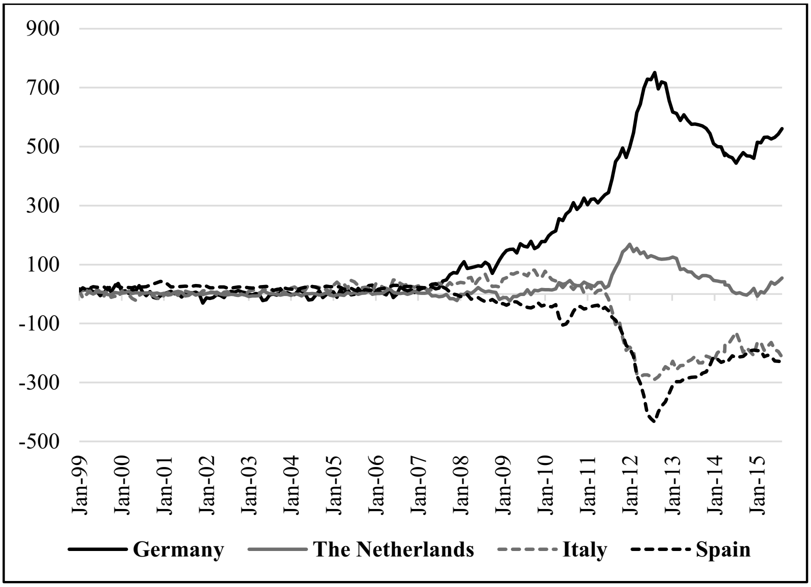


Figure B8.1: TARGET2 claims (positive) and liabilities (negative) for Germany, the Netherlands, Italy and Spain (billions of Euros). Sources: see Steinkamp and Westermann (2014).

The system works as follows: whenever a customer in, say, Spain purchases goods worth 1000 Euros from a supplier in, say, the Netherlands, the customer's bank account is charged with a debit of 1000 Euros by his Spanish commercial bank. The Spanish commercial bank, in turn, is charged 1000 Euros by the Spanish central bank. The Spanish central bank is, at length, charged with 1000 Euros at the European Central Bank (ECB), thus increasing its liabilities within the TARGET2 system. On the Dutch side, by contrast, the supplier is credited 1000 Euros by his commercial bank, which receives this sum from the Dutch central bank, which is ultimately credited with 1000 Euros by the ECB. As a result of these transactions, Dutch “TARGET2 claims” and Spanish “TARGET2 liabilities” have increased by 1000 Euros. Under normal circumstances, purchases and sales of goods, services and assets within the Eurozone were roughly equal for individual countries, such that ***TARGET2 balances*** remained small. However, when the international capital market started to shun the GIIPS economies, these countries’ liabilities vis-à-vis other Euro area countries exploded. Figure B8.1 documents the evolution of TARGET2 balances for some Euro area countries between January 1999 and October 2015.

In the context of the European Debt Crisis, the TARGET2 system had thus unintentionally been transformed into a source of credit for troubled economies, and it turned out that – unlike in the USA where a similar clearing system exists among districts of the Federal Reserve System – there was no pre-defined mechanism to limit these countries’ TARGET2 liabilities. Moreover, the continued access to the ECB’s refinancing tools, which was available to all Euro area financial institutions, made sure that, despite the continuous outflow of money, the debtor countries were not short of liquidity.

The crucial role of TARGET2 balances in the European Debt Crisis was first highlighted by the German economists Hans-Werner Sinn and Timo Wollmershäuser (2012). Their main critique of the existing system referred to the fact that continued access to cheap finance through the ECB prevented the GIIPS countries from experiencing the necessary adjustment that would have been the normal consequence of the sudden drop in capital inflows they experienced. Moreover, Sinn and Wollmershäuser warned about the substantial fiscal risks for TARGET2 creditor countries: while TARGET2 claims are officially held and administered by the ECB, national central banks would take a heavy blow if one of the debtor countries actually left the Euro system and defaulted on its TARGET2 debt. Figure B8.2 documents that, as this book is written, this issue is far from being settled.

VIII.2.3 Foreign Exchange Reserves and the Money Supply

The relationship between the exchange rate regime, foreign exchange interventions and variations in foreign exchange reserves has important consequences for the evolution of the domestic money supply and for a central bank’s scope in conducting national monetary policy. To show this, we start by reviewing the basic elements of the money supply process: our point of departure is the ***monetary base (M0)***, which consists of ***currency in circulation*** – i.e. coins and banknotes held by individuals and institutions outside the banking sector – and the ***reserves*** of commercial banks. These reserves, in turn, are cash holdings of commercial banks – the so-called ***vault cash*** – and deposits on the ***reserve accounts*** that commercial banks hold at their country's central bank.[6] The size of these reserves is influenced – but not completely determined – by the central bank: though most central banks force commercial banks to hold a certain level of ***required reserves,*** banks are free to hold reserves in excess of this minimum level. Whether this is attractive or not depends on the economic and financial environment as well as on the interest rate paid on reserves.[7]

However, when people talk about the money supply, they usually don't have the monetary base M0 in mind, but some monetary aggregate, which – depending on its definition – comprises securities that differ in terms of their liquidity. In accord with most other central banks, the ECB defines measures of "narrow money" (***M1***), "intermediate money" (***M2***) and "broad money" (***M3***). On its homepage, the ECB offers the following definitions: "narrow money (M1) includes currency, i.e. banknotes and coins, as well as balances which can immediately be converted into currency or used for cashless payments, i.e. overnight deposits. 'Intermediate' money (M2) comprises narrow money (M1) and, in addition, deposits with a maturity of up to two years and deposits redeemable at a period of notice of up to three months. Broad money (M3) comprises M2 and marketable instruments issued by the Monetary Financial Institutions (MFI) sector. Certain money market instruments, in particular money market fund (MMF) shares/units and repurchase agreements are included in this aggregate" (ECB 2015). The monetary aggregates are much larger than the monetary base. This is due to the fact that any expansion of M0 results in a process of money creation, with commercial banks issuing credit that results in new deposits and gives other banks the opportunity to issue further credit. The coefficient μ_t^1, which describes the relationship between the monetary aggregate M1 and the monetary base is called the ***money multiplier***. We can write $M1_t = \mu_t^1\ M0_t$, with the subscript t highlighting the fact that μ_t^1 may vary over time. In what follows, we will often assume that the money multiplier is a constant. However, you should be aware of the fact that, in reality, aggregate money supply crucially depends on the volume of credit extended by commercial banks, and that banks

[6] Be careful to distinguish the ***(foreign exchange) reserves*** of the central bank from the ***reserves*** held by commercial banks on their accounts at the central bank.

[7] As of July 2016, the European Central Bank (ECB) had lowered the "remuneration rate" on minimum reserves to zero percent. "Excess reserves" – i.e. reserves exceeding the minimum – were subject to a penalty rate of -0.40 percent.

– like other profit-maximizing firms – flexibly react to changes in the economic environment.[8]

Both currency in circulation and the reserves of commercial banks appear on the right-hand (***liabilities***) side of the central bank's balance sheet. On the left-hand side, we find the central bank's ***assets***. These are claims against domestic institutions and firms – mostly the public sector and commercial banks – as well as foreign exchange reserves. Further assets – e.g. real estate owned by the central bank – complement the picture, while the right hand side shows further liabilities as well as central bank equity. This information is summarized in Figure 8.3.

Assets	Liabilities
Net foreign assets	Currency in circulation
	Bank deposits („reserves")
Net claims on the government	Other liabilities
Other assets	Central bank equity

Figure 8.3: A simplified version of the central bank's balance sheet.

Figure 8.4 and Figure 8.5 document how the size and composition of the balance sheets of the ECB and the US-American ***Federal Reserve System (the "Fed")*** evolved from 2005 through 2014. Various aspects of these developments are striking: first, both central banks' balance sheets expanded substantially during these ten years: while the sum of the ECB's assets amounted to 927 billion Euros in 2005, it had more than doubled by the end of 2014. For the Fed, the picture is even more dramatic, and the sum of assets increased by almost 400 (!) percent. These changes reflect the central banks' reactions to the sequence of severe financial crises that started to unfold in 2007 – more specifically, the substantial easing of commercial banks' access to liquidity. Apart from the size of the balance sheets, the figures also document how the relative importance of different items has changed over time: for the ECB, net foreign assets represented roughly one third of total assets shortly after the turn of the millennium, while currency in circulation represented two thirds of central bank liabilities. More recently, however, both government securities and other claims have become more important on the asset side, and commercial bank reserves have assumed a more prominent role on the liability side. For the Fed, the relative im-

[8] One feature of the recent financial crises was a substantial drop of the money multiplier, which reflected banks' ample access to central bank reserves and their reluctance to issue credit to private households and firms.

portance of government securities on the asset side decreased substantially between 2005 and 2014, while bank reserves became an increasingly dominant item on the liability side.

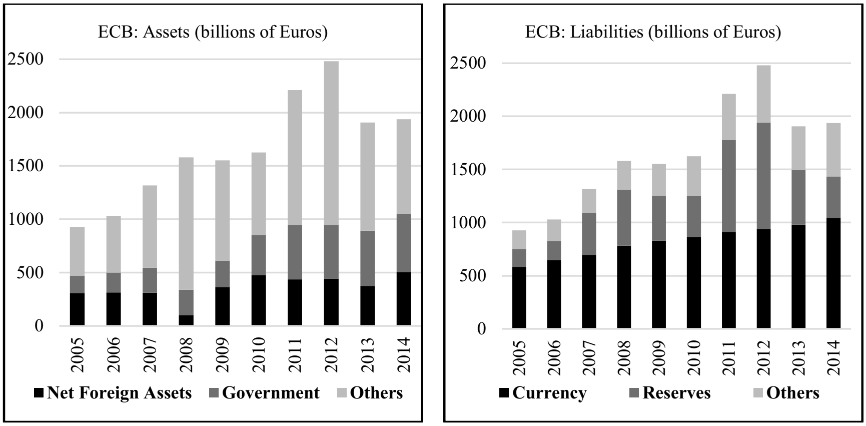


Figure 8.4: Assets and liabilities of the European Central Bank (ECB). All positions in billions of Euros. Source: IMF (International Financial Statistics).

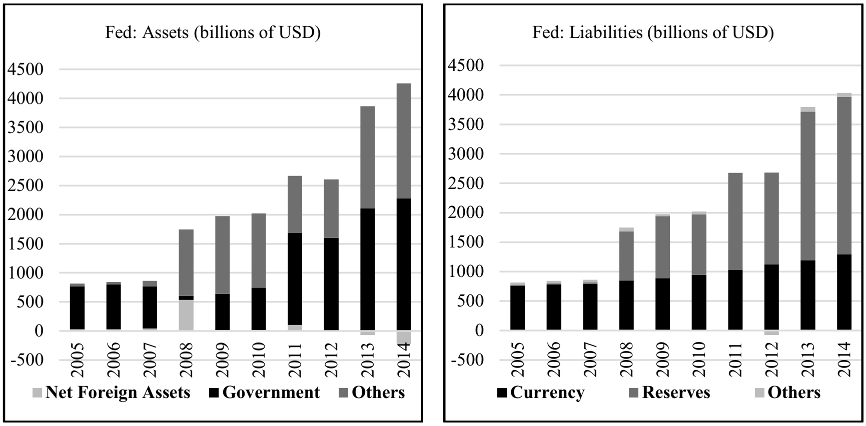


Figure 8.5 : Assets and liabilities of the United States Federal Reserve System (the "Fed"). All positions in billions of US dollars. Source: IMF (International Financial Statistics).

How is a central bank's balance sheet affected by developments on foreign exchange markets? If demand for the domestic currency exceeds supply at the given exchange rate, and if the central bank wants to prevent a nominal appreciation, it intervenes by buying foreign currency. The commercial bank that sells foreign currency is credited the respective amount on its reserve account. As a result, the stock of foreign assets held by the central bank increases, and so do the commercial banking sector's reserves – with the latter implying an expansion of the monetary base. Via the money creation process sketched above, the increase of the monetary base raises money supply. If, by contrast, there is an excess supply of domestic currency on foreign exchange markets, the central bank sells foreign currency denominated assets, charging commercial banks' accounts. This, in turn, reduces the monetary base and thus the domestic money supply.

An alternative way to influence the money supply by changing the monetary base are so-called ***open market operations***. In the context of such operations, the central bank lends reserves to commercial banks. These, in turn, have to offer collateral in the form of securities – e.g. government bonds – that have to satisfy certain requirements concerning their liquidity and creditworthiness. In the case of so-called ***repurchase agreements ("repos")***, banks sell these securities to the central bank and commit to buy them back at a pre-defined date.[9] Box 8.2 offers some more detail on the ECB's conduct of monetary policy.

Box 8.2: The ECB's Monetary Policy in Normal Times and Under Stress

During the so-called "***Great Moderation***", beginning in the mid-1980s and lasting until 2007, monetary policy in most industrialized countries – including the United States and the Euro area – was a steady business, characterized by the fine-tuning of a machinery that ran smoothly and delivered acceptable results. Central banks tried to influence an interest rate that reflected commercial banks' transactions on the ***interbank ("money") market*** – i.e. on the market where commercial banks sought and provided credit to meet short-run liquidity needs. These short-run interest rates eventually affected the long-run interest rates that are relevant for firms' and households' decisions.[10]

The key instrument in managing liquidity provision in the Euro area were the ECB's ***main refinancing operations***. These were regular auctions

[9] The term "open market operation" indicates that the purchase and sale of securities was originally performed on the "open market". The ECB uses this term to describe a broad set of monetary policy operations.

[10] The relationship between the return on securities and their time to maturity is called the "***term structure of interest rates***" or the "***yield curve***". The ***expectations theory of the term structure*** claims that long-run interest rates reflect market expectations on the future evolution of short-term rates.

– so called ***tenders*** – to commercial banks. The ECB defined the total volume of liquidity supplied and a ***minimum bid rate*** at which commercial banks could borrow reserves in the context of repo operations over relatively short time spans. In addition, banks had permanent access to a ***marginal lending facility*** and could store excess liquidity at a ***deposit facility***, with the ECB defining the interest rates for both facilities. Figure B8.2 illustrates that, until mid-2008, the relevant short-term interbank interest rate targeted by the ECB – the ***Euro Overnight Index Average (EONIA)*** – did not deviate too much from the interest rate on main refinancing operations and always stayed between the marginal lending rate and the deposit rate.

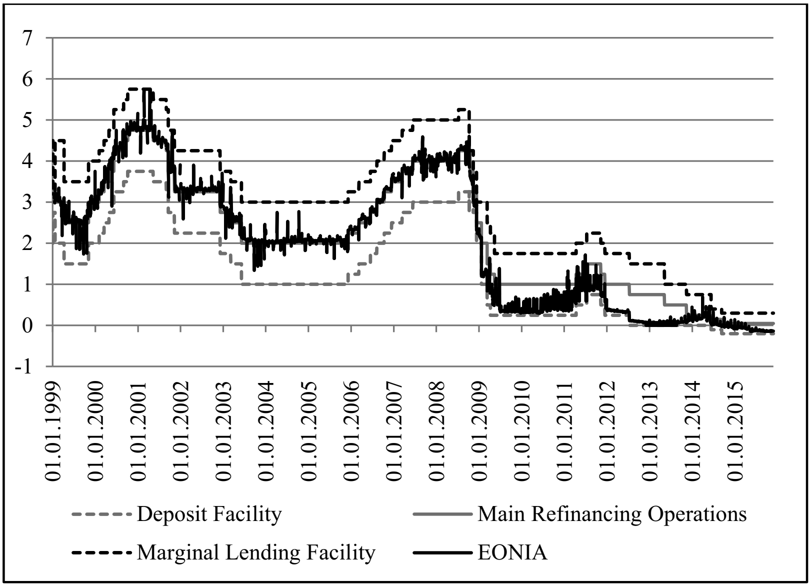


Figure B8.2: Key interest rates of the European Central Bank (in percent). Source: ECB.

In 2007, serious signs of stress started to occur in financial markets, and the collapse of real estate prices in several countries claimed its first victims among financial institutions. After the bankruptcy of the US investment bank Lehman Brothers in the fall of 2008, the interbank market broke down almost completely, as commercial banks were afraid of lending urgently needed resources to institutions that might no longer exist the other day. In the face of these problems, the ECB quickly reacted by lowering the interest rate on main refinancing operations. It turned out, however, that this was not enough, and in subsequent years, the toolbox of monetary policy was gradually expanded.

First, the time span for which commercial banks could borrow additional reserves was lengthened substantially, the minimum bid rate for main refinancing operations was replaced by a fixed rate, and banks were offered "full allotment" – i.e., instead of auctioning off a pre-defined volume of reserves, the ECB stood ready to meet any liquidity request at a fixed interest rate. Moreover, it broadened the set of assets that were accepted as collateral in refinancing operations.

Shortly after the Global Financial Crisis had left its acute stage in 2010, the European Debt Crisis called for more action. The ECB reacted by further extending the maturity of its ***long-term refinancing operations (LTROs)***. Moreover, it started various programs of outright securities purchases: while previous monetary policy measures had focused on (collateralized) loans, the ***Securities Markets Program (SMP)*** and various waves of the ***Covered Bonds Purchase Program (CBPP)*** enabled the ECB to buy certain assets on secondary markets. At the height of the European Debt Crisis in summer 2012, the ECB gave further weight to this type of measures by announcing the ***Outright Monetary Transactions Programme (OMT)***, which authorized it to purchase an unlimited amount of public securities on secondary markets, conditional on governments committing to undergo substantial economic reforms under an ESM macroeconomic adjustment program.[11]

Interestingly, the mere signal of engaging in outright monetary transactions helped to calm down markets in 2012 and 2013, and OMT has not been implemented yet. However, in the face of low (if not negative) inflation rates, tight bank credit, and sluggish economic growth in many Euro area countries, the ECB decided to take further action in 2014. First, a program of ***targeted long-term refinancing operations (TLTRO)*** granted commercial banks liquidity on favorable terms if these resources were used to lend to private companies. Moreover, the imposition of *negative* deposit rates made it very unattractive for banks to just store their reserves at the ECB, and a new wave of securities purchases programs was initiated. Finally, in January 2015, the ECB announced the ***expanded asset purchase program (APP)***, i.e. the plan that it would buy huge volumes of securities (60 billion per month) through at least September 2016. The ECB thus explicitly embarked on a policy of ***quantitative easing (QE)*** – an approach which the US Fed and the Bank of England had already adopted at an earlier stage.

[11] For a short description of the European Stability Mechanism (ESM), see Box 6.3.

The ECB's ***unconventional monetary policy*** of recent years has been the subject of an intensive public and academic debate. Critics argue that the enormous expansion of liquidity is likely to set wrong incentives in financial markets, spurring another housing boom and asset price bubbles, and that it will eventually result in high inflation. The ECB, by contrast, defends its policy by arguing that realized inflation rates are too low when compared to its objective to keep price-level growth below, but close to two percent, and by pointing at the need to prevent a "deflationary spiral". We will discuss the theoretical foundations of these arguments in later chapters. The question of whether the ECB's decisions were an appropriate response to the specific circumstances will be answered by history.

To what extent the central bank can influence the money supply via open market operations crucially depends on the exchange rate regime and on the degree of capital mobility. As we will see in the following sections, the scope for an autonomous determination of the money supply and of interest rates is limited if the central bank is committed to target a certain parity, and if cross-country interest rate differentials result in large swings of demand and supply on foreign exchange markets.

VIII.2.4 Exchange Rate Regimes in Detail

Given our brief description of the monetary policy framework, we can now return to a somewhat finer distinction between alternative exchange rate regimes. Our description will be based on the International Monetary Fund's exposition, which coarsely distinguishes between fixed exchange rate regimes (***pegs***), ***intermediate regimes***, and flexible exchange rate regimes (***floats***).

Within the group of fixed exchange rate regimes, we can differentiate between ***hard pegs***, which make it very costly to change the parity or to abandon the fixed exchange rate, and ***traditional pegs***, which allow parity adjustment. Examples for hard pegs are ***currency unions*** where different countries have agreed to use a common currency – the European Monetary Union being the most prominent recent example – "***dollarized***" systems which officially replace the domestic means of payment by a foreign currency (e.g. the US-dollar or the Euro), and ***currency boards***. With a currency board, the asset side of the central bank's balance sheet almost exclusively consists of foreign exchange reserves. As a consequence, an expansion of the monetary base is only possible if the central bank's foreign exchange reserves increase. Within the group of traditional fixed exchange rate regimes, we distinguish between ***single currency***

pegs, which fix the price of the domestic currency in terms of a single ("anchor") currency, and ***basket pegs***, which define the price of the domestic currency relative to a *group* of other currencies.

Among the intermediate regimes there are arrangements where the central bank does not announce an official exchange rate target, but follows a pre-defined rule for interventions on foreign exchange markets (***floats with rule-based intervention***). As an example, some central banks jointly agree on reducing the volatility of exchange rates by engaging in coordinated interventions if necessary (***cooperative regimes***). Alternatively, the parity changes according to a pre-announced pattern (***crawling pegs***), or the exchange rate is allowed to fluctuate within a pre-defined interval – with the central bank intervening whenever the market-determined exchange rate is about to leave this interval (***target zones and bands***). In contrast to these rule-based intermediate solutions, a regime of ***managed floating*** allows the central bank to intervene on a ***discretionary*** basis without, however, adhering to some pre-specified rule.

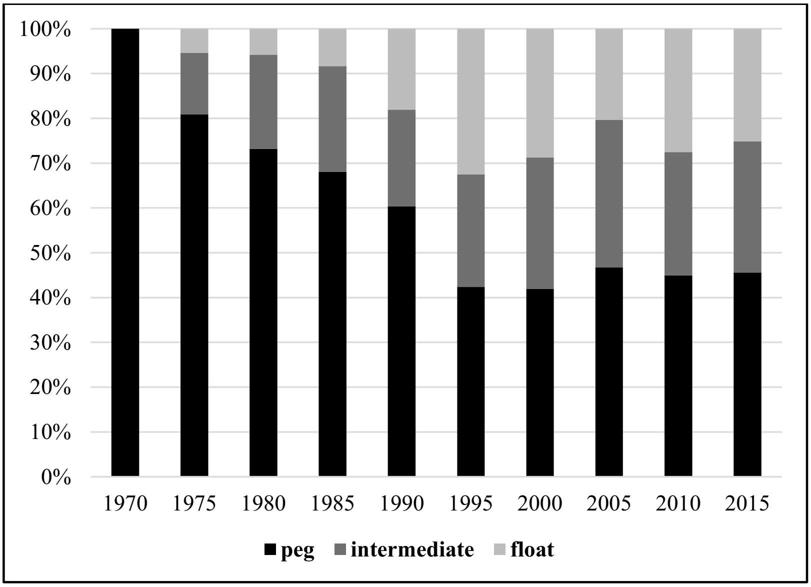


Figure 8.6: The relative frequency of different exchange rate regimes between 1970 and 2015. Source: IMF (Annual Report on Exchange Arrangements and Exchange Restrictions, different versions).

Figure 8.6 shows the relative frequency of different exchange rate regimes from 1970 through 2015.[12] When drawing this plot, we have followed the IMF's coarse classification, distinguishing between pegs, intermediate regimes, and (pure) floats. As the figure documents, the popularity of fixed exchange rate regimes has decreased considerably since the early 1970s. The relative number of pure floats increased in the mid-1990s, but in the more recent past, intermediate arrangements that leave the central bank some scope for discretionary interventions have gained in importance.

Note that, for the time being, we simply state that, at different points in time, different countries picked different alternatives with respect to their exchange rate regimes, but we do not *explain* these choices. The reasons why some countries may prefer a peg over a float, or vice versa, will be discussed in Chapter X.

VIII.3 Capital Mobility, Interest Rates, and the Nominal Exchange Rate

VIII.3.1 Spot and Forward Exchange Rates

When considering nominal exchange rates, we distinguish between ***spot exchange rates*** and ***forward exchange rates***. For spot transactions, the point in time at which the contract is concluded and the ***value date*** – i.e. the point in time at which delivery and payment take place – are usually identical.[13] By contrast, a forward contract represents a binding commitment to deliver a certain amount of currency at a later date, using an exchange rate that is fixed *today*. Forward exchange rates usually refer to standardized intervals, e.g. one week, one month, sixth months, one year or two years.

Table 8.1 shows the spot and forward exchange rates of the Euro against various currencies on December 2, 2015. While 1000 US dollars cost 943.90 Euros on the spot market, the one-year forward exchange rate amounted to

[12] To draw this graph, we have used data published in the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER)*. These data reflect a combination of countries' official announcements on their exchange rate regimes and some ex-post adjustments, made by IMF staff whenever the de-facto regime seems to differ from the announced regime. Moreover, we have deviated from the *AREAER* by classifying Euro area countries as pegs instead of floats, arguing that each of these countries has a fixed exchange rate vis-à-vis its main trading partners. Note, finally, that every country is represented as a single data point, regardless of its size. If we had weighted countries according to their GDP, the picture looks somewhat differently, with the floats accounting for a larger share, due to the US dollars flexible exchange rate (see Rose, 2011).

[13] Sometimes there is a gap of up to two days between the time of the contract and the value date.

931.50 Euros. Purchasing 1000 US dollars at this price guaranteed the delivery of 1000 US dollars in December 2016 and established the liability to deliver 931.50 Euros at that point in time.

	Spot	1 month	6 months	1 year	2 years
USD/EUR	0.9439	0.9430	0.9385	0.9315	0.9136
GBP/EUR	1.4188	1.4176	1.4111	1.4022	1.3811
CHF/EUR	0.9199	0.9213	0.9250	0.9298	0.9396

Table 8.1: Spot and forward exchange rates of the Euro (EUR) against the US dollar (USD), the Pound sterling (GBP) and the Swiss franc (CHF) on December 2, 2015 (Euros per unit of foreign currency). Source: Deutsche Bank (www.db-markets.com).

If individuals anticipate today that they will want to sell or purchase a certain amount of foreign currency at a future date, they can eliminate all ***exchange rate risk*** by concluding a forward contract.[14] Whether such a transaction turns out to be profitable ex post – i.e. at the value date – depends on the evolution of the spot exchange rate: if the spot exchange rate in December 2016 *exceeds* 0.9315 Euros per US dollar, the purchaser of US dollars benefits from having secured a lower price in December 2015. Conversely, if the spot exchange rate in December 2016 is *lower* than 0.9315 Euros per US dollar, it would have been better to wait for another year and to buy dollars on the spot market. This simple example suggests that the forward exchange rate is closely related to market participants' expectations about the future evolution of the spot exchange rate – a conjecture to which we will return later in this chapter.

VIII.3.2 Covered Interest Rate Parity

The possibility to fix the future price of a foreign currency by concluding a forward contract generates opportunities that go beyond the elimination of exchange rate risk. In particular, market participants may exploit differences between nominal returns on assets that are denominated in different currencies. This, of course, requires that different securities can be bought without being constrained by administrative barriers, i.e. that there is a sufficient degree of ***capital mobility***. Moreover, the securities under consideration have to be identical in terms of default risk and liquidity.

[14] Finance lingo has it that eliminating the risk associated with one transaction by engaging in another transaction is called "***hedging***".

If these conditions are satisfied, and if the nominal return on securities denominated in domestic currency is i_t^H, the return on securities in foreign currency is i_t^F, the spot exchange rate is E_t and the forward exchange rate whose value date is identical with the maturity date of the securities considered is F_t, the following ***covered interest rate parity condition (CIP)*** has to hold:

$$(8.2) \qquad \left(1+i_t^H\right)=\left(1+i_t^F\right)\frac{F_t}{E_t}$$

If this condition were not satisfied, market participants could realize ***arbitrage profits*** by buying and selling currency and securities. Let us consider an example in which the domestic currency is the Swiss franc (CHF) and the foreign currency is the US dollar (USD). Suppose that $1+i_t^{CHF}<\left(1+i_t^{USD}\right)\cdot\left(F_t/E_t\right)$ and that value/maturity dates are one year. In this case, profits could be earned from adopting the following strategy:

– Borrow X Swiss francs in the current period by selling securities that promise a gross return of $\left(1+i_t^{CHF}\right)$.
– Turn the X Swiss francs into US dollars at the current spot exchange rate E_t.
– Use the resulting X/E_t US dollars to purchase securities denominated in US-dollars that promise a gross return of $\left(1+i_t^{USD}\right)$.
– Sell the $X\left(1+i_t^{USD}\right)/E_t$ US dollars that you will receive in one year at the forward exchange rate F_t.
– One year later, you would dispose of $X\left(1+i_t^{USD}\right)F_t/E_t$ Swiss francs. Given the above deviation from covered interest rate parity, this sum would be higher than the $X\left(1+i_t^{CHF}\right)$ Swiss francs that you have to repay, and making X very large would result in enormous profits.

As you can imagine, the possibility to earn a lot of money without being exceptionally smart, inventive or courageous would attract many individuals' attention. As a result, the supply of Swiss francs on the spot market and the demand for Swiss francs on the forward market would increase. This would result in an adjustment of spot and forward exchange rates until the arbitrage opportunity has disappeared and the covered interest parity condition is reinstated.

Figure 8.7 plots the left-hand side and the right-hand side of (8.2), treating the Euro as the domestic currency and the Swiss franc as the foreign currency. The figure documents that, for a maturity of three months, covered interest rate parity gets strong empirical support, i.e. the two lines are almost identical. In fact, the overwhelming share of deviations from CIP is in the range of one basis point, which is likely to reflect transaction costs on foreign exchange markets.

The few periods during which return differences became larger – most notably, the fall of 2008 and the winter of 2011/12 – were characterized by extreme stress in financial markets. In these months, the assumption of perfect asset substitutability, which underlies the covered interest rate parity condition, was probably not satisfied.

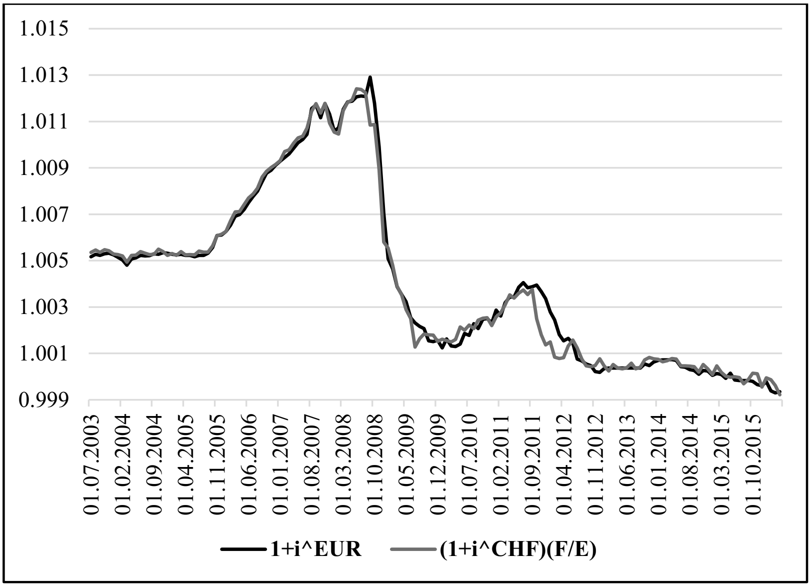


Figure 8.7: Black line: Three-month Euro deposit rate. Grey line: Implied Euro return on three-month Swiss franc deposits, i.e. three-month Swiss franc deposit rate multiplied by the three-month CHF/EUR forward exchange rate (Euros per Swiss franc) divided by the CHF/EUR spot exchange rate. Source: Thomson Reuters.

Taking logarithms on both sides of (8.2), we can derive a linear approximation to the covered interest rate parity condition that is often used in the literature:[15]

(8.3) $$i_t^H = i_t^F + f_t - e_t$$

This expression suggests that the difference between the logarithm of the forward exchange rate and the logarithm of the spot exchange rate – the so-called ***forward premium*** – should coincide with the difference between the interest rate on securities denominated in foreign and domestic currency.

[15] When deriving this expression, we use the approximation $\ln(1+x) \approx x$ which is fairly accurate for small values of x.

VIII.3.3 Uncovered Interest Rate Parity

Suppose the conditions enumerated in the previous subsection – perfect capital mobility and identical characteristics of securities – are satisfied, and the future spot exchange rate can be *perfectly anticipated*. In this case the following equation has to hold:

$$(8.4) \qquad \left(1+i_t^H\right)=\left(1+i_t^F\right)\frac{E_{t+1}}{E_t}$$

If (8.4) were violated, market participants could, again, reap profits from purchasing and selling securities and currencies. The only difference to the example in Subsection VIII.3.2 would be that the price at which currencies would be exchanged in the future would not be fixed on today's forward market, but determined by next year's spot market. Nevertheless, there would be the same arbitrage opportunities since, by assumption, there would be no uncertainty about the future spot exchange rate.

However, the assumption of perfect foresight is not very plausible in many cases: with a flexible exchange rate, forecasts about the future evolution of E_t are subject to large uncertainty. And even if the exchange rate is fixed, agents face the possibility of a realignment, or the peg may be abandoned completely. Hence, market participants have to base their decisions on their *expectations* about the future evolution of the spot exchange rate.

Expected profits from buying and selling foreign securities and currencies would be positive if the following ***uncovered interest rate parity (UIP)*** condition was not satisfied:

$$(8.5) \qquad \left(1+i_t^H\right)=\left(1+i_t^F\right)\frac{E_{t+1}^e}{E_t}$$

In (8.5), E_{t+1}^e represents the spot exchange rate that is expected to be realized in period $t+1$.[16] If market participants are ***risk neutral*** they base their portfolio decisions exclusively on expected returns, while the variability of these returns does not matter to them. In this case, equilibrium on foreign exchange markets with perfect capital mobility and perfect asset substitutability requires (8.5) to hold. Otherwise, we would observe an extreme difference between demand and supply, since all market participants would try to purchase the same currency.

[16] For the time being, we are using the superscript "*e*" to denote expectations about future variables. Note that, at this stage, we do not yet specify *how* these expectations are formed. We will discuss alternative concepts of expectations formation in Subsection VIII.4.3.

This discrepancy, in turn, would result in an adjustment of the spot exchange rate.

As we did for covered interest rate parity, we can derive a log-linear approximation of the uncovered interest rate parity condition:

$$(8.6) \qquad i_t^H = i_t^F + e_{t+1}^e - e_t$$

Equation (8.6) has a straightforward interpretation: with perfect capital mobility and risk neutrality of all market participants, securities that are denominated in different currencies but that are otherwise identical have to offer the same return in terms of the domestic currency. A lower interest rate on domestic currency securities $(i_t^H < i_t^F)$ is only compatible with foreign exchange market equilibrium if the domestic currency is expected to appreciate $(e_{t+1}^e - e_t < 0)$. By contrast, a higher interest rate on domestic currency securities requires that agents expect a nominal depreciation $(e_{t+1}^e - e_t > 0)$.

If market participants are ***risk averse***, equation (8.6) does not have to be satisfied: under a flexible exchange rate, holding foreign currency denominated securities is associated with exchange rate risk, and domestic market participants purchase these securities only if a positive return differential compensates them for this risk. A slightly modified version of (8.6) that captures this aspect reads

$$(8.7) \qquad i_t^H = i_t^F + e_{t+1}^e - e_t - \rho_t$$

The variable ρ_t represents the deviation from uncovered interest rate parity, which we interpret as a ***risk premium***. The size and sign of this deviation depends on market participants' preferences, the volatility of the exchange rate, and the correlation with other relevant shocks.[17] Note that all these relationships refer to nominal magnitudes so far. Box 8.3 relates uncovered interest rate parity to real interest rates and the evolution of the real exchange rate.

Box 8.3: Real Interest Rate Parity

The uncovered interest rate parity condition of equation (8.6) is closely related to the concepts we introduced in Chapters III and IV. To demonstrate this, we have to transform nominal variables, which refer to payments in monetary units, into real variables, which refer to payments in goods units. To accomplish this task, we first use the Fisher equation (see Box

[17] Lucas (1982) is the classic reference for a general equilibrium model that endogenizes the risk premium.

3.1) to define the expected real interest rate r^e as the difference between the nominal interest rate i and the expected inflation rate π^e. For the domestic country, this implies

$$r_t^{H,e} = i_t^H - \pi_t^{H,e}$$

By substituting this equation and the respective expression for the foreign economy into (8.6), and by taking into account the definition of the real exchange rate from (7.1), we get

$$r_t^{H,e} = r_t^{F,e} + q_{t+1}^e - q_t$$

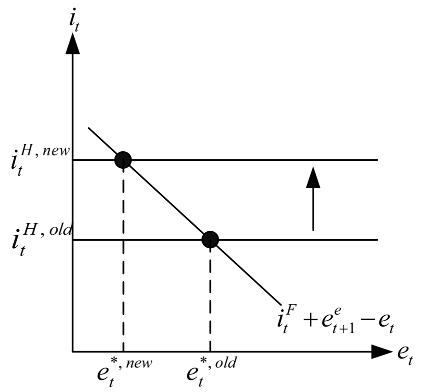
This equation requires that the expected *real* interest rate in the domestic economy equals the expected *real* interest rate in the foreign economy plus the expected *real* depreciation of the domestic currency. Note that both real interest rates refer to their domestic economy's goods bundles, i.e. they are effective (consumption-based) interest rates as introduced by equation (4.48) of Chapter IV. The real exchange rate enters the picture since a comparison of real interest rates across countries requires considering how the value of the foreign goods bundle (in terms of the domestic goods bundle) evolves over time.

In earlier chapters, we have met some special cases of this condition: if purchasing power parity prevails at all points in time, the real exchange rate is constant, and expected real interest rates have to be identical. In case of perfect foresight, this not only applies to expected, but also to actual real interest rates. In fact, the concept of a "world" real interest rate prevailing on all financial markets, on which most of our analysis in Chapter III was based, rested on the joint assumptions of perfect capital mobility, perfect foresight, and purchasing power parity. If we drop the assumption of purchasing power parity, the above equation requires that anticipated changes of the real exchange rate are mirrored by differences of real interest rates.

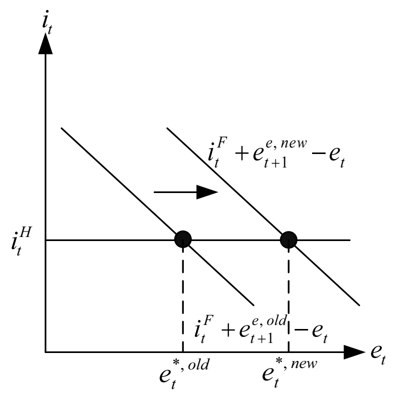
VIII.3.4 Determining the Nominal Exchange Rate under Perfect Capital Mobility: A Simple Diagram

If the exchange rate is fixed and market participants do not expect any change of E, i.e. $E_{t+1}^e = E_t$ the uncovered interest parity condition has an important implication: with perfect capital mobility, $i_t^H = i_t^F$ has to prevail, i.e. nominal interest rates must be identical for the two countries considered. We will return to the policy consequences of this insight in Chapter X.

By contrast, a flexible exchange rate adjusts to changes in market constellations. To understand the forces at play, we illustrate the log-linear version of the uncovered interest rate parity condition from (8.6) in Figure 8.8. The position of the horizontal line is determined by the domestic interest rate i_t^H. The downward-sloping line reflects the expected return in domestic currency units that can be reaped by buying foreign-currency denominated securities and by selling the returns at the future spot exchange rate. This return is lower if a lot of domestic currency units have to be paid for one unit of the foreign currency. The line is therefore decreasing in the current spot exchange rate e_t. Its position is determined by the foreign interest rate i_t^F and market participants' expectations about the future spot exchange rate e_{t+1}^e, which, for the time being, we treat as an exogenous variable.



8.8a: Effects of a domestic interest rate increase



8.8b: Effects of changing expectations

Figure 8.8: Using uncovered interest rate parity to determine the nominal exchange rate in equilibrium

Figure 8.8a shows that the domestic currency appreciates if the domestic interest rate increases ceteris paribus – i.e. with i_t^F and e_{t+1}^e remaining constant. The intuition behind this result is straightforward: a higher value of i_t^H makes domestic securities more attractive and raises the demand for the domestic currency. This, in turn, results in an appreciation in period *t*. In equilibrium, the higher interest rate on domestic securities is compensated by a higher expected (!) depreciation of the domestic currency $(e_{t+1}^e - e_t)$. Figure 8.8b illustrates that an increasing value of e_{t+1}^e results in a nominal depreciation of the domestic currency – i.e, a higher value of e_t – in the *current* period: the anticipation of a lower value in the future reduces the demand for the domestic currency on current spot markets and therefore results in a nominal depreciation in period *t*.

The latter result conveys an important message: today's exchange rate is driven by observable variables, but also by market participants' expectations about the future exchange rate e_{t+1}^{e}. Of course, the simple comparative-static exercises in Figure 8.8 are rather a point of departure than a final result, especially since we have treated markets' expectations as exogenous. In the following section, we will start to ***endogenize*** these expectations and embed the insight gained from Figure 8.8 into a more comprehensive model.

VIII.4 The Monetary Model of Exchange Rates

VIII.4.1 Motivation

The uncovered interest rate parity condition implies that the current nominal exchange rate crucially depends on market participants' expectations about its future evolution. If e_{t+1}^{e} increases for given interest rates, this implies an immediate depreciation of the current spot exchange rate. Hence, the nominal exchange rate – the relative price of a currency – behaves like most asset prices, for which market expectations are at least as important as observable data. This becomes even more obvious if we shift (8.6) one period into the future and substitute the result into the original version of that equation:

$$(8.8) \qquad e_t = i_t^F - i_t^H + i_{t+1}^{F,e} - i_{t+1}^{H,e} + e_{t+2}^{e}$$

This process of forward substitution can be continued *ad infinitum*. As a result, we arrive at

$$(8.9) \qquad e_t = i_t^F - i_t^H + \sum_{j=1}^{\infty} \left(i_{t+j}^{F,e} - i_{t+j}^{H,e} \right) + \lim_{\tau \to \infty} e_{t+\tau}^{e}$$

The current nominal exchange rate thus not only depends on the current interest rate differential, but also on the *entire expected time path* of future interest rate differentials. This is because, in every period, the *current* exchange rate is tied to the expected *future* exchange rate – and thus future interest rates – through the uncovered interest rate parity condition. Moreover – and still following the logic of the uncovered interest rate parity condition – the nominal exchange rate expected for the infinitely distant future plays a role.

The contribution of the ***monetary model of the exchange rate***, which we will present in this section, consists in tracing the interest differentials in (8.9) back to their fundamental determinants – in particular, national money supplies and real output levels. The model is based on the following assumptions:

- Due to perfect capital mobility and risk neutrality of all market participants, the ***uncovered interest rate parity condition***, i.e. equation (8.6), is satisfied in every period.
- All goods are tradable without costs, and national goods bundles are identical. Hence, ***absolute purchasing power parity*** prevails in every period.[18]
- Since all prices are perfectly flexible, the evolution of nominal magnitudes (interest rates, prices, exchange rates) does not influence the level and evolution of real output, i.e. the model postulates ***monetary neutrality***. Real GDP, consumption etc. are determined by the mechanisms presented in sections III to V. These magnitudes are not necessarily constant, but exogenous to the model.
- In every period, nominal money supply equals money demand, i.e. there is ***money market equilibrium***.[19]
- Market participants have ***rational expectations***, i.e. when making predictions about future variables they use all available information and do not commit *systematic* mistakes.

The concepts of purchasing power parity and uncovered interest rate parity have been considered quite extensively on the preceding pages. By contrast, the assumptions on the money market and expectations formation are new. This is why we will continue by shedding light on the determinants of money demand and on the implications of alternative hypotheses on expectations formation. After this, we will combine the various components of the model and show how we can use them to determine the nominal exchange rate.

VIII.4.2 Money Supply and Money Demand

In Section VIII.2, we described how the central bank can influence the money supply through various channels – foreign exchange interventions and open market operations, in particular. We also emphasized that a complete control of

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[18] Given the devastating empirical evidence on the validity of PPP in the short run, this assumption seems quite problematic at first glance. However, it can be shown that the central predictions of the monetary model still hold if the real exchange rate is subject to fluctuations. What is important is that these fluctuations are exogenous to the model, and that they are not, e.g., affected by variations in the nominal money supply.

[19] In the context of this model, money market equilibrium does not just refer to the (interbank) money market that we have mentioned in Section VIII.2. What we have in mind, instead, is the market on which the supply of a certain monetary aggregate – e.g. M1 – meets agents' money demand.

the money supply is impossible since a large share of all monetary aggregates is driven by private agents' decisions, on which the central bank's influence is limited. In this section, however, we abstract from these qualifications and assume that the ***nominal money supply*** M^s is completely determined by the central bank.

In equilibrium, money supply and ***money demand*** have to coincide. To derive a money demand function, it is important to review the motives that induce individuals to hold money:

- Money acts as a ***unit of account*** and a ***medium of exchange*** and thus facilitates transactions. First, in a world with n different goods, using money as a numéraire reduces the number of relevant prices from $n(n-1)/2$ to n. Moreover, economic transactions do not have to be based on a ***double coincidence of wants*** if money is accepted as a medium of exchange.[20] The buyer of a good or service does not have to offer a good or service desired by the seller. Instead, he pays a certain amount of money, which the seller can then use at will. The ***transactions motive*** for holding money, which is based on these arguments, should be reflected by the fact that money demand increases as the volume of transactions grows. Moreover, the nominal money demand should positively depend on the ***price level*** since higher prices reduce the volume of real transactions that can be realized with a given nominal amount of money.
- Apart from its function as a medium of exchange, money can be used as a store of value. Cash holdings and checking accounts are inferior to alternative securities due to their lower expected return, but they are available more quickly – i.e. characterized by higher liquidity – and not subject to asset price fluctuations. A money demand function should therefore account for this ***store of value motive***.

There are different ways to represent these basic considerations in a formal framework. A popular approach is to treat real money holdings as a variable that enters agents' utility function. This approach seems arbitrary at first glance, but it may be justified by invoking money's role as a medium of exchange and unit of account: in this role, money generates utility since its possession and use reduces the time necessary for transactions – the so-called ***shopping time*** – and thus increases individuals' leisure.[21]

[20] This motivation of money demand and the term "double coincidence of wants" go back to the British economist William Jevons (1835-1882).

[21] Critics of this approach like Neil Wallace (2000) emphasize that the "shopping time" argument does not explain why individuals do not use other securities as means of payment.

Using such a framework, we can derive money demand as the solution to an intertemporal optimization problem. To achieve this, we follow the approach introduced in Chapter III and use the two-period model of a representative consumer (RC) who has perfect foresight and who maximizes the following objective function:

$$(8.10) \qquad U_1 = \ln C_1 + \chi \ln\left(\frac{M_1}{P_1}\right) + \beta\left[\ln C_2 + \chi \ln\left(\frac{M_2}{P_2}\right)\right] \text{ with } \chi > 0$$

The dependence of RC's utility on ***real money holdings*** (*M/P*) is due to the fact that the volume of transactions which can be realized with a given (nominal) amount of money is the lower, the higher the price level. When maximizing (8.10), RC faces the following constraints:

$$(8.11) \qquad B_{t+1} + M_t = \left(1 + i_t\right) B_t + M_{t-1} + P_t Y_t - P_t C_t \qquad t = 1, 2$$

This equation differs from the law of motion of the net international investment position, which we introduced in Chapter III, in several ways. First, all magnitudes are denoted in monetary units: at the start of period t, RC holds securities worth B_t that promise a nominal interest rate i_t. Real income Y_t and real consumption C_t are multiplied with the price level P_t. The fact that RC allocates his savings of period t to interest-bearing bonds (B_{t+1}) and money (M_t) reflects money's characteristic as a store of value: the amount of money that is used for purchasing and selling goods and services at the end of period t does not disappear, but represents a part of the wealth that RC carries into period $t+1$.[22]

The further constraints RC has to take into account are:

$$(8.12) \qquad B_1 = 0$$

$$(8.13) \qquad M_0 = 0$$

$$(8.14) \qquad B_3 = 0$$

[22] The convention to use different time subscripts for bond holdings and money holdings at the end of a period has become standard in the literature. The reason is that this allows to highlight the tradeoff between holding money as an (inferior) store of value and as a (utility-enhancing) means of payment. In a two-period framework, this has the strange consequence that RC possibly holds a positive sum of money at the end of period 2. However, this implication is inconsequential as long as we focus on optimal money demand in period 1, and it disappears in an infinite-horizon version of the model.

In what follows, we will concentrate on the conditions that characterize RC's optimal consumption, his optimal demand for bonds, and his optimal demand for money in period 1. To this end, we specify the following Lagrange function:

$$
\begin{aligned}
Z \;=\; & \ln C_1 + \chi \ln\left(\frac{M_1}{P_1}\right) + \beta\left[\ln C_2 + \chi \ln\left(\frac{M_2}{P_2}\right)\right] \\
& + \Lambda_1 \left[P_1 Y_1 - P_1 C_1 - B_2 - M_1 \right] \\
& + \Lambda_2 \left[\left(1 + i_2\right) B_2 + M_1 + P_2 Y_2 - P_2 C_2 - M_2 \right]
\end{aligned}
\tag{8.15}
$$

By taking derivatives of Z with respect to C_1, C_2, M_1 and B_2 and setting them equal to zero, we arrive at the following necessary conditions for a utility maximum:

$$\frac{1}{C_1} - \Lambda_1 P_1 = 0 \tag{8.16}$$

$$\frac{\beta}{C_2} - \Lambda_2 P_2 = 0 \tag{8.17}$$

$$\frac{\chi}{M_1} - \Lambda_1 + \Lambda_2 = 0 \tag{8.18}$$

$$-\Lambda_1 + \Lambda_2 \left(1 + i_2\right) = 0 \tag{8.19}$$

We can combine equations (8.16), (8.17) and (8.19) to get the following expression:

$$\frac{1}{C_1} = \beta\left(1 + i_2\right)\frac{P_1}{P_2}\frac{1}{C_2} \tag{8.20}$$

This is the intertemporal Euler equation, which we know from previous chapters. Obviously, the time path of real consumption depends on the real interest rate, which we get by correcting the nominal interest rate for the (perfectly anticipated) increase of the price level.

By combining equations (8.16), (8.18) and (8.19) we arrive at

$$\chi \frac{P_1 C_1}{M_1} = \frac{i_2}{1 + i_2} \tag{8.21}$$

This condition requires the marginal rate of substitution between real consumption and real money to equal the relative price of holding money.[23] This price depends on the nominal interest rate i_2, which is paid on bonds that are bought in period 1 and that mature in period 2: the higher i_2, the higher the opportunity costs of holding wealth in the form of money instead of interest-yielding bonds. Equation (8.21) can be used to derive the following ***money-demand equation***:

$$(8.22) \qquad \frac{M_1}{P_1} = \chi\left(\frac{1+i_2}{i_2}\right)C_1$$

This expression shows that nominal money demand increases in the price level and in real consumption, and that it decreases in the nominal interest rate. All three effects are intuitive: a higher price level P_1 raises the amount of money that is necessary to buy a given amount of goods. A higher level of consumption C_1 increases the real volume of transactions and thus the required money holdings. Finally, a higher nominal interest rate i_2 raises the opportunity costs of holding money and therefore reduces the attractiveness of money as a store of value. Box 8.4 explains that these relationships could also be derived from other approaches to money demand.

Box 8.4: Alternative Money Demand Motives

Equation (8.22) is based on the maximization of a utility function which increases in real money holdings. This approach, which was brought forward by Sidrauski (1967) is not the only way to motivate the dependence of real money demand on the real volume of transactions and the nominal interest rate.

As an alternative, Baumol (1952) and Tobin (1956) describe money demand as the solution to an optimization problem that is analogous to a firm's choice of inventories: when deciding on their average money holdings, individuals consider the opportunity costs in the form of foregone interest payments, but also the transaction costs associated with moving their wealth from interest-bearing securities into money. The lower these transaction costs, the lower individuals' money demand. A positive dependence of desired money holdings on income results from the assumption that agents' total wealth – including the share that is held as money – is proportional to their income. The negative dependence of money demand

[23] Recall that the marginal rate of substitution is the ratio of the partial derivatives $\partial U_1 / \partial(M_1/P_1)$ and $\partial U_1 / \partial C_1$.

on the interest rate is due to the opportunity-cost argument mentioned above.

A third approach goes back to Clower (1967) who argues that total consumption in a period has to be financed out of money holdings available at the *start* of this period. Due to this ***cash-in-advance constraint*** individuals, when deciding on how to allocate their wealth to interest-bearing bonds and to money, account for the fact that a high consumption level in the following period is only feasible if real money holdings are sufficient. As in the other models, the downside of holding too much money is the high opportunity cost in the form of foregone interest payments.

VIII.4.3 Rational Expectations

The concept of rational expectations, which goes back to John Muth (1961), and which was firmly anchored in economic theory by Robert Lucas (1976), postulates that individuals base their forecasts about the future on *all available information*. The value of variable X anticipated in period t for period $t+1$ can thus be written as a conditional expectation:[24]

$$X^e_{t+1} = \mathrm{E}_t X_{t+1} \tag{8.23}$$

In the second part of this expression, the index t indicates that expectations about period $t+1$ are based on all information available in period t.

While the concept of rational expectations seems simple and straightforward at first glance, it turns out to be quite demanding. This is because it assumes that agents process all information about the current state and the future evolution of exogenous parameters. Moreover, they have to be able to combine these observations and forecasts with the correct model to compute the expected equilibrium values of all endogenous variables.

As a result, the realization of any variable may still deviate from the conditional expectation in (8.23), i.e.

$$X_{t+1} = \mathrm{E}_t X_{t+1} + \varepsilon_{t+1} \tag{8.24}$$

However, the conditional expectation of the ***forecast error*** ε_{t+1} equals zero, i.e. $\mathrm{E}_t \varepsilon_{t+1} = 0$. That is, individuals do not commit ***systematic errors*** when forming their expectations. The absence of systematic errors is the key property of

[24] Recall that, in order to avoid a confusion of the expectations operator E_t with the spot exchange rate E_t, we denote the exchange rate by using *italics* (E_t), while the expectations operator is represented by a "straight" letter (E_t).

rational expectations, since alternative plausible expectation formation mechanisms do not satisfy this property. Box 8.5 illustrates this by comparing rational expectations to the alternative concept of "adaptive expectations".

Box 8.5: Adaptive Expectations

It is the key feature of rational expectations that individuals use all available information to make their predictions about the future. By contrast, the alternative concept of ***adaptive expectations*** postulates that individuals adjust their forecast to correct *past expectation errors*, i.e.

$$X_{t+1}^{e,adaptive} = X_t^{e,adaptive} + \theta\left(X_t - X_t^{e,adaptive}\right)$$

with $\theta \in [0,1]$. The notion that individuals correct past mistakes seems quite plausible at first glance. However it is easy to show that this approach allows for *systematic* expectation errors. To illustrate this, we use a simple example: we assume that the evolution of variable X is determined by the following first-order autoregressive process:

$$X_{t+1} = \rho\, X_t + v_{t+1}$$

By assumption, the disturbance v_{t+1} is zero in expected value, and is not correlated over time. In period 0 we have $X_0 = 0$. Using this information, we can compute the expectations error – i.e. the deviation of the realized value from the expected value of X – that emerges from rational vs. adaptive expectations. Figure B8.5 shows the evolution of the expectations error for the parameter values $v_1 = 1, v_2 = v_3 = \ldots = 0, \rho = 0.9, \theta = 0.5$, starting in period 1.

Regardless of the way they form their expectations, individuals are surprised by the positive shock to X in period 1. However, while the expectations error has disappeared in period 2 for the case of rational expectations, it persists for quite a while in the case of adaptive expecations. This is because individuals only slowly incorporate their past mistakes into their forecasts about the future.

The main justification of rational expectations is that it is not plausible to see individuals accepting the losses associated with systematic errors for a long time. Instead, they should be eager to base their forecasts on all available information. Critics of rational expectations object that the concept is too demanding in terms of market participants' information about the evolution of exogenous variables, their computational capacities, and their knowledge of economic relationships – i.e. of the "correct model". If the economic environment is reasonably stable, and if the costs of information retrieval and processing exceed the costs of systematic expectations errors, the use of simple heuristics may be compatible with the idea of rational behavior.

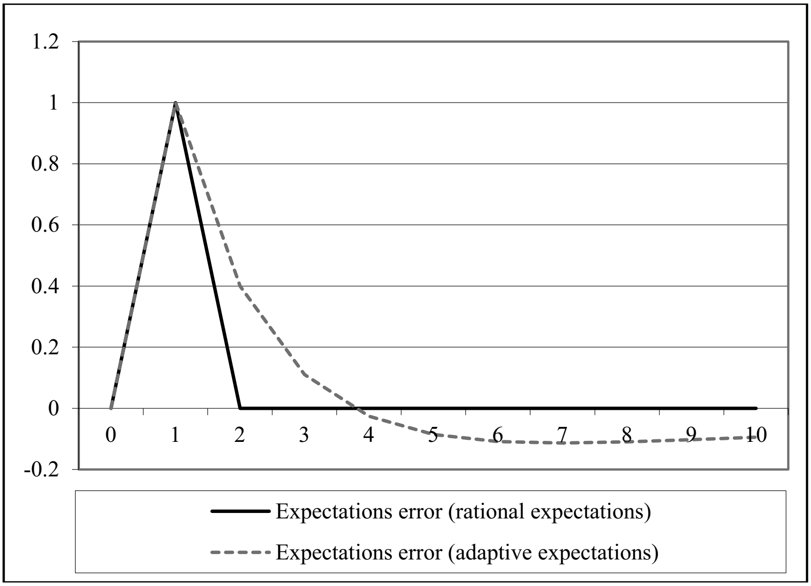

Figure B8.5: Evolution of the expectations error for rational and adaptive expectations.

VIII.4.4 The Structure of the Monetary Model of the Exchange Rate

Having introduced the determinants of money demand and the concept of rational expectations, we are now in a position to review the structural equations of the monetary model. When doing this, we replace all variables – except for the interest rates – by their (natural) logarithms, denoting them as lower-case letters. With rational expectations, the log-linearized version of the uncovered interest rate parity condition thus reads as follows:

$$(8.25) \qquad i_t^H = i_t^F + \mathrm{E}_t\, e_{t+1} - e_t$$

For the (natural logarithm of the) domestic price level, absolute purchasing power parity implies

(8.26) $$p_t^H = e_t + p_t^F$$

The natural logarithm of domestic nominal money demand is given by

(8.27) $$m_t^{H,D} = p_t^H + \phi\, y_t^H - \lambda\, i_t^H$$

where $\phi > 0$ representing the elasticity of money demand with respect to income and $\lambda > 0$ the (semi-)elasticity with respect to the domestic interest rate.[25] Finally, equilibrium on the domestic money market requires domestic money demand $m^{H,D}$ to equal the (exogenous) domestic money supply m^H, i.e.

(8.28) $$m_t^{H,D} = m_t^H$$

Note that money demand in (8.27) slightly differs from the function we derived in (8.22) since we have replaced real consumption by real GDP. In the present model, this modification is inconsequential because – due to monetary neutrality – both consumption and GDP are exogenous. Moreover, the use of y is less restrictive than the use of c, and accounts for the fact that other components of GDP like investment and government consumption are associated with transactions that also exploit the properties of money as a medium of exchange. Box 8.6 documents that the theoretical specification of money demand in (8.27) enjoys broad empirical support.

Box 8.6: Empirical Evidence on Money Demand

The properties of money demand are the subject of intensive empirical research, and there are numerous estimates of money demand functions. The respective analyses usually estimate variants of the following regression equation:

$$m_t - p_t = \phi\, y_t + \lambda\, i_t + \sum_{k=1}^{n} \beta_k\, x_{kt} + \varepsilon_t$$

The summation term on the right-hand side reflects the fact that, in addition to income and interest rates, other variables are also included as potential determinants of (real) money demand. Individual studies differ with respect to the samples they are based on, the estimation approaches they adopt, the set of regressors, and the data they use for m and i. For example, one can employ a narrow or a broad monetary aggregate (M1, M2, or M3) for m

[25] This is a *semi*-elasticity since it describes the reaction of the logarithm of money demand to a change in the interest rate.

on the left-hand side, and i can be a short-run or a long-run interest rate (or both).

In a meta-analysis published in 2006, Markus Knell and Helmut Stix summarize the large number of results on money demand, computing averages for the estimated parameter values. Considering the numbers in Table B8.6, which is based on the Knell/Stix study, we see that the estimated income and interest rate elasticities differ across countries and regions. Moreover, it seems to be important whether a narrow monetary aggregate like M1 or a broad aggregate like M3 is analyzed. Nevertheless, we arrive at the fairly robust result that the income elasticity of money demand is positive and close to one, while the interest rate elasticity is negative, as postulated by theoretical models.

	Narrow monetary aggregate		Broad monetary aggregate	
	Income elast.	Interest rate elast.	Income elast.	Interest rate elast.
All	0.83	-0.45	1.10	-0.28
USA	0.65	-0.50	0.96	-0.19
Germany	1.24	-0.60	1.18	-0.16

Table B8.6: Estimated parameters of the money demand function (Averages of the studies considered by Knell and Stix, 2006). The interest rate elasticity shows the reaction of money demand to a change of long-term interest rates. Source: Knell and Stix (2006).

VIII.4.5 The Nominal Exchange Rate in Equilibrium

By combining equations (8.25) – (8.28), we arrive at the following difference equation:

$$(8.29) \qquad e_t = \left(\frac{1}{1+\lambda}\right)\left(m_t^H - p_t^F - \phi\, y_t^H + \lambda\, i_t^F\right) + \left(\frac{\lambda}{1+\lambda}\right)\mathrm{E}_t\, e_{t+1}$$

Hence, the nominal exchange rate depends on variables that can be observed in the current period, but also on the expected future level of the exchange rate $\mathrm{E}_t\, e_{t+1}$. Note that this expression differs from equation (8.8) by relating the difference between domestic and foreign interest rates to the domestic money supply, the foreign price level, the domestic income, and the foreign interest rate.

As mentioned above, we treat domestic income as an exogenous variable. Moreover, we assume that the country under consideration is a ***small open economy***, which implies that foreign prices and interest rates are not affected by macroeconomic conditions in the domestic economy.

By shifting (8.29) one period into the future and forming period-t expectations, we get

$$(8.30)\qquad \mathrm{E}_t\, e_{t+1} = \left(\frac{1}{1+\lambda}\right) \mathrm{E}_t\left(m_{t+1}^H - p_{t+1}^F - \phi\, y_{t+1}^H + \lambda\, i_{t+1}^F\right) + \left(\frac{\lambda}{1+\lambda}\right) \mathrm{E}_t\, e_{t+2}$$

This term can be substituted into (8.29). If we repeat this forward-substitution an infinite number of times, we arrive at

$$(8.31)\qquad \begin{aligned} e_t &= \left(\frac{1}{1+\lambda}\right) \sum_{s=t}^{\infty} \left(\frac{\lambda}{1+\lambda}\right)^{s-t} \mathrm{E}_t\left(m_s^H - p_s^F - \phi\, y_s^H + \lambda\, i_s^F\right) \\ &\quad + \lim_{\tau\to\infty} \left(\frac{\lambda}{1+\lambda}\right)^{\tau} \mathrm{E}_t\, e_{t+\tau} \end{aligned}$$

In what follows, we will call the first term on the right-hand side of (8.31) the ***fundamental value*** (e_t^{fund}) of the nominal exchange rate in period t: this value is the discounted sum of the – current and expected – ***monetary fundamentals*** ($m_s^H - p_s^F - \phi\, y_s^H + \lambda\, i_s^F$). Whether the second term on the right-hand side of (8.31) disappears or not depends on the long-run evolution of the nominal exchange rate: If $\mathrm{E}_t\, e_{t+\tau}$ converges against a finite number, this expression equals zero, and the nominal exchange rate coincides with its fundamental value.[26]

We start by assuming that this condition is satisfied. In this case, the nominal exchange rate in period t is given by

$$(8.32)\qquad e_t = e_t^{fund} = \left(\frac{1}{1+\lambda}\right) \sum_{s=t}^{\infty} \left(\frac{\lambda}{1+\lambda}\right)^{s-t} \mathrm{E}_t\left(m_s^H - p_s^F - \phi\, y_s^H + \lambda\, i_s^F\right)$$

The central message of this expression is that the current value of the nominal exchange rate not only depends on currently observed monetary fundamentals, but also on agents' expectations about the future evolution of these variables. This implies that the nominal exchange rate may fluctuate as a result of changing expectations – even if current fundamentals do not move at all.

[26] This is because – as in the transversality condition introduced in Section III.7 – the term $\left[\lambda/(1+\lambda)\right]^{\tau}$ converges to zero as τ approaches infinity.

We illustrate this by using a simple example: suppose that, through period 0, the nominal money supply is given by the constant $\underline{m}$, and that market participants do not expect any policy changes for the future. For simplicity, we assume that $\left(p_s^F + \phi\, y_s^H - \lambda\, i_s^F\right) = 0$ for all s. This implies that the nominal exchange rate in the initial steady state is given by $\underline{m}$. In period 1, the central bank credibly announces that, in period T, it will raise the (natural logarithm of the) money supply from $\underline{m}$ to $\overline{m}$. For market participants' expectations in period t, this implies

$$(8.33) \qquad \mathrm{E}_t m_s^H = \begin{cases} \underline{m} & \text{für } s = 0, 1, ..., T-1 \\ \overline{m} & \text{für } s \geq T \end{cases}$$

By substituting the expected time path of money supply given by (8.33) into (8.32), we get

$$e_t = \left(\frac{1}{1+\lambda}\right) \sum_{s=t}^{T-1} \left(\frac{\lambda}{1+\lambda}\right)^{s-t} \underline{m} + \left(\frac{1}{1+\lambda}\right) \sum_{s=T}^{\infty} \left(\frac{\lambda}{1+\lambda}\right)^{s-t} \overline{m}$$

For $t = 1, 2, \ldots T$. To simplify this expression, we use the fact that, for $\left|a\right| < 1$, we can write:

$$\sum_{s=t}^{T-1} a^{s-t} = \frac{1-a^{T-t}}{1-a}$$

Using this result, we get

$$(8.34) \qquad e_t = \overline{m} - \left(\overline{m} - \underline{m}\right)\left[1 - \left(\frac{\lambda}{1+\lambda}\right)^{T-t}\right] \qquad \text{for } t = 1, 2, ..., T$$

The time path of the nominal exchange rate for this example is depicted in Figure 8.9. It is not surprising that the exchange rate arrives at its new steady-state level $\overline{m}$ in period T: starting in this period, no further fluctuations are expected, the domestic interest rate coincides with the foreign interest rate, the (natural logarithm of the) domestic price level depends on the nominal exchange rate and the foreign price level. Since we have set $\left(p_s^F + \phi\, y_s^H - \lambda\, i_s^F\right) = 0$, we arrive at $e_t = \overline{m}$ for $t \geq T$.

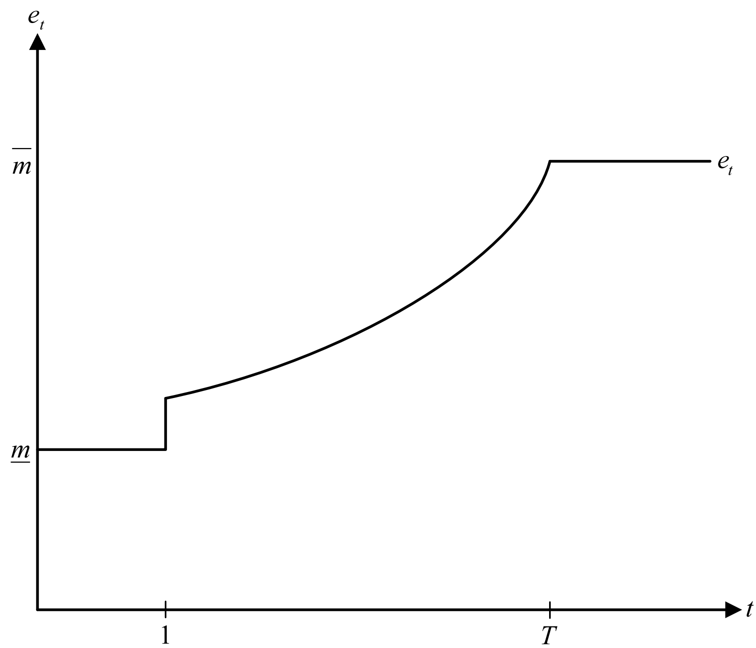

Figure 8.9: The time path of the nominal exchange rate for an announced increase of the money supply.

It is striking, however, that e already changes in period 1 – i.e. in a period in which the money supply still remains at its previous level. All that has changed are market participants' *expectations*. This surprising finding is due to the relationship between the expected future nominal exchange rate and the current nominal exchange rate that is established by uncovered interest rate parity. If the exchange rate remained at its initial level through period $T-1$, market participants would expect a substantial depreciation between periods $T-1$ and T. This expected depreciation would increase e_{T-1} – i.e. a part of the depreciation would have to occur one period before the actual increase of the money supply. Following the same logic, depreciations have to take place in periods $T-2$, $T-3$, …, 1. This explains why e_t increases at a time at which none of the observable fundamentals has actually changed.

VIII.4.6 Speculative Bubbles

In the last section, we have derived the *fundamental value* of the nominal exchange rate, e_t^{fund}, by using the transversality condition introduced above, i.e.

$\lim_{\tau\to\infty}[\lambda / 1+\lambda]^{\tau}\ \mathrm{E}_t\, e_{t+\tau} = 0$. In order to better understand the economic content of this equation, we slightly rewrite (8.31), for simplicity defining $\Phi_s \equiv m_s^H - p_s^F - \phi\, y_s^H + \lambda\, i_s^F$:

(8.35)

$$e_t = \left(\frac{1}{1+\lambda}\right)\sum_{s=t}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^{s-t}\ \mathrm{E}_t\,\Phi_s + \left(\frac{1+\lambda}{\lambda}\right)^{t}\lim_{\tau\to\infty}\left(\frac{\lambda}{1+\lambda}\right)^{t+\tau}\ \mathrm{E}_t\, e_{t+\tau}$$

which is equivalent to

(8.36) $$e_t = \left(\frac{1}{1+\lambda}\right)\sum_{s=t}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^{s-t}\ \mathrm{E}_t\,\Phi_s + \left(\frac{1+\lambda}{\lambda}\right)^{t} b_0$$

with $b_0 = \lim_{\tau\to\infty}\left[\lambda / \left(1+\lambda\right)\right]^{t+\tau}\ \mathrm{E}_t\, e_{t+\tau}$. Equation (8.36) is the „general solution" of the difference equation (8.29).[27] The fundamental value e_t^{fund} is the solution of (8.29) for the case of setting $b_0 = 0$.

What happens if b_0 differs from zero? For a positive value of b_0 in equation (8.36), e_t grows infinitely large over time, i.e. the domestic currency depreciates up to the point of being completely worthless. Conversely, e_t goes towards minus infinity if b_0 is negative. To understand the economic mechanisms behind these somewhat disconcerting results, we set $\mathrm{E}_t\,\Phi_s = 0$ for all s. This implies that $e_t^{fund} = 0$.[28] By contrast, the general solution in (8.36) reads

(8.37) $$e_t = b_0\left(\frac{1+\lambda}{\lambda}\right)^{t}$$

Expectations about the future values of e_t are:

(8.38) $$\mathrm{E}_t\, e_{t+j} = b_0\left(\frac{1+\lambda}{\lambda}\right)^{t+j}$$

Hence, if $b_0 > 0$ market participants expect that e keeps growing, i.e. that there will be an infinite sequence of nominal depreciations. To check whether these expectations can be justified, we substitute (8.38) into a version of (8.29) that

[27] Chiang and Wainwright (2005) as well as Obstfeld and Rogoff (1996: 726ff.) offer very helpful instructions on how to solve linear difference equations.

[28] Recall that e_t is the natural logarithm of the nominal exchange rate, which equals zero if the nominal exchange rate equals one.

is shifted one period into the future. Given our assumption that $\Phi_s = 0$ in all periods, this yields

$$(8.39) \qquad e_{t+1} = \left(\frac{\lambda}{1+\lambda} \right) \mathrm{E}_t\, e_{t+2} = b_0 \left(\frac{1+\lambda}{\lambda} \right)^{t+1}$$

Hence, the depreciation that is *expected* for period $t+1$ is confirmed by the actual evolution of the exchange rate. This is due to the fact that the loss in value that is expected for future periods results in an increasing value of e in the current period. Conversely, an expected future *decline* of e results in an appreciation in the current period. As a consequence, we may observe an exponentially decreasing deviation of the nominal exchange rate from its fundamental value. The crucial feature of such ***speculative bubbles*** is that they are compatible with rational expectations. For as long as the bubble does not burst – i.e. as long as individuals keep believing in a sequence of appreciations or depreciations – these expectations are validated by the actual evolution of the exchange rate.

When we determined e_t^{fund} in the previous subsection, we explicitly suppressed such bubbles by making the following assumption:

$$(8.40) \qquad \lim_{\tau \to \infty} \left[\lambda / 1+\lambda \right]^{\tau} \mathrm{E}_t\, e_{t+\tau} = 0$$

As we have shown above, this is identical to the assumption that $b_0 = 0$. Hence, we have excluded the existence of speculative bubbles by selecting among all possible time paths of the nominal exchange rate the one that reflected its fundamental value.

We already used a similar ***transversality condition*** to derive the intertemporal budget constraint in Section III.7. At that point, we argued that an infinitely high net international investment position would not be compatible with domestic residents' rationality. Conversely, a NIIP that approaches minus infinity would not be tolerated by other countries. When it comes to justifying the transversality condition for the nominal exchange rate, it is difficult to come up with a similar argument. This is because a currency is an asset which – by contrast to real assets – does not have an intrinsic value. As a consequence, its value entirely depends on market participants' expectations, and both pessimistic and optimistic expectations about its future value may quickly turn into ***self-fulfilling prophecies***. Nevertheless, most economists assign special importance to the fundamental value e_t^{fund}. This is probably due to the fact that, while foreign exchange markets are occasionally characterized by considerable appreciations or depreciations of individual currencies, these episodes rarely last very long.

VIII.4.7 A Look at the Data

In order to assess whether the monetary model offers a good explanation of observed nominal exchange rates, we extend our framework by introducing a foreign economy F. Combining the foreign version of the money market equilibrium condition (8.27) with equations (8.25) – (8.28), we arrive at an expression that describes the (fundamental) exchange rate in period t as

$$(8.41) \qquad e_t = \left(\frac{1}{1+\lambda}\right)\sum_{s=t}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^{s-t} \mathrm{E}_t\left(m_s^H - m_s^F + \phi\, y_s^F - \phi\, y_s^H\right)$$

The foreign price level and the foreign interest rate have vanished since they are now determined by the evolution of the money supply and of real GDP in country F. Using $\Phi_s^R \equiv \left(m_s^H - m_s^F + \phi\, y_s^F - \phi\, y_s^H\right)$ to denote the monetary fundamentals *in relative terms*, we can show that the growth rate of the nominal exchange rate is given by

(8.42)

$$e_{t+1} - e_t = \left(\frac{1}{1+\lambda}\right)\left\{-\Phi_t^R + \sum_{s=t+1}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^{s-t-1}\left[\mathrm{E}_{t+1}\,\Phi_s^R - \frac{\lambda}{1+\lambda}\,\mathrm{E}_t\,\Phi_s^R\right]\right\}$$

The evolution of e_t thus mirrors both observed fundamentals and revised expectations about the future (starting in period $t+1$). We assume that the fundamentals follow a first-order autoregressive process:

$$(8.43) \qquad \Phi_{s+1}^R = \rho\,\Phi_s^R + \nu_{s+1} \qquad s = t, t+1, \ldots$$

with $0 \le \rho \le 1$ and $\mathrm{E}_s \nu_{s+1} = 0$. Substituting this expression into (8.42) yields

$$(8.44) \qquad e_{t+1} - e_t = \frac{\Phi_{t+1}^R - \Phi_t^R}{1 + \lambda\left(1-\rho\right)}$$

The change of e is thus proportional to the change of Φ^R, with the factor of proportionality depending on the persistence of the autoregressive process that describes the evolution of monetary fundamentals (ρ). If Φ^R follows a random walk – i.e. if $\rho = 1$ – the exchange rate is as volatile as monetary fundamentals.

Conversely, if the process in (8.43) is stationary $(\rho < 1)$, the variance of observed depreciations and appreciations should be smaller than the variance of relative monetary fundamentals.
Combined with the assumption that monetary fundamentals follow a linear first-order autoregressive process, the monetary model thus delivers two important hypotheses.

- Nominal depreciations and appreciations should mirror changes of (relative) monetary fundamentals.
- Fluctuations of the nominal exchange rate should be less pronounced than fluctuations of the monetary fundamentals.

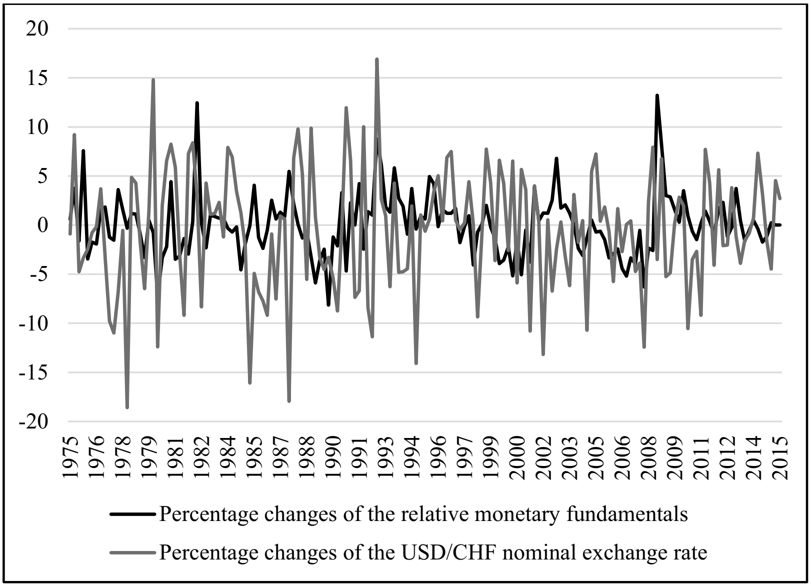

Figure 8.10 : Percentage changes of the relative monetary fundamentals (money supply M2 and real GDP) and percentage changes of the nominal USD/CHF exchange rate (Swiss francs per US dollar). Source: IMF (International Financial Statistics) and own computations.

Figure 8.10 confronts these hypotheses with data on the USD/CHF nominal exchange rate.[29] In order to produce this graph, we followed equation (8.41) in

[29] Recall the convention that the USD/CHF nominal exchange rate defines the amount of Swiss francs that have to be paid for one US dollar.

subtracting the natural logarithms of national output levels and national monetary aggregates from each other, setting $\phi = 1$ as suggested by empirical studies (see Box 8.6). In Figure 8.10, the first difference of this time series is confronted with quarter-to-quarter rates of depreciation of the Swiss franc against the US dollar. In many respects, the result is sobering for the monetary model: first, exchange-rate fluctuations are not obviously correlated with relative monetary fundamentals. Moreover, the nominal exchange rate seems to be much more volatile than the fundamentals for most of the sample.

A possible conclusion to draw from Figure 8.10 is that the structure of the monetary model offers an accurate description of reality, but that market participants‘ expectations are subject to wild variations. According to this interpretation, the pronounced fluctuations of the exchange rate reflect the permanent – and possibly erratic – updating of expectations.

As an alternative, we can stick to the assumption of rational expectations and modify the structure of the model such that it is able to account for the high volatility of nominal exchange rates. This approach will be considered in detail in Section VIII.5.

VIII.4.8 The Monetary Model with a Fixed Exchange Rate

So far, we have used the monetary model to explain the evolution of the nominal exchange rate. However, if the exchange rate is fixed, the endogenous variable in the model is *by definition* not the exchange rate, but the stock of the central bank’s foreign reserves. To demonstrate this, we combine equations (8.25) – (8.28), taking into account that a credible peg implies that $\mathrm{E}_t e_{t+1} - e_t = 0$:

$$(8.45) \qquad m_t^H = p_t^F + e_t + \phi\, y_t^H - \lambda\, i_t^F$$

The money supply is proportional to the monetary base, which consists of domestic assets (D_t^H) and foreign exchange reserves (R_t^H), i.e. $M_t^H = \mu_t\, M0_t^H = \mu_t\,(R_t^H + D_t^H)$. Setting μ equal to one for simplicity, we get

$$(8.46) \qquad \ln\left(D_t^H + R_t^H\right) = p_t^F + e_t + \phi\, y_t^H - \lambda\, i_t^F$$

This result can be interpreted as follows: if the central bank keeps its stock of domestic assets D_t^H constant, an increase of y_t^H *ceteris paribus* must result in an increase of the total money supply and thus a rising stock of foreign reserves. This is due to the positive effect of income on money demand, which would result in an increasing domestic interest rate if the monetary base was held constant. An increasing domestic interest rate, however, would result in an appreciation of the domestic currency. To prevent this appreciation from happening, the central bank has to purchase foreign reserves, which implies an increase of R_t^H.

Conversely, a rise of domestic assets in the central bank's balance sheet – due, e.g., to expansionary open market operations – necessarily results in a decline of foreign reserves, such that the nominal money supply remains constant. This is because a *rising* money supply ceteris paribus would push down the domestic interest rate. To avert the impending depreciation, the central bank has to sell reserves on the foreign exchange market, which reduces R_t^H up to a point where the sum $D_t^H + R_t^H$ has returned to its initial value.

The fact that it is impossible to combine perfect capital mobility – as represented by uncovered interest rate parity – with a fixed exchange rate and an autonomous monetary policy is often called the ***„macroeconomic policy trilemma"*** (Obstfeld et al., 2005). The trilemma implies that economic policy has to sacrifice one of the three goals to reach the other two – either by restricting capital mobility, by renouncing an autonomous monetary policy, or by abandoning the fixed exchange rate.

Box 8.7: The "Forward Premium Puzzle"

The uncovered interest rate parity condition (UIP) is a central ingredient of the monetary exchange rate model and of many other macroeconomic models of open economies. The notion that, under perfect capital mobility, international interest rate differentials reflect market participants' exchange rate expectations can be tested empirically by first combining the covered interest rate parity and the uncovered interest rate parity conditions from (8.3) and (8.6). This yields:

$$e_{t+1}^e - e_t = f_t - e_t$$

The ***forward premium*** should thus reflect the expected evolution of the spot exchange rate. Adding the assumption that market participants form rational expectations such that their predictions are not systematically wrong, we can transform the above equation into

$$e_{t+1} - e_t = f_t - e_t + \varepsilon_{t+1}$$

with ε_{t+1} as a disturbance whose expected value is zero and that is not correlated over time. On average, we should thus see a currency's actual rate of depreciation coincide with the forward premium. While forecasts may always be subject to errors, these errors should not be *systematic*.

Given this clear-cut prediction, the empirical evidence on the relationship between the forward premium and the actual development of the spot exchange rate is rather surprising: the scatterplot in Figure B8.7 demonstrates that, for the British pound/US dollar relationship and a three-month horizon, there is no clear pattern. If there is any correlation at all, it seems to be negative. In fact, numerous empirical studies have found that, in a regression of spot exchange rates on forward premia or interest rate differentials, the relevant coefficient is very different from one and in many cases smaller than zero. This, in turn, implies that large gains can be reaped from ***carry trades***, i.e. a strategy which amounts to borrowing in the currency that offers the low interest rate and lending in the currency that offers the high interest rate.

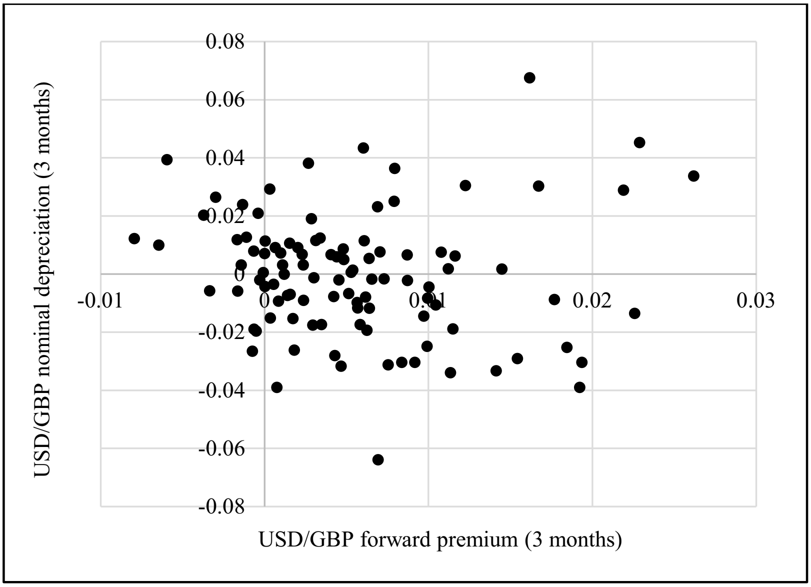

Figure B8.7: Forward premia and the evolution of the spot exchange rate. Horizontal axis: difference between the three-month USD/GBP forward exchange rate (Pound sterling per US dollar) and the spot exchange rate (both in logarithms). Vertical axis: growth of the USD/GBP spot exchange rate over the same three-month interval. Source: Thomson Reuters.

Research has offered various approaches to explain this ***forward premium puzzle***. First, the failure to confirm uncovered interest rate parity by estimating the above equation may be due to the fact that – in contrast with the assumptions underlying UIP – agents are risk-averse. If the ***risk premium***

required by agents to engage in foreign-currency transactions is time-variant and negatively correlated with expected exchange-rate movements, it may generate the negative relationship between the forward premium and the evolution of the spot exchange rate.
An alternative interpretation focuses on the possibility that market participants expect an event which will result in a strong movement of the exchange rate. However, for some reason this event does not occur within the time span covered by the available data. Under such circumstances, expectations seem to be systematically off track. Referring to the low price at which the Mexican peso traded on forward markets in the early 1970s, this phenomenon is often labelled a ***peso problem***.

The third strand of explanations focuses on the ***microstructure*** of foreign exchange markets and starts from the observation that, usually, new information is not immediately available to *all* market participants. Instead, it disseminates in an asymmetric fashion, providing some agents with an informational advantage. In case of a foreign interest rate increase, the foreign currency appreciates *gradually*, allowing better informed market participants to earn positive excess returns for some time. This may result in the negative correlation between the forward premium and the evolution of the spot exchange rate, which is at the heart of the forward-premium puzzle.

Another reason why uncovered interest rate parity seems to fail empirically is an inappropriate estimation strategy: the regression described above is based on the notion that interest differentials and thus forward premia are exogenous. If, however, policymakers set interest rates with an eye on exchange rate fluctuations, the negative relationship between the forward premium and the observed depreciation rather reflects the endogeneity of interest rate differentials than the failure of UIP.

A fifth strand of the literature attempts to explain the forward premium puzzle by highlighting the fact that the above equation tests uncovered interest rate parity under the assumption that all agents have rational expectations. If this assumption is not satisfied – e.g. because market participants misinterpret the information they receive or because they use other expectations formation mechanisms – the data may suggest to reject the validity of the uncovered interest rate parity condition although it is rather an incorrect assumption on agents' expectations formation than a genuine failure of UIP that generates the forward premium puzzle.

VIII.5 Exchange-Rate Overshooting

VIII.5.1 Motivation

The past section demonstrated that fluctuations of the Swiss-franc/US dollar exchange rate have usually been much more pronounced than what would have been justified by variations of relative incomes and money supplies. The inability to explain this ***excess volatility***, which can also be observed for other currency pairs, is one of the crucial weaknesses of the monetary model. In addition, the monetary model is based on the assumption that the theory of purchasing power parity holds at all points in time – a notion that, as shown in Chapter VII, is not supported by the empirical evidence.[30]

In Chapter VII, we touched on an alternative interpretation of real exchange-rate fluctuations which focused on the role of ***sticky prices***: if the prices of goods and services react with a delay to changes in the environment, movements of the nominal exchange rate may result in variations of the real exchange rate, and thus in deviations from purchasing power parity. These deviations should be temporary, i.e. they should disappear once all prices have adjusted. The assumption of slowly adjusting goods prices is the crucial ingredient of the ***Dornbusch model***, which goes back to a paper published in 1976 by Rüdiger Dornbusch. Considering a small open economy with a flexible exchange rate and perfect capital mobility, the model highlights the fact that, with delayed price adjustment, an increase in the nominal money supply results in a temporary increase of the *real* money supply. This, in turn, generates the possibility that moderate monetary policy changes result in an extreme reaction of the nominal exchange rate – the so-called ***overshooting***. The Dornbusch model is thus able to explain the high volatility of the nominal exchange rate in a framework that is characterized by rational expectations and international capital mobility.

VIII.5.2 The Dornbusch Model: Structure and Assumptions

The version of the Dornbusch model that we will present on the following pages adopts the assumptions and the notation of the monetary model when it comes to describing the money market and the foreign-exchange market: both markets are constantly in equilibrium, and real money demand depends on real income and on the nominal interest rate. Due to perfect capital mobility, equilibrium on

[30] It is, of course, possible to modify the monetary model by adding a term to equation (8.26) that represents changes of the equilibrium real exchange rate – due, e.g., to Balassa-Samuelson effects. However, it is quite unlikely that the high volatility of real exchange rate time series is driven by rapid changes of productivity, preferences, etc.

the foreign exchange market requires the uncovered interest rate parity condition to be satisfied. We therefore have

$$(8.47) \qquad m_t^H - p_t^H = \phi\, y_t^H - \lambda\, i_t^H$$

$$(8.48) \qquad i_t^H = i_t^F + \mathrm{E}_t e_{t+1} - e_t$$

It is important to note that real GDP, which appears in the money demand function, is *exogenous* – i.e. the model is characterized by ***monetary neutrality*** in the sense that variations of nominal variables have no effect on aggregate production. However, while the monetary model was based on the notion that purchasing power parity holds at all points in time, the Dornbusch model assumes that prices take some time to adjust after a change in external circumstances, and that this may result in variations of the real exchange rate.

In the medium run, prices increase if the aggregate demand for domestic goods $y_t^{H,D}$ is greater than aggregate supply y_t^H, which we assume to be exogenous. For the sake of simplicity, we model demand as a linear function of the real exchange rate, i.e.

$$(8.49) \qquad y_t^{H,D} = \delta\left(e_t + p_t^F - p_t^H\right)$$

with $\delta > 0$. This specification is based on the notion – already presented in Chapter VII – that a real depreciation is associated with an improved „price competitiveness" of domestic exporters or – which is just the other side of the same coin – a „worsening" of the domestic terms of trade. Given that the Marshall-Lerner condition is satisfied (see Section VII.5), this variation of relative prices results in rising domestic exports and a decline of domestic imports. The equation that describes the evolution of domestic prices is given by

$$(8.50) \qquad p_{t+1}^H - p_t^H = \varphi\left[\delta\left(e_t + p_t^F - p_t^H\right) - y_t^H\right]$$

Prices thus react to a discrepancy between demand and (exogenous) supply, and the adjustment is the quicker, the higher is φ. If φ approaches infinity, price adjustment is immediate, and variations of the real exchange rate are only driven by variations of y_t^H.

VIII.5.3 Dynamic Properties of the Model

In what follows, we will explore the short-run, medium-run, and long-run reactions of the exchange rate and of the price level to a surprising and permanent increase of the domestic money supply. We assume that the economy is not exposed to any other changes, and that, except for the non-anticipated monetary policy shock, individuals have perfect foresight. It thus holds that $E_t e_{t+1} = e_{t+1}$. Using this assumption in the uncovered interest rate parity condition (8.48) and substituting the resulting expression into (8.47), we get

$$(8.51) \qquad e_{t+1} - e_t = \frac{1}{\lambda}\left[\phi\, y_t^H - \lambda\, i_t^F - m_t^H + p_t^H\right]$$

The equations (8.50) and (8.51) represent a system of linear difference equations whose properties can be analyzed with the help of a ***phase diagram***.[31] We start by drawing the ***demarcation lines***, which represent combinations of e_t and p_t^H at which the nominal exchange rate or the price level do not change. Using the above equations, we can show that these lines are given by

$$(8.52) \qquad \Delta\, p_{t+1}^H = 0: \quad p_t^H = e_t + p_t^F - \frac{1}{\delta}\, y_t^H$$

$$(8.53) \qquad \Delta\, e_{t+1} = 0: \quad p_t^H = \lambda\, i_t^F + m_t^H - \phi\, y_t^H$$

Both lines are represented in Figure 8.11. The point of intersection of the two demarcation lines defines the exchange rate and the price level in the ***steady state***. Removing the time subscripts to highlight the constancy of all variables, we can show that the steady state is given by the following expression:

$$(8.54) \qquad e^{SS} = p^{H,SS} - p^F + \frac{1}{\delta} y^H$$

$$(8.55) \qquad p^{H,SS} = \lambda\, i^F + m^H - \phi\, y^H$$

It follows from (8.54) that, in the steady state, the real exchange rate ($q^{H,SS} = e^{SS} + p^F - p^{H,SS}$) does not depend on the domestic money supply. However, it increases in the level of domestic production y^H : a permanent increase of domestic GDP necessitates a long-run real depreciation to make sure that the increased supply meets sufficient demand.

The dynamic properties of the system are represented by the arrows in Figure 8.11. These, in turn, result from taking a derivative of the right-hand side of (8.50) with respect to e_t and from taking a derivative of the right-hand side of (8.51) with respect to p_t^H. Both derivatives are positive. Hence, if the price level is above the demarcation line for the nominal exchange rate, $\Delta\, e_{t+1}$ is greater than zero, i.e. there is a nominal depreciation. Conversely, the price

[31] We introduced the use of phase diagrams when we presented the neoclassical growth model in Chapter V.

level decreases (increases) if the nominal exchange rate is to the left (to the right) of the demarcation line for p_t^H. The system is saddle-path stable in the sense that, for a given price level, there is just one value of the nominal exchange rate that guarantees convergence to the steady state. This unique (saddle) path is also depicted in Figure 8.11.

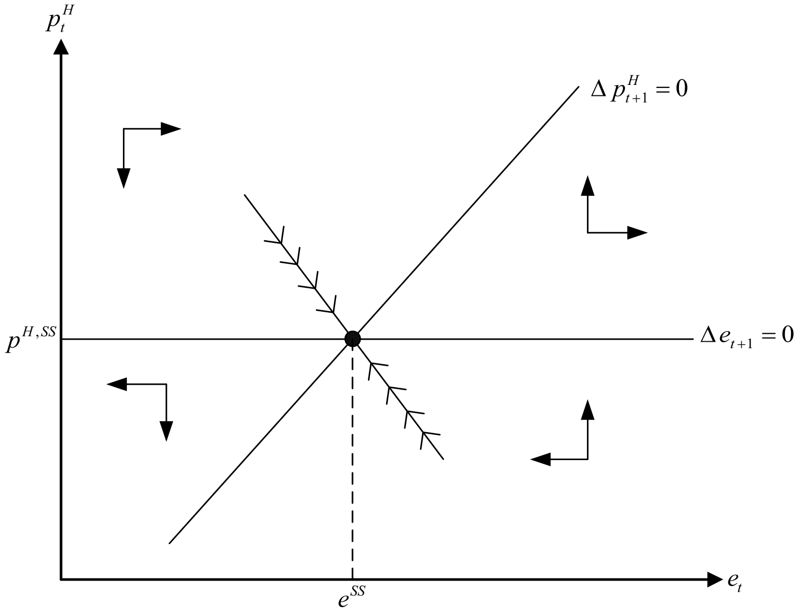

Figure 8.11: Price and exchange rate dynamics in the Dornbusch model

VIII.5.4 Expansionary Monetary Policy and Exchange Rate Overshooting

Suppose that the central bank surprises markets by permanently increasing the domestic money supply. A permanent increase of m^H shifts the ("exchange rate") demarcation line (8.53) in Figure 8.11 upward while leaving the ("price") demarcation line (8.52) unaffected. This results in a new steady state, which is characterized by a higher nominal exchange rate and a higher price level. Since the demarcation line (8.52) has a slope of one, the exchange rate and the price level vary to the same extent. Hence, as long as domestic output remains constant, the real exchange rate does not change in the long run.

Figure 8.12 describes the adjustment path to the new long-run equilibrium: in the period in which the money supply increase actually takes place (the "shock period"), the nominal exchange rate jumps onto the new saddle path.

Afterward, it converges to the new long-run equilibrium by moving on this saddle path. The fact that the price level does not change in the shock period reflects our assumption of delayed price adjustment.

The time path depicted in Figure 8.12 implies that the nominal exchange rate is above its (new) long-run equilibrium until it has reached the new steady state. Hence, in the short run, the reaction of the exchange rate is much stronger than what would be justified by the monetary expansion. The mechanisms that are responsible for this ***exchange rate overshooting*** can be summarized as follows:

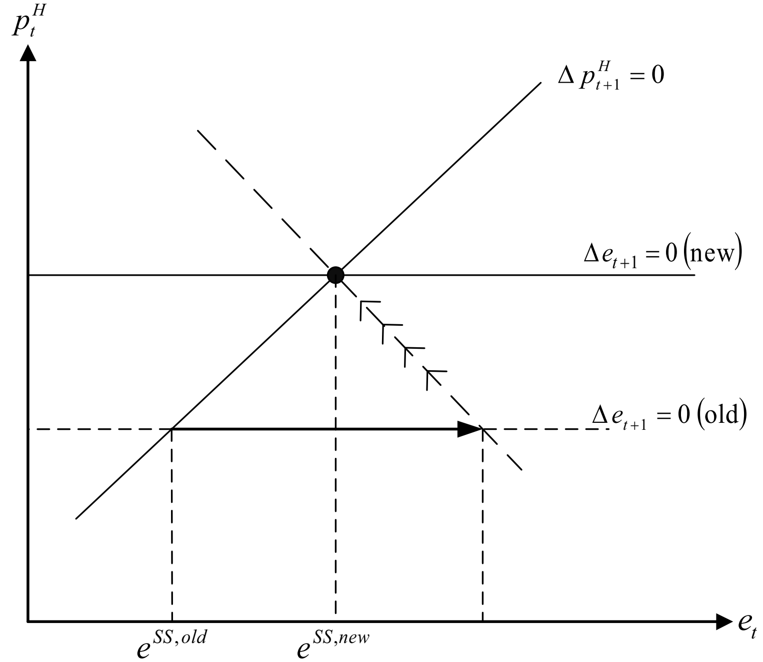

Figure 8.12 : Exchange rate overshooting and convergence to the new long-run equilibrium for a permanent increase of the nominal money supply.

- As the price level is predetermined and cannot change in the shock period, the monetary expansion implies an increase of the *real* money supply. Since real output is constant, the domestic interest rate has to decrease in order to sustain money market equilibrium.
- Given the uncovered interest rate parity condition, a decreasing domestic interest rate is only compatible with an equilibrium on foreign exchange markets if individuals expect a subsequent *appreciation* of the domestic currency. In order to validate such appreciation expectations, the short-run de-

preciation must be stronger than the *long-run* depreciation, such that the domestic currency actually appreciates during its convergence to the new steady state. This is the overshooting property of the model. Since the price level does not move in the shock period, the initial nominal depreciation is associated with a real depreciation.
- During the adjustment to the new equilibrium, the domestic price level increases, while the nominal exchange rate decreases. Hence, convergence to the new steady state is characterized by a sequence of real appreciations. This development eventually undoes the initial real depreciation and restores goods market equilibrium. During convergence, the nominal interest rate increases and eventually returns to its initial level.

The important contribution of the Dornbusch model is to explain the seemingly "excessive" volatility of the nominal exchange rate in a framework that is based on rational expectations, and to relate it to the different adjustment speed of goods prices and exchange rates. Moreover – and unlike the monetary model – the Dornbusch model allows for short-run fluctuations of the real exchange rate. However, these fluctuations are without consequences for aggregate production, which is still assumed to be exogenous. In Chapter IX, we will consider the possibility that the real exchange rate affects domestic GDP by affecting export demand.

Box 8.8: How "Useful" are Structural Exchange Rate Models?

Both the monetary model and the Dornbusch model interpret the exchange rate as a function of observed and expected monetary fundamentals. One possibility to assess the quality of these structural models is to consider the accuracy of their predictions by using ***(pseudo) out-of-sample-forecasts***. Performing such forecasts works as follows: suppose that you have data for T periods. You start by estimating the empirical relationship between observed fundamentals and exchange rates for the first $T-k$ periods. The forecasts for the second part of the sample – i.e. the periods $T-k+1$ to T – can then be computed by using the observed fundamentals and the estimated relationship. To assess the quality of the model, we compare the forecasts with the values that were actually observed. The "better" model should be characterized by lower forecast errors.

In a seminal paper published in 1983, Richard Meese and Kenneth Rogoff demonstrated that none of the structural models they considered was superior to a simple random walk. Put differently, even if structural models do a good job in explaining the observed data ("in sample"), the best prediction of the *future* exchange rate is the *current* exchange rate.

It is not surprising that the Meese and Rogoff (1983) result shocked the profession – in particular since repeated attempts to "beat the random walk" failed in subsequent years. Nevertheless, this does not completely discredit structural exchange rate models. In a study that was published in 2007, Charles Engel, Nelson Mark and Kenneth West demonstrate that models in which expectations about the future have a large weight – e.g. the monetary model with a large value of λ in (8.31) – imply that the exchange rate behaves *as if* it followed a random walk. The inability of structural models to produce better forecasts than a random walk therefore says less about the quality of these models than about the importance of expectations in determining the nominal exchange rate.

VIII.6 The Portfolio Balance Approach and Foreign Exchange Interventions

VIII.6.1 Motivation

Most of our arguments in this chapter rested on the notion that the nominal exchange rate is primarily determined by what is happening on the international capital market, and that it mainly reflects the demand for assets which are denominated in different currencies. So far, however, we have modelled foreign exchange markets in a rather simplistic fashion: if all agents are risk neutral, if capital is perfectly mobile, and if assets denominated in different currencies are perfect substitutes, equilibrium on foreign exchange markets is only feasible if – with respect to one currency – all securities offer the same expected return, i.e. if the uncovered interest rate parity condition holds.

The ***portfolio balance approach*** replaces the assumption of perfect substitutability by the notion that the demand for domestic (foreign) securities may be strictly positive even if the expected return on these securities is lower than the return on foreign (domestic) securities. One reason for such a deviation from uncovered interest rate parity may be that agents are risk-averse, such that it is optimal to hold an internationally diversified portfolio. As we have seen in Section IV.5, international diversification implies that individuals' portfolio choices not only depend on an asset's *expected* return, but also on the contribution to overall consumption risk. Based on these arguments, the portfolio balance approach explores the consequences of imperfect asset substitutability and allows to analyze how changes in the supply of (or demand for) different assets influence the nominal exchange rate.

This is particularly important when it comes to assessing the consequences of monetary authorities' ***foreign exchange market interventions***. As we have argued above, such interventions may be used to fight fluctuations of the exchange rate. For example, if monetary authorities want to prevent an appreciation, they can sell domestic currency and purchase foreign currency. As a result, the stock of foreign reserves increases, the domestic money supply expands, and the appreciation is dampened, if not completely averted. Sometimes, however, monetary authorities have an interest in constraining this monetary expansion – e.g. because they want to reduce inflationary pressure. In this case, they ***sterilize*** the intervention by selling domestic securities to market participants, thus reducing the liquidity available in the money market. In the extreme case of a completely ***sterilized intervention***, all that changes is the structure of the central bank's balance sheet, while the total money supply does not vary. This, however, leaves us with the question why a sterilized intervention should have *any* effect on exchange rates: if the domestic money supply does not change, the difference between the domestic and the foreign interest rate does not change either. And if foreign exchange market equilibrium is fully described by the uncovered interest rate parity condition, a constant interest rate differential implies that the exchange rate does not change. To rationalize the potential role of sterilized foreign exchange interventions, we thus have to abandon the concepts of perfect asset substitutability and uncovered interest rate parity.

VIII.6.2 Foreign Exchange Interventions in a Portfolio Balance Model

To demonstrate how sterilized foreign exchange interventions may affect the exchange rate, we will present a slightly modified version of a model that has been published in 2015 by Olivier Blanchard, Gustavo Adler and Irineu de Carvalho Filho. Their starting point is the balance of payments equilibrium condition (8.1), which we interpreted as a foreign exchange market equilibrium condition in Subsection VIII.2.2, and which we reproduce for convenience:

$$(8.56) \qquad CA_t + KA_t = FA_t^{NR} + \Delta R_{t+1}$$

For the sake of simplicity, we continue by ignoring the capital account and setting $KA_t = 0$ in all periods. We assume that the "non-reserves" part of the financial account is described by the following equation:

$$(8.57) \qquad FA_t^{NR} = \alpha \left(i_t^F + \mathrm{E}_t e_{t+1} - e_t - i_t^H \right) - z_t$$

where $\alpha > 0$. Recall that FA_t^{NR} represents the net increase of a country's foreign *assets* minus the net increase of its foreign *liabilities*, i.e. the change of its net international investment position (NIIP), excluding the central bank's activities. Equation (8.57) states that the evolution of the NIIP depends on the *expected return differential*, with agents being more willing to purchase foreign assets if their expected return exceeds the expected return on domestic assets.[32] Note that, as α becomes infinitely large, the expression in (8.57) turns into the uncovered interest rate parity condition: as soon as expected returns differ across currencies, there is either excess demand for or excess supply of domestic currency, since market participants instantaneously move into the higher-return securities. Conversely, if α is finite, agents are willing to hold domestic assets even if their expected return is lower than the expected return on foreign assets. This assumption is at the heart of the portfolio balance model. The "(net) capital inflow shock" z_t is meant to reflect the various exogenous forces that make domestic assets more (or less) attractive relative to foreign assets – e.g. an increase or decrease of market participants' appetite for risk. This shock is assumed to follow the first-order autoregressive process $z_t = \phi z_{t-1} + \varepsilon_t$, with $0 < \phi < 1$ and $\mathrm{E}_{t-1}\varepsilon_t = 0$.

The current account balance depends on the nominal exchange rate and (exogenous) "current account shocks"

$$(8.58) \qquad CA_t = \gamma e_t + \zeta_t ,$$

with $\zeta_t = \varphi \zeta_{t-1} + \nu_t$, $0 < \varphi < 1$, and $\mathrm{E}_{t-1}\nu_t = 0$. The assumption that the current account increases if the domestic currency depreciates is based on the notion that a nominal depreciation is associated with a "worsening" of the terms of trade which, in turn, boosts net exports. The current account shock is meant to reflect all forces that increase or reduce the demand for domestic goods and services.

Monetary policy follows a rule that relates the domestic interest rate to the foreign interest rate and the nominal exchange rate, but it is also subject to random "monetary policy shocks", i.e.

$$(8.59) \qquad i_t^H = i_t^F + \delta e_t + \xi_t$$

with $\xi_t = \psi \xi_{t-1} + \iota_t$, $0 < \psi < 1$, and $\mathrm{E}_{t-1}\iota_t = 0$. Moreover, monetary authorities credibly announce that they will react to capital inflow shocks by intervening in foreign exchange markets. For foreign exchange reserves this implies

[32] Recall that variations in the NIIP are also driven by valuation changes, stemming, e.g., from exchange rate fluctuations. Here, we are abstracting from valuation effects for the sake of simplicity. These effects are, however, at the heart of another version of the portfolio balance model presented by Blanchard et al. (2005).

(8.60) $$\Delta R_{t+1} = \theta\, z_t$$

with $0 < \theta < 1$. Combining the above equations and solving for the nominal exchange rate yields

(8.61) $$e_t = \frac{\alpha\, \mathrm{E}_t\, e_{t+1} - \alpha\, \xi_t - \zeta_t - (1-\theta)\, z_t}{\alpha(1+\delta)+\gamma}$$

This expression already conveys an important part of the overall intuition: the net capital inflow shock z_t results in a decline of FA_t^{NR}, i.e. an increasing demand for domestic assets. The resulting demand increase for domestic currency brings about a nominal appreciation, which reduces the current account balance. For given expectations about the future evolution of the spot exchange rate, the appreciation raises $\mathrm{E}_t e_{t+1} - e_t$, and thus the relative expected return on foreign assets. Depending on the size of α, this dampens the effect of the capital inflow shock. The reaction of the exchange rate is further muted by the central bank's foreign exchange intervention, whose strength is reflected by the size of θ: if this parameter is large, the central bank sells large amounts of domestic currency-denominated assets, thus reducing the excess demand for domestic currency and the resulting appreciation pressure.

To solve the model, we have to account for the fact that $\mathrm{E}_t e_{t+1}$ is endogenous. By forward-iterating equation (8.61) and evoking the time series properties of the exogenous shocks, we arrive at the following expression:

(8.62) $$\begin{aligned} e_t = \; & -\sum_{s=t}^{\infty}\left(\frac{\alpha}{\alpha(1+\delta)+\gamma}\right)^{s-t}\left(\frac{\alpha\,\psi^{s-t}\xi_t + \varphi^{s-t}\zeta_t + (1-\theta)\phi^{s-t} z_t}{\alpha(1+\delta)+\gamma}\right) \\ & + \lim_{\tau\to\infty}\left(\frac{\alpha}{\alpha(1+\delta)+\gamma}\right)^{\tau} \mathrm{E}_t e_{t+\tau} \end{aligned}$$

Since we exclude speculative bubbles, we can set the last term on the right-hand side equal to zero. Solving the above equation then yields

(8.63) $$e_t = -\frac{\alpha}{\alpha(1+\delta-\psi)+\gamma}\,\xi_t - \frac{1}{\alpha(1+\delta-\varphi)+\gamma}\,\zeta_t - \frac{1-\theta}{\alpha(1+\delta-\phi)+\gamma}\, z_t$$

To interpret this term, we start by considering the extreme case of perfect asset substitutability. This is

(8.64) $$\lim_{\alpha \to \infty} e_t = -\frac{1}{(1+\delta-\psi)}\xi_t$$

If domestic and foreign assets are perfect substitutes, all that matters for the evolution of the exchange rate are variations in monetary policy: an exogenous increase of the domestic interest rate results in a nominal appreciation, which is the stronger the more persistent the policy. Neither the "net capital inflow shock" z_t nor the strength of the central bank's interventions are of any importance, since they are dwarfed by the demand shifts on financial markets that are associated with deviations from uncovered interest rate parity.

By contrast, if α is finite, both the "(net) capital inflow shock" z_t and the "current account shock" ζ_t result in a nominal appreciation, since both an exogenous increase of net exports and an increasing appetite for domestic assets raise the demand for domestic currency. Monetary policy can dampen these effects by setting $\delta > 0$, i.e. by adjusting the domestic interest rate. However, if this is not an option – i.e. if the domestic money supply is supposed to be constant – monetary authorities can influence the exchange rate through (sterilized) foreign exchange interventions. The effects of this policy are the higher, the higher is the parameter θ, i.e. the stronger the intervention.

Box 8.9: Stemming the Tide – The European Debt Crisis and the Swiss Franc.

When the collapse of the US investment bank Lehman Brothers hit the global financial system in the fall of 2008, some of Switzerland's banks were caught wrong-footed. However, due to massive government intervention and with the help of new foreign investors, a failure of financial institutions was avoided. In subsequent months, public authorities were quick to tighten the regulatory framework for the Swiss banking system, and by the end of 2009, the worst seemed to be over. This, however, meant that the Swiss franc regained its status as a safe-haven currency, which it had already played during previous financial crises.

Especially as the European Debt Crisis unfolded in 2010 and debates about the integrity of the Euro area started to dominate the headlines, the demand for assets denominated in Swiss francs rose considerably. This accelerated the appreciation of the Swiss franc against the Euro, which had already started in early 2008. Although, at that time, the Swiss National Bank (SNB) had no explicit exchange rate target, it started to intensify its foreign exchange interventions in 2010. In Figure B8.9, this is reflected by a steep increase of foreign reserves held by the SNB. These repeated interventions, however, did not stem the tide of capital inflows – especially from

Euro area countries – and in September 2011, the Swiss franc appreciated dramatically against the Euro. With the Euro area as the main destination of Swiss exports, public pressure for stronger policy measures built up, and in mid-September 2011, the SNB announced that it would establish a one-sided peg, defining an exchange rate of 1.20 as a lower bound for the Swiss franc/Euro exchange rate. This announcement seemed to impress market participants, and the stock of foreign reserves did not change for some time. At the height of the European Debt Crisis in the summer of 2012, however, further interventions were necessary to prevent the Swiss franc/Euro exchange rate from breaking the unilateral peg.

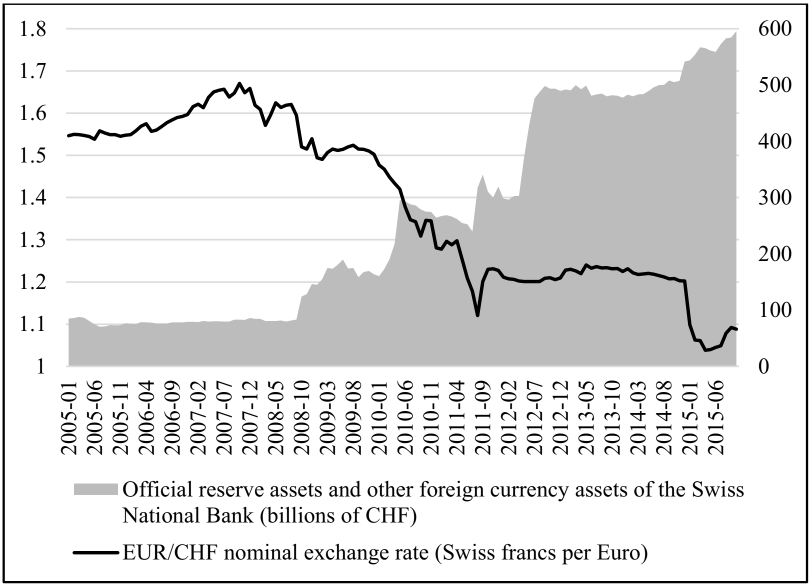

Figure B8.9: The EUR/CHF nominal exchange rate (Swiss francs per Euro, left-hand scale) and the foreign exchange reserves of the Swiss National Bank (billions of Swiss francs, right-hand scale). Source: Swiss National Bank.

As things seemed to calm down in the Euro area, the need for further interventions disappeared, and the Swiss franc fluctuated in a narrow band above the lower boundary of 1.20 against the Euro. However, when the ECB announced its intention to massively expand the money supply in the Euro area through its extended asset purchase program, it was obvious that demand for Swiss francs would increase massively before too long. Anticipating that the future capital inflows would be too large to be contained by foreign exchange interventions, the SNB abandoned the unilateral peg in January 2015. The result was another massive nominal appreciation of the Swiss franc against the Euro. Since then, the SNB has returned to its pre-2011 flexible exchange rate regime that allows for occasional (discretionary) interventions.

VIII.7 Summary and Outlook

Starting from the observation that the majority of foreign exchange transactions is associated with the purchase or sale of securities denominated in different currencies, this chapter has focused on the asset-market approach to the nominal exchange rate. The crucial message of this paradigm is that the relative price of a currency is not only determined by observed fundamentals, but also by market participants' expectations about future monetary policy, economic growth etc. This implies the important prescription that, if policymakers want to reduce exchange rate fluctuations, influencing market expectations is at least as important as changing the current value of policy variables.

All models considered so far have been based on the assumption that movements of the exchange rate do not affect aggregate output. Even in the Dornbusch model the delayed price adjustment in the wake of a monetary expansion resulted in a short-run deviation from purchasing power parity, but this real deprecation had no influence on GDP. If this was an exhaustive description of reality, we could return to the question we asked at the beginning of this chapter: why do policymakers, academics and the general public devote so much attention to the exchange rate? Apparently, this is not just because the nominal exchange rate affects returns on assets denominated in different currencies. It must be because exchange rate fluctuations are likely to affect the "price competitiveness" of an economy, and because this may have an influence on aggregate demand and production. The following chapter will be devoted to the question under which circumstances such a relationship may emerge, and what this implies for economic policy.

VIII.8 Keywords

Adaptive expectations
Carry trade
Covered interest rate parity
Dornbusch model
Exchange rate regimes
Foreign exchange market interventions
Foreign exchange reserves

Forward exchange rate
Forward-premium puzzle
Macroeconomic policy trilemma
Money demand
Monetary model of the exchange rate
Monetary neutrality
Open market operations
Overshooting
Portfolio balance approach
Rational expectations
Risk premium
Speculative bubble
Spot exchange rate
Sterilized intervention
Uncovered interest rate parity

VIII.9 Literature

A broad overview of the theory and empirics of exchange rates can be found in Sarno und Taylor (2002), MacDonald (2007), Evans (2011) and, more recently, Engel (2014). Mishkin (2012) is a very accessible introduction to monetary theory and policy, while Walsh (2010) discusses these topics using more advanced concepts and methods. Neely und Sarno (2002) summarize research on the predictive power of the monetary model, and Menkhoff (2013) provides a review on foreign exchange interventions with a special focus on emerging markets. An overview of the microstructure approach to foreign exchange markets is presented in Lyons (2006), while Bacchetta and van Wincoop (2012) survey exchange rate models with incomplete information. The portfolio balance model originally goes back to Branson (1977) and Kouri (1981) and was further elaborated by Blanchard et al. (2005).

VIII.10 Exercises

8.1. Siegel's paradox. Under rational expectations, uncovered interest parity requires that

$$\left(1+i_t^H\right)=\left(1+i_t^F\right)\frac{\mathrm{E}_t\left(E_{t+1}\right)}{E_t}$$

That is, with respect to the *domestic* currency, the expected return on domestic securities has to equal the expected return on foreign securities.

a) Derive the condition that has to hold if the *foreign* currency is used as a base currency.
b) Why aren't the two conditions identical? (This problem goes back to a contribution by Jeremy Siegel published in 1972. It is therefore known as ***Siegel's paradox***)

c) Why does the problem disappear if we use the logarithmic approximation to uncovered interest parity, i.e. $i_t^H = i_t^F + \mathrm{E}_t\, e_{t+1} - e_t$?

8.2. Uncovered interest parity and the "Grexit". In Chapter VI, we discussed how market fears of a sovereign default in Greece pushed up returns on Greek government bonds in 2011 and 2012. In fact, these fears were augmented by worries that Greece might soon exit the Euro area – i.e. that a "Grexit" was imminent. Use the uncovered interest rate parity condition (considering Greece as the domestic economy) to show how the "Grexit" debate may have contributed to increasing interest rates on Greek government bonds.

8.3. Money demand. Provide an economic explanation for the fact that money demand depends on the *nominal* interest rate, not the *real* interest rate.

8.4. A monetary model with two large open economies. We consider a monetary model of two structurally identical economies which are linked by a flexible exchange rate, i.e. the equations from Section VIII.4.4 are augmented by

$$m_t^F = p_t^F + \phi\, y_t^F - \lambda\, i_t^F$$

We assume that the money supply in country F $\left(m_t^F\right)$ is constant. The evolution of real GDP in country c is given by $y_{t+1}^c = y_t^c + \rho^c$, with $c = H, F$.

Describe the evolution of the domestic money supply that makes sure that the nominal exchange rate is constant.

8.5. Fundamentals and exchange rates in the monetary model. In Subsection VIII.4.7, we have shown that, according to the monetary model, the growth rate of the nominal exchange rate should be less volatile than the growth rate of monetary fundamentals. Provide an economic interpretation of this result.

8.6. The Dornbusch model with government spending. We extend the Dornbusch model presented in Section VIII.5 by adding (the natural logarithm of) government spending g_t^H as a further component of domestic demand. Equation (8.50) thus turns into

$$p_{t+1}^H - p_t^H = \phi\left[\delta\left(e_t + p_t^F - p_t^H\right) + g_t^H - y_t^H\right]$$

Use a phase diagram to describe the short-run and long-run reactions of the domestic price level, the nominal exchange rate and the real exchange rate to a surprising and permanent increase of government spending.

8.7. The effect of discretionary foreign exchange interventions. The portfolio balance model introduced in Section VIII.6 was based on the assumption that domestic monetary authorities' foreign exchange interventions follow the rule $\Delta R_{t+1} = \theta z_t$, and that this rule is common knowledge among market participants. Suppose that, instead, interventions are discretionary, i.e. $\Delta R_{t+1} = \eta_t$, with $\mathrm{E}_t \eta_{t+j} = 0$ for $j > 0$. Describe the nominal appreciation resulting from a positive net capital inflow shock z_t in period 1 (with $z_t = \phi z_{t-1} + \varepsilon_t$) for such a discretionary intervention. Compare it with the effect of a rule-bound intervention as described in Section VIII.6. Assume that, in the shock period, $\eta_1 = \theta z_1$. Interpret your result.

8.8. The problem of abandoning foreign exchange interventions. Explain intuitively why a central bank that has been intervening for a long time to avert an appreciation of the domestic currency may be reluctant to abandon this strategy.