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16.3.1998

Monetary Policy in a Bipolar International Monetary System

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Monetary Policy in a Bipolar International Monetary System

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Abstract

The study deals with the international transmission of economic shocks, their consequences for exchange rates and the reconciliation of exchange rate management with monetary policy. The theoretical part of the study consists of a mainstream model of two large, interdependent economies with special emphasis on the effects of various shocks on the inflation rate and exchange rate. The empirical application uses US and German data to shed light on the exchange rate implications of the choices faced by European and US monetary policymakers. The results suggest that the inflation rate is dominated by domestic supply shocks in both economies studied. When such shocks raise the domestic price level, the currency also depreciates. This aspect of the results means that, from a single-country perspective, monetary policy measures aimed at stabilizing the price level can be compatible with stabilization of the exchange rate as well. However, from the viewpoint of the other country, a conflict emerges between exchange rate and price stability. This difference causes a dilemma in international monetary coordination. Allowing that exchange rate considerations affect monetary policy, the situation is further complicated by the fact that exchange rate volatility seems to be for the most part independent of the economic fundamentals included in the study.

Keywords: euro, monetary policy, exchange rate, shock transmission

Rahapolitiikka kaksinapaisessa kansainvälisessä rahajärjestelmässä

Suomen Pankin keskustelualoitteita 1/98

Sinimaaria Ranki
Tutkimusosasto

Tiivistelmä

Tutkimuksessa käsitellään taloudellisten häiriöiden välittymistä maasta toiseen, niiden vaikutuksia valuuttakursseihin ja valuuttakurssipolitiikan yhteensovittamista rahapolitiikan kanssa. Teoreettinen osa koostuu valtatyyppiä edustavasta kahden suuren, toisistaan riippuvaisen talouden mallista, jossa on erityisesti tarkasteltu erityyppisten häiriöiden vaikutusta inflaatiovauhteihin ja valuuttakurssiin. Empiirissä sovelluksessa valotetaan Yhdysvaltojen ja Saksan aineiston avulla eurooppalaisten ja amerikkalaisten rahapoliittisten päättäjien vaihtoehtojen vaikutuksia valuuttakursseihin. Tulosten mukaan inflaatiovauhdit riippuvat lähinnä kotimaisista tarjontahäiriöistä molemmissa tutkituissa maissa. Kun tällainen häiriö kiihdyttää kotimaista inflaatiota, se myös heikentää valuutan kurssia. Tämä merkitsee, että yksittäisen maan näkökulmasta hintojen vakauttamiseen pyrkivä rahapolitiikka voi olla yhteensopivaa valuuttakurssin vakauttamisen kanssa. Toisen maan näkökulmasta syntyy tällöin kuitenkin ristiriita valuuttakurssin ja hintojen vakauden välillä. Tämä ero aiheuttaa rahapolitiikan kansainvälisen koordinaatio-ongelman. Valuuttakurssinäkökohtien huomioon ottamista rahapolitiikassa vaikeuttaa myös havainto, että valuuttakurssien vaihtelu näyttää olevan enimmäkseen riippumatonta tässä tutkimuksessa käsitellyistä taloudellisista perustekijöistä.

Asiasanat: euro, rahapolitiikka, valuuttakurssi, häiriöiden välittyminen

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1 Introduction

Countries differ in size and monetary significance. The resulting asymmetry of the international monetary system confers a broad array of benefits and problems on countries that issue leading currencies. These few special currencies have strategic importance for others, so how those others behave reflects on the issuer country.

Since the Great Depression, most European currencies have not been used as key currencies in the international monetary system because, as individual currencies, their relative importance in the world economy was too small to back up developments in international markets with sufficient supply. European Economic and Monetary Union (EMU) may change this aspect of European life quite dramatically. Implementation of the Maastricht Treaty imposes a single currency throughout the EMU area, creating at a stroke one of largest monetary blocs in the world economy. As transition to the single currency is effected, we could expect an irresistible structural shift in the international monetary system. That shift has huge potential to destabilize exchange rate regimes; it will very likely to be a major concern of monetary policymakers in the EMU area.

This study seeks to identify possible ways that Europe's planned single currency, the euro, could influence foreign exchange markets, and thereby anticipate monetary policy issues that could eventually face the European Central Bank (ECB). The discussion mainly concerns the international dimension of ECB monetary policy and the case for careful coordination of monetary and exchange rate policies.

The discussion is premised on two assumptions: the euro (EUR) will replace the Deutschmark (DEM) as the number two currency after the US dollar (USD) in the international monetary system, and use of the EUR will be more widespread than the DEM because it inherits the currencies of several EU member states. Judging from history, we can further assume that the ascendance of a new key currency in the international monetary system holds broad implications.

Article 2 of the Constitution of the ESCB (European System of Central Banks) states that the primary objective of ECB policy will be to maintain price stability. It won't be their only objective, though. The ECB's leaders will clearly have to confront exchange rate issues as well. Indeed, the EUR exchange rate could become volatile precisely because it gains extensive use as an international asset. With such status, its price could be determined by spurious expectations rather than macroeconomic fundamentals. Excessive volatility, in turn, would make it difficult for officials to set policy or for private agents to make plans. A serious long-running misalignment could have economic consequences quite independent of Europe's macroeconomic fundamentals. We think the ECB has strong motives to work for stabilization of exchange rate movements.

Exchange rate management of an international currency is a non-trivial task. The price of such currency is largely determined by demand, which, in turn, is largely affected by the expectations of international investors and other actors. A policy action intended to compensate for the effects of an inflationary shock could quite unintentionally destabilize the exchange rate. To illustrate this dilemma, we construct a simple two-country model with an IS-LM-AS framework. We then hit our model economy with different types of shocks: demand shocks, supply shocks, money supply shocks, money demand shocks and exchange rate shocks. The

qualitative effects of these shocks on interest rates, inflation, output and the exchange rate are explored. The proposed framework indicates that the likelihood of conflict between inflation stabilization and exchange rate stabilization depends on the type of shock. In the model, a demand shock always drives the value of the domestic currency in opposite directions in the goods market and the foreign exchange market. Other shocks may, of course, be less problematic for the policysetter, but nevertheless the results argue strongly that the exchange rate problem needs to be assessed empirically.

Having established that there may be situations where that force a trade-off between price stability and exchange rate stability, we then briefly discuss the prospects for international monetary cooperation. It appears that a certain amount of monetary coordination is needed to avoid excessive exchange rate volatility or, in the longer run, misalignments (especially if the currency blocs are heavily integrated).

The study is constructed as follows. Chapter 2 briefly describes the roles of an international currency and the possibilities of the EUR to attain wide use in the international monetary system.

To consider how a domestic monetary target can be achieved without harming the desired degree of exchange rate flexibility, Chapter 3 reviews earlier discourses on exchange rate flexibility and economic shocks. Using an IS-LM-AS framework, we subject a theoretical model of two economies with key currencies to various shocks (demand, supply, monetary, all-domestic, foreign, and exchange-rate shocks). The analysis seeks to uncover which types of shocks, or combinations thereof, bring monetary actions to maintain price stability into conflict with actions to promote exchange rate stability. We next apply the model empirically using US and German data to portray a world with two large economies and two main currencies. We contrast the effects on the US-German model with effects on the theoretical model with VAR methodology that isolates predominant sources of volatility.

Chapter 5 provides an interpretation of the results and discusses their consequences in terms of conduct of the monetary policy and exchange rate management. Chapter 6 concludes.

2 The euro in the international monetary system

An international currency can be defined as a currency that performs all monetary roles. When an international currency is used on a global scale it can be considered a key currency. Thanks to its universal acceptability, a key currency may act as a vehicle currency in situations where the indirect exchange costs of using it are lower than the direct exchange costs between two less popular currencies.¹ Vehicle

¹Here, strict distinction between key currency and vehicle currency is unnecessary. The terms are basically interchangeable within this discussion.

currencies can be highly useful; for example, in invoicing or holding liquid balances.²

2.1 The roles of an international currency

A key attribute of money is its general acceptability in the settlement of debt. As a means of international payment, a currency is used either in direct exchange or as a vehicle of indirect exchange between two other currencies.

When serving as a unit of account, the currency is the common denominator by which goods and services are valued and debts expressed. A currency can be used to invoice merchandise trade and denominate financial transactions.

When used as a store of value, the currency becomes a means of hold wealth. An international store of value is involved whenever held assets are denominated in a currency other than that of the country of the holder.

International currencies have demonstrated an ability to maintain their value over time. Confidence in the stability of a currency is determined mainly by its inflation record. Therefore, the safest currency for all investors regardless of their country is the currency of the country with the lowest and most predictable inflation.

Whether a currency becomes an international currency may also be contingent on the structure of the financial markets in its home country. Obviously, investors prefer assets from countries with the best-organized, most-efficient financial institutions and markets. They require markets that are open, broad and deep enough to provide economies of scale and a wide variety of instruments. This precondition is largely self-fulfilling: as use of a currency increases, a market develops thereby making it even more convenient to use that currency. When money markets for the currency are sufficiently liquid and deep, the currency assumes the role of the major international currency – a preferred medium of exchange.

The transaction domain of an international currency depends mainly on world trade patterns. The need to switch between currencies and, consequently, the ensuing transaction costs can be substantially diminished, when actors adapt their own currency mixes to that of most other actors and hold the most widely used currencies as international exchange media. Quite naturally, the choice of currency tends to concentrate on the international exchange media of those countries most predominant in international trade.

²The issue of the characteristics of an international currency is handled in more detail in the study of the ECU institute (1995), Ranki (1995), Bénassy-Quéré (1996) or Prem (1997). Thorough theoretical presentations of the properties of international currencies are Cohen (1971), Klump (1989), Tavlas (1991) and Van het dack (1992).

2.2 The euro as an international currency

To consider the factors affecting the euro's potential to become an international currency, we draw upon some real-world observations. Previous experiences with other internationally used currencies (USD, GBP, DEM and JPY) reveal three joint developments that auger growing acceptance as an international currency. First, the importance of a currency increases as it continues to exhibit stable inflation performance and be backed by a credible monetary policy. Second, a wide menu of financial instruments and lifting of capital controls based on the currency are developed. Finally, the extent to which the currency is used in world trade increases.

Agents are normally want to manage the risk that the value of a currency they hold may change. They further understand that a currency may lose purchasing power due to changes in domestic price levels, nominal exchange rates, or both. Thus, the degree to which the EUR competes with the USD as a key currency in the long run, is likely to depend on the stability of the purchasing power demonstrated by each of these two currencies. Initially, the EUR will be hard to judge against the USD, since the ECB has yet to establish any sort of track record for EUR inflation or credible monetary policy.

Nor is time alone all the ECB needs to establish credibility in implementing its policy commitments. The stability characteristics of the EUR will have to be designed in from the start through creation of an institutional framework with all preconditions to conduct a credible anti-inflationary monetary policy. The monetary constitution embodied in the Maastricht Treaty lays the foundations for such credibility by setting price stability as the primary objective of ECB monetary policy of the. The treaty also guarantees the ECB and its affiliate national central banks an independent position in monetary policy decisionmaking. In principle, an ECB that successfully continues to meet its price stability objective would lay a basis for the EUR to supplant the USD, at least partly, as the preferred key currency.³

Although the market for the EUR will clearly be deeper than the market for any EU currency at present, the EUR will also have to be made more fully usable as a means for international payments if it is to play an important role as an international reserve asset. For both the interbank market and the non-bank private sector, reluctance to use the EUR will persist until banking in the EUR is as cheap, or cheaper than, the alternatives. This depends on the success of further financial deregulation in bringing down the cost of banking in the EU.

The transaction domain for the EUR within the EU will be inherited from current EU currencies. As the second most important currency in foreign exchange markets, the EUR market will be deeper than the market for any of the individual EU currencies. Economies of scale should rapidly benefit the international use of the EUR, making it an efficient medium of exchange.

³When discussing stability, political risk should also be considered. Political risk measures the probability of a borrower being forced to default because of the imposition of exchange or other controls by a political authority. Hence, the conditions for the EUR to become an international currency can be improved by strengthening political stability in the EMU area, which for its part makes the commitment to liberalized financial markets credible.

The EUR could also gain from changes in invoicing patterns. EU trade invoiced in EUR would feed the growth of the currency's use as a means of payment in international transactions.⁴

The above said, there is little reason to imagine that the EUR will dethrone the USD as the world's preferred international currency. The size of the market and scale advantages for the USD are now so large that it can withstand tremendous pressures. Incidents in isolation (eg increased inflation risk, worsening of the US current account, or diminishing importance of the USD in world trade) do little to shake people's abiding faith in the USD. In fact, in times of global currency disturbances, the demonstrated flexibility of US financial markets and confidence in the country's long record of political and economic stability make the USD a haven currency.

Further, the USD's continued retention of its prime position in the international monetary system could continue simply because the switch to a different key currency involves substantial hysteresis. For example, Cooney (1987) has argued that it is actually in the interests of the rest of the world to support US deficits and maintain the dollar as the key currency.⁵ After all, most traders would consider a rapid or severe correction in the US current account as harmful to the interests of non-US exporters. Investors, too, might be averse to the idea of having to find new places to invest the present surpluses of their major trading partners.

2.3 Costs and benefits of an international euro for EMU

The effects of EUR's international roll on EMU have been widely considered.^{6,7} Here, we restrict our focus to three issues related to aspects of monetary and exchange rate policy of the ECB.⁸ We first consider the cost of loss of control over the money supply when the EUR serves as an international currency. Next, we examine the potential costs and benefits accruing through exchange rate management, and consider the merits of a development path towards making the relative positions of the USD and the EUR more symmetric. We close this section

⁴It should be noted that the change of invoicing currency in *intra*-EU trade does not have any direct *external* effects on the use of the EUR. There is, however, an important indirect effect. If intra-EU trade increases, the domestic financial markets for the EUR will develop and, thus, promote the preconditions for international use of the EUR.

⁵It should be noted that a reduction of the trade deficit of the US would necessitate stronger growth performance in other major economies. For a further discussion on the trade deficit problem of the US, see eg Cooney (1987).

⁶This question is addressed in *Commission of the European Communities* (1990). Goodhart (1993) provides a discussion of the results of the Commission study.

⁷The costs and benefits for EMU from the international use of the EUR depend, first of all, on the position of the EUR in the international monetary system. In a tripolar system where the USD dominates, both the EUR and the JPY would remain international, but not key, currencies. The effects from the EUR are thus less than if it assumes a key currency position.

⁸Further issues are discussed in Ranki (1995), Bénassy-Quéré (1996) and Funke & Kennedy (1997).

of discussion by speculating on consequences of a more symmetric international monetary system in global exchange rate developments. The discussion assumes that integration and liberalization on a global level will progress, or at least remain at the current level.

2.3.1 Losing control over the money supply

The international importance of a central bank is not solely determined by size or degree of its country's trade participation; the bank's tone, reputation for stability, sophistication, and sureness of touch in financial matters are all essential to winning respect in international monetary affairs. The ECB must demonstrate a good understanding of its strengths and vulnerabilities, and it must be allowed to develop in a convincing fashion.

Inaccurate accounting is an example of a possible impediment to the ECB's task of promoting the credibility of European economic policies and stability of the EUR. Because flows of EUR abroad can only be measured imprecisely, assessment of money growth becomes more difficult. In the event of an offshore disequilibrium, the excess supply of EUR offshore might cause the EUR exchange rate to depreciate. This, in turn, improves the current account, and offshore EUR becomes onshore EUR. However, the rate of growth of domestic EUR balances also increases, so some of the offshore EUR inflation is swept onshore. The ECB, in turn, would find it harder to pursue effective anti-inflationary policies.

2.3.2 Exchange rate management

An EUR foreign exchange market of sufficient depth to dampen volatility will also be harder to control by official intervention. Assuming that EMU participants are no more vulnerable to exchange rate fluctuations than the US, exchange rate management could become a focal issue for the ECB, independent of the formal USD-EUR exchange rate regime.

Large-scale substitution of the EUR for the USD could cause strong EUR appreciation against the USD, so transitional arrangements should be designed to prevent any shift from USD to EUR from having seriously disruptive consequences on the exchange rate and trade. In any case, extensive substitution would take a while to accomplish: the USD is presently used in over 80 % of world foreign exchange transactions and makes up over 60 % of world foreign exchange reserves. What reason could be so compelling as to cause public or private sector agents to switch currencies by suddenly selling off a large part of their holdings and incurring huge capital losses? Kenen (1993) argues, rather than rapid asset switching, it is far more likely that growth in EUR holdings will take place gradually through accumulation.

The popularity of the EUR will depend in part on the stability of its exchange rate against other international currencies. The inflation record of the EUR relative to the USD and the JPY will, in the long term, affect the exchange rate development between these currencies. If inflation in EMU area is assumed to be lower than in the US or Japan, it would probably contribute to EUR strength.

Like the USD, the EUR could be strong even if the EMU area runs a current account deficit. The deficit would, of course, have to be the result of excess investment over saving, so that it would be difficult for EMU participants to reduce the deficit through a depreciation of the currency. Market agents might even be quite willing to hold EUR-denominated assets. In such case, the exchange rate would not reflect the balance-of-payments situation of EMU and no depreciation would occur. On the other hand, if EMU shows a current account surplus, the EUR would also be a rather scarce international currency unless some mechanism is invoked to assure a continuous capital outflow from the EMU area.

2.3.3 Does symmetry confer stability or instability?

There are quite opposite views on how the introduction of the EUR will affect the symmetry of the international monetary system. One view holds that the international monetary system would become more stable with the EUR as major international currency because it increases symmetry in the system. The EMU area would constitute an economic power on a par with the US, which would mean that EU and US bargaining power match.⁹ Highly mobile capital, currency diversification and direct investment all drive the system towards greater symmetry, even if trade between the currency blocs never expands to any considerable extent.¹⁰ A multicurrency reserve system might even have certain advantages over one based on a single national currency, because competition between currencies would restrain authorities within the system from practising anything but fiscally virtuous policies. In such a world, flexible exchange rates would encompass a continuous process of adjustment, and it would be easier to let exchange rates move than harmonize domestic policies within the currency blocs. Thus, flexible exchange rates would give relatively greater room for domestic economic policy actions than fixed exchange rates.

The other line of argument holds that a symmetric system would prove more unstable than an asymmetric system, because the actual degree of autonomy in domestic economic policy is less than what is theoretically indicated. Garritsen de Vries (1987) note the experience with greater exchange rate flexibility after 1973 shows that while floating was helpful to balance-of-payments adjustment insofar as exchange rate movements prevented current account imbalances from widening caused by divergent rates of inflation, exchange rate changes did nothing to help reduce chronic current account imbalances. In addition, even where national policy independence is quite minimal, there is still a danger that some officials may abuse what they perceive as room to manoeuvre. Such danger becomes pronounced in situations where the cyclical positions of the issuer countries of the major international currencies differ.

⁹The opposite view is that EMU will not cause a qualitative switch from an asymmetric to a symmetric international monetary system. The proponents of this view argue that US leadership has already been eroded by Germany and Japan.

¹⁰For a discussion on EMU's effect on the symmetry of the international monetary system, see eg Padoa-Schioppa (1988), Giavazzi & Giovannini (1989), Alogoskoufis & Portes (1990), Jaquet (1991), Currie (1993), Goodhart (1993) or Kenen (1993).

Indeed, cyclical changes could be quite problematic for ECB policymakers unless there is consensus on national-level economic policy measures. For example, there could be a deflationary bias if all EMU countries simultaneously try to reduce inflation by letting the nominal exchange rate appreciate. Obviously, the exchange rate cannot appreciate for everybody, so some countries will be frustrated. There could also be the situation where everybody simultaneously conducts over-restrictive monetary policy, thereby imposing unnecessarily high unemployment levels. Countries could unilaterally try to achieve full employment through depreciation of the nominal exchange rate without coordinating their domestic policies, only to cause an inflationary bias. Across-the-board monetary expansion in the EMU area could even result in higher world inflation, and cause prolonged misalignments instead of desired smooth adjustments. The cost arising from spillovers of economic policies directed to meet domestic targets will only stay small as long as the proportion of trade between the currency blocs remained low.

3 Economic shocks, exchange rate stabilization and monetary policy

There is wide consensus among economists that price stability provides a meaningful policy target. Many studies¹¹ have concluded that price stability has positive macroeconomic implications: it raises the efficiency of the monetary system, reduces uncertainty about the future, confers higher long-term growth rates, increases cyclical stability, etc. Thus, our questions mainly concern whether the central bank should be concerned about the exchange rate, and if so, to what extent.

There is an extensive body of literature seeking to determine the amount of exchange rate flexibility appropriate to given situations. In these discussions, flexibility to set exchange rates is usually seen as a supplemental tool of monetary policy to be used, for example, when compensating for imperfect capital mobility.¹² Floating, the “hands-free” approach to exchange rate management, can allow excessive exchange rate variability that sends false or confusing signals to policymakers and private agents.

¹¹See eg Taylor (1996) for arguments for monetary stability.

¹²See Mussa (1979) for a discussion.

3.1 Arguments for exchange rate stability

Most central banks have a formal mandate to stabilize domestic prices, and use the classical approach of targeting the supply of money. The transmission of monetary policy is thought to take place mainly through interest rates.

However, especially when an economy is very open, the exchange rate can affect prices through at least two channels. First, the price of imports affects domestic prices. Second, central bank interventions in foreign exchange markets, unless sterilized, affect domestic liquidity. Both aspects make exchange rate a substantial consideration for macroeconomic policy. The need for exchange rate stabilization is also argued for as a means to reduce excessive exchange rate fluctuations disturb financial flows, or, in the medium-term, long swings that may disturb trade flows.

There is no satisfactory way to reduce exchange rate expectations to fundamentals – exchange rates simply do not behave as any existing theoretical models for exchange rate determination predict.¹³ Certain kinds of volatility, for example, cannot be traced to any specific source. Further, the mere expectation of an exchange rate change can lead to an immediate change in the exchange rate and, through that channel, causes output to change in the two respective countries. Krugman (1989) argues that unstable exchange rates make firms cautious, unwilling to change their production and pricing decisions in response to the exchange rate; the delinking of exchange rates from real variables allows the exchange rates to become still more unstable; and so on. Hence, changes in the expected rate of change of the exchange rate are a potentially important source of disturbance to the world economy and a potentially important channel through which other disturbances may be transmitted from one economy to another. To avoid output changes that are due to exchange rate volatility not linked to real economy, the central bank may want to stabilize exchange rate movements and, consequently, expectations of exchange rate movements. These short-run movements can be affected through intervention on the foreign exchange markets.

A fixed exchange rate system¹⁴ may lower exchange rate volatility, and as a result risk to international traders is lowered, simplifying their profit-maximizing calculations. Competition between producers located in different countries is also facilitated, encouraging further integration of economies. Thus, overall such a system can have a beneficial effect on growth. The argument for fixed exchange rates is quickly dispelled, however, if there are frequent changes in the fixed rates. Frequent changes increase uncertainty in foreign trade and in the financial markets, so the benefit of fixed rates in promoting international trade and effective allocation of capital is eroded. Depending on the structure of the economy, exchange rate stabilization may also cause a loss or weakening in the ability to gear monetary policy to domestic targets.

No matter what the exchange rate system, misalignments may arise. The prevention of misalignments requires international coordination of economic

¹³See MacDonald & Taylor (1992) or MacDonald (1995) for surveys of exchange rate economics.

¹⁴Eg Levačić & Rebmann (1982) compare the advantages and disadvantages of fixed versus flexible exchange rate systems. Krugman (1989) describes the experience with floating exchange rates.

policies. Three factors increase the need for coordination as economies become more interdependent. First, the increased number and magnitude of disturbances to which each country's balance of payments are subjected directs national policy instruments towards the restoration of external balances. Second, greater interdependence impedes the process by which policy authorities reach their domestic objectives. Third, greater integration can provide perverse incentives for a community of nations to engage in counterproductive behaviour that ultimately leaves all participants worse off than they need be.¹⁵

3.2 The model

In order to analyse the interaction of the monetary policies in two large economies, the US and the anticipated EMU area, we construct a traditional Mundell–Fleming (MF) symmetric two-country open economy macromodel.¹⁶ Generally, some transmission of various disturbances to the home country can be shown to occur if desired expenditure in the home country is affected by the terms of trade, or if import prices affect the demand for money, or if import prices directly affect the cost of domestic output. In the version of the MF model constructed here, we have three markets in both of the countries: a domestic goods market (the IS curve), a money market (the LM curve), and resources or the labour market (the AS curve). Conventionally, we have four assets: domestic and foreign money; domestic and foreign bonds. Domestic and foreign money are held only by local residents, whereas bonds can be traded across borders. The model assumes perfect capital mobility so that uncovered interest rate parity holds, thereby making domestic and foreign bonds perfect substitutes. Both countries are large and each country's interest rate is linked to the interest rate of the other country via interest rate parity. Each country can affect the common interest rate through its domestic policies. Exchange rate expectations, however, can also induce differentials between interest rates.

For the home country, we write the following equations

$$\begin{aligned} y &= \theta(s + p^* - p) - \sigma r + \gamma y^* + \epsilon_d && \text{IS function} \\ m - p &= y - \lambda r + \epsilon_m && \text{LM function} \\ p &= \pi y + \epsilon_s && \text{AS function} \end{aligned}$$

Symmetry means that the structural parameter vector $(\theta, \sigma, \gamma, \lambda, \pi)'$ is the same at home and abroad. Otherwise, foreign variables are denoted by an asterisk (*). Hence, we write for the foreign country

$$\begin{aligned} y^* &= -\theta(s + p^* - p) - \sigma r^* + \gamma y + \epsilon_d^* && \text{IS function} \\ m^* - p^* &= y^* - \lambda r^* + \epsilon_m^* && \text{LM function} \\ p^* &= \pi y^* + \epsilon_s^* && \text{AS function} \end{aligned}$$

¹⁵Hamada (1979) provides an excellent discussion of international interaction and the consequent need for policy coordination.

¹⁶For a description of the standard Mundell–Fleming model, see Steveson et al. (1988), Copeland (1989), or Pentacost (1993).

Inflation expectations, as is standard in such short-run (one-period) analyses, are static (and exogenous). To simplify, we let real and nominal interest rates be equal. The model will be solved first under the assumption that the domestic and foreign interest rates will be equal (as determined by the money markets); an exogenous “peso shock” ϵ_E , will be added to the model without introducing any additional complexities. The shock is linked to the interest rates as

$$r^* = r + \epsilon_E$$

so that it drives a wedge between the domestic and foreign interest rates. Exchange rate expectations can easily be incorporated by substituting the interest rate parity condition for the domestic interest rate in the model. In the thus modified model, domestic goods and money market disturbances should be interpreted as composites, ie $\epsilon_d - \sigma\epsilon_E$ and $\epsilon_m - \lambda\epsilon_E$.

We derive the reduced form solution for the common interest rate r , eliminating the terms of trade term, $s + p^* - p$, from the two IS equations to arrive at

$$(1 - \gamma)(y + y^*) = -2\sigma r^* + \epsilon_d + \epsilon_d^* \quad (1)$$

The LM and AS equations, give us

$$(m + m^*) - (p + p^*) = (y + y^*) - 2\lambda r^* + (\epsilon_m + \epsilon_m^*) \quad (2)$$

and

$$(p + p^*) = \pi(y + y^*) + (\epsilon_s + \epsilon_s^*) \quad (3)$$

so from these two equations we have, by eliminating $(p + p^*)$,

$$(1 + \pi)(y + y^*) = (m + m^*) + 2\lambda r^* - (\epsilon_m + \epsilon_m^*) - (\epsilon_s + \epsilon_s^*) \quad (4)$$

Substituting this into equation (1) gives us

$$\begin{aligned} (1 - \gamma)[(m + m^*) + 2\lambda r^* - (\epsilon_m + \epsilon_m^*) - (\epsilon_s + \epsilon_s^*)] = \\ (1 + \pi)[-2\sigma r^* + (\epsilon_d + \epsilon_d^*)] \end{aligned} \quad (5a)$$

or

$$r^* = \chi^{-1} \left[(\epsilon_m + \epsilon_m^*) + (\epsilon_s + \epsilon_s^*) - (m + m^*) + \left(\frac{1 + \pi}{1 - \gamma} \right) (\epsilon_d + \epsilon_d^*) \right] \quad (5b)$$

where $\chi = 2(\lambda + \sigma(1+\pi)/(1-\gamma)) > 0$, assuming that $\gamma < 1$; the interest rate solution has the usual structure in the sense that positive money and aggregate demand shocks as well as adverse supply shocks will increase the interest rate, while money supply shocks will reduce it.¹⁷

To solve for terms of trade, we use the IS equations to derive the following equation

$$(1+\gamma)(y-y^*)=2\theta q+(\epsilon_d-\epsilon_d^*); \quad (6)$$

where $q = s + p^* - p$.

The LM and AS equations once again give

$$(m-m^*)-(p-p^*)=(y-y^*)+(\epsilon_m-\epsilon_m^*) \quad (7)$$

and

$$(p-p^*)=\pi(y-y^*)+(\epsilon_s-\epsilon_s^*) \quad (8)$$

so

$$(1+\pi)(y-y^*)=(m-m^*)-(\epsilon_m-\epsilon_m^*)-(\epsilon_s-\epsilon_s^*) \quad (9)$$

which, after substituting into equation (6) produces

$$q=(s+p^*-p)=\left[\frac{1+\gamma}{2\theta(1+\pi)}\right][(m-m^*)-(\epsilon_m-\epsilon_m^*)-(\epsilon_s-\epsilon_s^*)] - \left(\frac{1}{2\theta}\right)(\epsilon_d-\epsilon_d^*) \quad (10)$$

This leaves four (4) endogenous variables to be determined; y , y^* , p and p^* . The nominal exchange rate will thereafter be determined by the identity $s = q + (p - p^*)$.

Let ξ and ψ be the two composite random variables on the r.h.s of equations (5) and (10), respectively.

$$\xi=\chi^{-1}\left[(\epsilon_m+\epsilon_m^*)+(\epsilon_s+\epsilon_s^*)-(m+m^*)+\left(\frac{1+\pi}{1-\gamma}\right)(\epsilon_d+\epsilon_d^*)\right] \quad (11)$$

¹⁷Note that symmetry here is reflected in the form various disturbances affect the interest rate.

$$\psi = \left[\frac{1+\gamma}{2\theta(1+\pi)} \right] [(m-m^*) - (\epsilon_m - \epsilon_m^*) - (\epsilon_s - \epsilon_s^*)] - \left(\frac{1}{2\theta} \right) (\epsilon_d - \epsilon_d^*) \quad (12)$$

Thus, we can write the 4-dimensional system consisting of outputs and price levels as

$$\begin{aligned} y - \gamma y^* &= \theta \psi - \sigma \xi + \epsilon_d \\ -\gamma y + y^* &= -\theta \psi - \sigma \xi + \epsilon_d^* \\ \pi y - p &= -\epsilon_s \\ \pi y^* - p^* &= -\epsilon_s^* \end{aligned} \quad (13)$$

This system can be written in a compact form using matrix notation

$$\mathbf{A} \mathbf{z} = \mathbf{B} \boldsymbol{\omega} \quad (13')$$

where $\mathbf{z} = (y, y^*, p, p^*)'$, $\boldsymbol{\omega} = (\epsilon_s, \epsilon_d, \epsilon_m, m, \epsilon_s^*, \epsilon_d^*, \epsilon_m^*, m^*)'$ and where the matrices \mathbf{A} and \mathbf{B} are given by

$$\mathbf{A} = \begin{pmatrix} 1 & -\gamma & 0 & 0 \\ -\gamma & 1 & 0 & 0 \\ \pi & 0 & -1 & 0 \\ 0 & \pi & 0 & -1 \end{pmatrix}; \quad (14)$$

$$\mathbf{B} = \begin{pmatrix} -\beta_s & \beta_d & -\beta_s & \beta_s & \beta_s^* & \beta_d^* & \beta_s^* & -\beta_s^* \\ \beta_s^* & \beta_d^* & \beta_s^* & -\beta_s^* & -\beta_s & \beta_d & -\beta_s & \beta_s \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \end{pmatrix}$$

where

$$\beta_s = \left(\frac{\lambda(1+\gamma) + \left[\frac{2\sigma(1+\pi)}{1-\gamma} \right]}{(1+\pi)\chi} \right) > 0; \quad \beta_d = \lambda\chi^{-1} > 0;$$

$$\beta_s^* = \left(\frac{\lambda(1+\gamma) + \left[\frac{2\sigma\gamma(1+\pi)}{1-\gamma} \right]}{(1+\pi)\chi} \right) > 0; \quad \beta_d^* = \frac{1}{2} - \frac{\sigma(1+\pi)}{\chi(1-\gamma)} > 0$$

The solution to equation (13') is given by

$$\mathbf{z} = \mathbf{A}^{-1}\mathbf{B}\omega \quad (15)$$

where \mathbf{A}^{-1} denotes the inverse matrix of \mathbf{A} (it exists, since the determinant of \mathbf{A} is $1-\gamma^2$, which is less than one for bounded cross-country income effects $\gamma < 1$). The inverse is given by

$$\mathbf{A}^{-1} = [\det(\mathbf{A})]^{-1} \text{adj}(\mathbf{A}) = (1-\gamma^2)^{-1} \text{adj}(\mathbf{A})$$

where $\text{adj}(\mathbf{A})$ denotes the adjoint of \mathbf{A} . If α_{ij} denotes the ij^{th} element of the product matrix $\mathbf{A}^{-1}\mathbf{B}$, ie $\alpha_{ij} = [\mathbf{A}^{-1}\mathbf{B}]_{ij}$, we have

$$\begin{aligned} \alpha_{11} &= \frac{[\gamma\beta_s^* - \beta_s]}{(1-\gamma^2)} < 0; \quad \alpha_{12} = \frac{[\beta_d + \gamma\beta_d^*]}{(1-\gamma^2)} > 0; \quad \alpha_{13} = \alpha_{11} < 0; \\ \alpha_{14} &= \frac{[\beta_s - \gamma\beta_s^*]}{(1-\gamma^2)} > 0; \quad \alpha_{15} = \frac{[\beta_s^* - \gamma\beta_s]}{(1-\gamma^2)} > 0; \quad \alpha_{16} = \frac{[\beta_d^* + \gamma\beta_d]}{(1-\gamma^2)} > 0; \\ \alpha_{17} &= \alpha_{15} > 0; \quad \alpha_{18} = -\alpha_{15} < 0; \quad \alpha_{21} = \alpha_{15} > 0; \quad \alpha_{22} = \alpha_{16} > 0; \quad \alpha_{23} = \alpha_{15} > 0; \\ \alpha_{24} &= -\alpha_{15} < 0; \quad \alpha_{25} = \alpha_{11} < 0; \quad \alpha_{26} = \alpha_{12} > 0; \quad \alpha_{27} = \alpha_{11} < 0; \quad \alpha_{28} = -\alpha_{11} > 0; \\ \alpha_{31} &= -\pi\alpha_{11} + 1 > 0; \quad \alpha_{32} = \pi\alpha_{12} > 0; \quad \alpha_{33} = \pi\alpha_{11} < 0; \quad \alpha_{34} = -\pi\alpha_{11} > 0; \\ \alpha_{35} &= \pi\alpha_{15} > 0; \quad \alpha_{36} = \pi\alpha_{16} > 0; \quad \alpha_{37} = \pi\alpha_{15} > 0; \quad \alpha_{38} = -\pi\alpha_{15} < 0; \\ \alpha_{41} &= \pi\alpha_{15} > 0; \quad \alpha_{42} = \pi\alpha_{16} > 0; \quad \alpha_{43} = \pi\alpha_{15} > 0; \quad \alpha_{44} = -\pi\alpha_{15} < 0; \\ \alpha_{45} &= \pi\alpha_{11} + 1 > 0; \quad \alpha_{46} = \pi\alpha_{12} > 0; \quad \alpha_{47} = \pi\alpha_{11} < 0; \quad \alpha_{48} = -\pi\alpha_{11}. \end{aligned}$$

Given the solution to the model above, we derive the reduced form solution for the nominal exchange rate. By definition $s = q + (p - p^*)$, so that

$$\begin{aligned} q = (s + p^* - p) &= \left[\frac{1+\gamma}{2\theta(1+\pi)} \right] [(m - m^*) - (\epsilon_m - \epsilon_m^*) - (\epsilon_s - \epsilon_s^*)] \\ &\quad - \left(\frac{1}{2\theta} \right) (\epsilon_d - \epsilon_d^*) \end{aligned} \quad (10')$$

and

$$\begin{aligned}
p - p^* = & [1 - \pi(\alpha_{11} + \alpha_{15})]\epsilon_s + \pi(\alpha_{12} - \alpha_{16})\epsilon_d + \pi(\alpha_{11} - \alpha_{15})\epsilon_m \\
& - \pi(\alpha_{11} - \alpha_{15})m - [1 + \pi(\alpha_{11} - \alpha_{15})]\epsilon_s^* + \pi(\alpha_{16} - \alpha_{12})\epsilon_d^* \\
& + \pi(\alpha_{15} - \alpha_{11})\epsilon_m^* - \pi(\alpha_{15} - \alpha_{11})m^*
\end{aligned} \tag{16}$$

where

$$\begin{aligned}
1 - \pi(\alpha_{11} + \alpha_{15}) &= 1 - \frac{2\sigma}{\chi(1-\gamma)} > 0; \quad \pi(\alpha_{12} - \alpha_{16}) = 0; \\
\pi(\alpha_{11} - \alpha_{15}) &= -\frac{2\pi}{\chi(1+\pi)} \left[\lambda + \frac{\sigma(1+\pi)}{(1-\gamma)} \right] < 0
\end{aligned} \tag{17}$$

Previously, we have assumed static exchange rate expectations. However, at any point in time, the exchange rate in a floating rate regime with high capital mobility depends both on current variables and expectations about future exchange rates. Fundamentals matter in the long run, but often the prospects for the fundamentals are unclear, so that expectations are dominated by uncertainty. Thus, short-run fluctuations in exchange rates can be explained to a great extent by fluctuations in expectations. To account for this, we introduce exchange rate expectations into the model.

We thus calculate the effects of the “peso shock” on domestic and foreign output-price level combination. The notation here is identical to the one in the matrix solution to the output-price level combination in domestic and foreign economy presented in equation (14), ie α_{ij} refers to the ij^{th} -element of the product matrix $\mathbf{A}^{-1}\mathbf{B}$. Thus

$$\frac{\partial y}{\partial \epsilon_E} = -[\sigma\alpha_{12} + \lambda\alpha_{13}] = \frac{\lambda}{\chi(1+\pi)} \left[\lambda + \frac{\sigma(1+\pi)}{1-\gamma} \right] = \frac{\lambda}{2(1+\pi)} > 0 \tag{18}$$

$$\frac{\partial y^*}{\partial \epsilon_E} = -[\sigma\alpha_{22} + \lambda\alpha_{23}] = -\frac{\lambda}{\chi(1+\pi)} \left[\lambda + \frac{\sigma(1+\pi)}{1-\gamma} \right] = -\frac{\lambda}{2(1+\pi)} < 0 \tag{19}$$

$$\frac{\partial p}{\partial \epsilon_E} = -\pi[\sigma\alpha_{12} + \lambda\alpha_{11}] = \frac{\partial y}{\partial \epsilon_E} > 0 \tag{20}$$

$$\frac{\partial p^*}{\partial \epsilon_E} = -\pi[\sigma\alpha_{16} + \lambda\alpha_{15}] = \frac{\partial y^*}{\partial \epsilon_E} < 0 \tag{21}$$

From equations (18) and (19) we see that aggregate output ($y + y^*$) is not affected by the “peso shock”, only the distribution of the aggregate output across countries.

Table 3.1 summarizes the qualitative effects of the different shocks on domestic and foreign production and inflation, and the exchange rate. Most of the effects of the various shocks are conventional. Moreover, the effects of all but two can be controlled by monetary policy. An effect either increases inflation and depreciates the currency, or vice versa.

Table 3.1 **The qualitative effects of the structural disturbances on macroeconomic variables**

| Effect on | of | ϵ_E | ϵ_s | ϵ_d | ϵ_m | m | ϵ_s^* | ϵ_d^* | ϵ_m^* | m^* |
|-----------|----|--------------|--------------|--------------|--------------|-----|----------------|----------------|----------------|-------|
| r | | + | + | + | + | - | + | + | + | - |
| p | | + | + | + | - | + | + | + | + | - |
| y | | + | - | + | - | + | + | + | + | - |
| e | | + | +/- | - | - | + | +/- | - | + | - |
| r^* | | + | + | + | + | - | + | + | + | - |
| p^* | | - | + | + | + | - | + | + | - | + |
| y^* | | - | + | + | + | - | - | + | - | + |

Consider how shocks change *exchange rate expectations*. A positive shock in exchange rate expectations, ie the expectation the domestic currency will depreciate strongly (a “peso shock”), makes holding of foreign assets more attractive than the holding of domestic assets. This induces a capital flow from the home country to the foreign country. The capital flow forces up the value of foreign money relative to the money of the home country. This appreciation of the foreign currency shifts demand towards domestic output, leading to an expansion of output at home and a reduction of output abroad. When asset holders can take positions in foreign assets, expectations of future exchange rates play a vital role in determining the current exchange rate and other macroeconomic variables. An asset holder who has choice about the currency denomination of his assets will not hold his assets in a currency that he expects to depreciate, unless he is compensated by a nominal interest rate differential in favour of such assets. At home, at least, the increase in output is dampened by a rise of the interest rate.

A *monetary shock* can occur either as a change in the supply of money or a change in the demand for money. Money supply changes are the result of a change in central bank strategy. Money demand changes may, for example, due to a change in the velocity of money or preferences for financial instruments.

Assume now that a positive domestic monetary shock pushes down the world interest rate. The fall in the interest rate, however, is not enough to restore overall balance of payments equilibrium at the prevailing exchange rate, as in our model the world interest rate is determined jointly across the two countries. Therefore, the initially expansionary country will experience a balance-of-payments deficit. The foreign country, in turn, will experience the increase in the expansionary country’s income as an increase the partner country’s exports, so that income in the partner country also rises. The fall in world interest rate, however, generates a balance of payments surplus, so the exchange rate must be adjusted. The currency

of the expansionary country depreciates vis-à-vis the currency of the other country. Depreciation in the expansionary country further increases output, while appreciation in the other country dampens output.

If we look at demand and monetary disturbances, we see that each effect is distinct. This is because each of these shocks affects the interest rate differently. A demand shock from the real side has no direct effect on either nation's interest rates, nor on the world interest rate. But as output changes, the demand for money also changes, affecting the interest rate. Exchange rate changes then adjust to keep output levels at equilibrium with the world interest rate.

A monetary shock, by contrast, has a direct effect on the interest rate of the country where the disturbance occurs. Under perfect capital mobility, it induces capital flows between high-interest rate countries and low-interest rate countries. This, in turn, calls for further exchange rate changes. The exchange rate change affects output in both countries.

The three types of shocks (ie exchange rate, money demand and money supply shocks) all have qualitatively the same effect on the monetary policy target variables. A positive shock from any of these accelerates inflation and depreciates the domestic currency. The monetary policy response intended to stabilize a target variable (say, the exchange rate) would also hopefully stabilize the other target variable (inflation). However, from Table 3.1 we can see situations where the target variable's inflation rate and exchange rate call for quite contradictory monetary policy actions. This is clearly the case for demand shock, and possible for a foreign supply shock.

Typically, supply shocks involve exogenous changes in energy prices or the terms of trade, productivity shocks, or tax and wage shocks. Adverse supply shocks include the exogenous increase in factors of production. When commodity prices increase faster than goods prices, producers face increased production costs. When producers pass higher intermediate goods prices on to their own prices, inflation is higher no matter what the level of output. Hence, the economy faces a combination of declining real growth and rising inflation.

The qualitative effect of the supply shock on the exchange rate depends on whether $\pi(\alpha_{11} + \alpha_{15})$ in (16) is greater or smaller than one. This term reflects the relative sizes of the two effects. The supply shock, by reducing the supply of output, increases the price level. This diminishes the real stock of money, so the interest rate increases. Since the interest rate is higher than the equilibrium world interest rate, this leads into an inflow of capital that tends to appreciate the domestic currency. However, an increase in the price level diminishes output, because the foreign demand component of demand diminished due to the deteriorated competitiveness of domestic products in international markets. To restore this equilibrium, the exchange rate has to depreciate. Thus, the final effect of a supply shock on the exchange rate depends on which of these two effects dominates.

Demand shocks can also be problematic for monetary policymakers. Demand shocks might also be thought of as government spending shocks or shifts in investment and consumption functions. Generally, while aggregate demand shocks have only temporary effects on the level of output, they effect prices over the long term so that a positive shock leads to a higher price level.

Internationally, a demand shock from the real side of the economy in the foreign country is likely to be transmitted with greater force to the home economy

under a flexible exchange rate regime. Say an increase in domestic expenditure increases the country's demand both for its own goods and the goods of the foreign country. The increase in the home country's demand for imports implies that the foreign country experiences a trade surplus. The interest rate in the home country is higher (and the interest rate in the foreign country lower) than the equilibrium world interest rate. When capital is internationally mobile, an inflow of capital follows in the home country, and an outflow in the foreign country. The domestic currency, hence, appreciates, and the foreign currency depreciates. This dampens the initial shock in the home country and strengthens the spill-over effect in the foreign country.

Thus, the demand shock increases domestic inflation, but appreciates the currency, because the shock raises inflation rates in both countries. This implies there is no trade effect through prices. To restore equilibrium, the exchange rate has to adjust. The central bank can either control inflation by tightening monetary policy and accepting an appreciation of the currency, or it can let inflation rise and prevent the currency from appreciating.

4 Model results and discussion

Having constructed a theoretical model to capture the qualitative effects of various shocks on interest rates, inflation, output and the exchange rate in a two-country world, we now estimate a VAR system to examine the relative importance of the underlying structural shocks as implied by the model. Since monetary policy target variables are dependent on policy decisions, they create simultaneous equation bias when a policy variable is regressed on targets. To alleviate this, we use a VAR procedure whereby, in the system we include the "domestic" variables interest rate r , inflation rate π and output y . The complete two-country model also includes the domestic variables of the "foreign" country.¹⁸ For foreign variables, we use the foreign interest rate, r^* , the foreign inflation rate π^* and foreign output y^* . Finally, we include exchange rate s . In the VAR system, all variables are endogenous. One particularly useful interpretation of the VAR here is that it incorporates a monetary policy rule or a reaction function in the form of an interest rate rule, whereby US interest rates respond to changes in the other variables in the VAR. Since the VAR residuals are (linear) combinations of underlying structural shocks of the type present in the theoretical model introduced earlier, US interest rates (as well as all other VAR variables) basically respond to these underlying shocks. Thus, the VAR system to be estimated takes the form

$$X_t = a + \sum_{i=1}^3 B_i X_{t-i} + u_t \quad (22)$$

where X_t is a 7x1 vector including the variables listed above, a is the constant vector of constants of order 7x1, B_i is a 7x7 coefficient matrix for the lagged values of X_t , and u_t is the error term vector of order 7x1. All variables are

¹⁸For a similar test, see Galí (1992).

logarithmic differences except the interest rates, which are differences, but not logarithms. We test the period 1980–1996 using monthly data and defining the lag structure for three months. Aside from the interest rates taken from the BIS, the data are taken from IFS tapes provided by the IMF. The interest rates are one-month inter-bank offer rates,¹⁹ inflation rates are calculated from CPI data and output is represented by industrial production series. The exchange rate is the monthly average for the DEM/USD spot rate. Standard tests were done on the time series properties of the data; the results are reported in the Appendix.

4.1 Results

The results are reported in Tables 4.1 and 4.2. Table 4.1 displays t-values for the individual lags of the variables, and Table 4.2 reports F-statistics for the groups of lags for each variable. Figures 4.1–4.7 show the impulse response functions²⁰ for each of the variables. Tables presenting the variance decompositions are found in the appendix. The results are summarized and contrasted with the theoretical results from Chapter 3 in Table 4.3. Tables displaying the decomposition of variance also appear in the appendix. Sections 4.1.1 through 4.1.4 present the results verbally.

¹⁹Conceptually, the ideal interest rate to use as a measure of the stance of monetary policy would be the official interest rate at which marginal financing is provided to the banking system. Unfortunately, it is impractical to pursue this approach for several reasons. As Gerlach & Smets (1995) point out, central banks typically provide financing using a number of different interest rates, which makes it difficult to choose “the” representative rate. Further, the exact interest rate that is relevant has changed over time in many countries in response to major developments in central bank monetary operating techniques. Central banks may also alter the stance of monetary policy without changing official interest rates, for instance by varying the availability of credit at official rates. Cochrane (1994), for example, has tested the one-month Treasury Bill rate as well as the Federal Funds rate and come to the conclusion that the results are almost identical. Thus, since market-determined interest rates typically respond very quickly to changes in monetary irrespective of whether they are expressed by a change in an official interest rate or by a change in the availability of credit, we use one-month interest rates as measures of the stance of the policy.

²⁰ Hamilton (1994) provides a lively discussion of the mathematics of impulse response functions.

Table 4.1 **t-values of VAR coefficients (equation 22)**

| t-values | US interest rate | US inflation | US production | Exchange rate DEM/USD | German interest rate | German inflation | German production |
|----------|--------------------------------|---------------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------------|---------------------------------|
| INTUS | 3.32 -1.16 0.66 | 1.78 0.06 0.08 | 1.08 2.56 0.31 | 1.95 0.16 0.92 | - 2.25 0.63 -1.04 | 0.26 0.93 - 1.92 | 0.29 0.50 0.87 |
| INFUS | 2.69 -0.69 0.82 | 4.66 - 1.81 -1.28 | 2.24 -1.05 -0.36 | 1.09 - 1.96 1.33 | 3.43 -0.19 1.62 | 1.45 -1.06 1.91 | 0.77 -0.64 0.05 |
| PRODUS | 0.88 0.32 -0.79 | 1.33 -1.54 -0.47 | 1.22 1.24 2.25 | 3.18 -0.20 0.72 | -0.62 -1.52 -0.91 | -0.03 0.40 -0.74 | 1.21 -0.05 0.72 |
| EXR | - 1.84 0.63 -0.48 | -1.02 2.02 -0.65 | - 2.27 0.88 0.66 | 4.60 -0.08 1.17 | -0.63 -0.96 -1.58 | -0.63 0.21 1.03 | 3.48 0.75 -1.04 |
| INTG | 0.49 -1.14 1.06 | -0.96 2.77 0.55 | -0.25 0.69 -0.15 | 1.34 2.31 -1.41 | -1.23 2.77 1.33 | 0.15 0.97 -1.41 | 1.26 1.02 0.03 |
| INFG | 1.58 -0.10 -0.94 | 0.12 -1.15 -0.45 | 0.45 0.61 -0.55 | 2.04 0.09 0.26 | 1.80 0.58 0.69 | 2.67 0.03 1.69 | -0.20 -1.23 -1.11 |
| PRODG | -0.69 -0.26 0.62 | -0.17 1.68 -0.30 | -0.19 0.23 0.02 | 0.37 -0.74 0.21 | 1.42 0.58 -1.54 | -0.36 -1.43 0.98 | - 5.94 -1.46 -0.02 |

Significant values (at 10 % level) are bold.

Table 4.2 F-statistics for VAR variables (equation 22)

| t-values | US interest rate | US inflation | US production | Exchange rate DEM/USD | German interest rate | German inflation | German production |
|----------|---------------------|-----------------|------------------|--------------------------|-------------------------|---------------------|----------------------|
| INTUS | 3.72* | 1.21 | 3.06* | 1.67 | 2.60* | 1.34 | 0.72 |
| INFUS | 2.57* | 8.75* | 1.89 | 1.62 | 5.77* | 2.04 | 0.66 |
| PRODUS | 0.55 | 1.48 | 3.45* | 4.04* | 1.26 | 0.20 | 0.91 |
| EXR | 1.15 | 1.41 | 1.92 | 8.92* | 1.46 | 0.50 | 4.85* |
| INTG | 0.62 | 3.67* | 0.17 | 3.59* | 3.62* | 0.83 | 0.68 |
| INFG | 1.22 | 0.82 | 0.20 | 1.71 | 1.54 | 3.91* | 0.67 |
| PRODG | 0.34 | 1.09 | 0.26 | 0.19 | 1.31 | 0.96 | 12.3* |

Significant values (at 10 % level) are bold.

Table 4.3 Comparison of empirical results with theoretical model

| The effect of (1) on (-) | US interest rate | US inflation rate | US production | DEM/USD exchange rate | German interest rate | German inflation rate | German production |
|---|------------------|-------------------|---------------|-----------------------|----------------------|-----------------------|-------------------|
| Empirical effect of US interest rate | * | + | (-) | + | (0) | (0) | (0) |
| Theoretical effect of ϵ_s | + | + | - | +/- | + | + | + |
| Empirical effect of US inflation rate | (+) | * | (-) | - | + | - | (+) |
| Theoretical effect of ϵ_s | + | + | - | +/- | + | + | + |
| Empirical effect of US production | + | + | * | + | (-) | (-) | (0) |
| Theoretical effect of ϵ_E | + | + | + | - | + | - | - |
| Theoretical effect of ϵ_m^* | + | + | + | - | + | - | - |
| Empirical effect of DEM/USD exchange rate | - | - | - | * | + | + | (-) |
| Theoretical effect of ϵ_E | + | - | - | + | + | + | + |
| Theoretical effect of m | - | - | - | + | - | + | + |
| Empirical effect of German interest rate | - | + | (-) | (-) | * | + | (+) |
| Theoretical effect of ϵ_s^* | + | + | - | +/- | + | + | + |
| Empirical effect of German inflation | - | + | (0) | (+) | - | * | (-) |
| Theoretical effect of ϵ_s | + | + | + | +/- | + | + | - |
| Theoretical effect of ϵ_s^* | + | + | - | +/- | + | + | + |
| Theoretical effect of (ϵ_s^*) | + | + | + | - | + | + | + |
| Empirical effect of German production | (+) | (+) | (+) | + | (+) | (-) | * |
| Theoretical effect of ϵ_d | + | + | + | + | + | + | + |

4.1.1 Analysing exchange rate changes

The decomposition of variance shows that 94.8 % of exchange rate variability is explained by innovations the exchange rate itself. Within a year, the share falls to 82 %. The second most important component in explaining variation in the exchange rate is German production, with its share rising to 6.7 %. The roles of the interest rates are such that the US interest rate explains 2.7 % and the German interest rate 1.4 % of the variation in the exchange rate. For the inflation rates, in turn, the variance decomposition yields a share of 1.9 % for the US inflation rate and of 1 % for the German inflation rate. Hence, we see that volatility of the exchange rate is linked to the underlying fundamentals only weakly. Instead, exchange rate movements seem to be largely autonomous, which leaves room even for self-validating bubbles etc.

If we analyse the nature of exchange rate changes by their effects on other variables, we see (at least in Table 4.3) that they resemble “peso” or expectation shocks. The empirically obtained effects are qualitatively closest to the theoretically derived effects of an exchange rate expectation disturbance. In particular, we see that a positive exchange rate innovation, ie an appreciation of the USD, or a depreciation of the DEM, tends to slow inflation in the US and to increase inflation in Germany.

Like all financial markets, foreign exchange markets are sensitive to collective opinions. The report of the ECU Institute (1995) argues that prices on foreign exchange markets not only reflect average opinion, they are also important sources of information that shape opinion. Thus the processes at work are self-validating; prices are both starting points and outcomes that shape expectations. In other words, mimesis could be more influential than exogenous factors. This already makes argues strongly for exchange rate stabilization that can be achieved without causing problems in other variables.

On the other hand, the exchange rate must be seen to react rationally to changes in other variables. If we look at the effects of interest rate innovations, for instance, we see that an increase in the US interest rate tends to appreciate the USD, while a German interest rate increase appreciates the DEM. Moreover, an increase in the US inflation rate is associated with a depreciating USD, and an increase in the German inflation rate results in depreciation of the DEM. All these results are in accordance with the theoretical model.

Empirical evidence pointing to the same direction has been presented in Eichenbaum & Evans (1995). They have investigated the effects of shocks to US monetary policy on exchange rates. They found substantial evidence of a link between monetary policy and exchange rates: a contractionary shock to US monetary policy leads to a persistent and significant appreciation in the nominal exchange rate of the USD. Moreover, the maximal effect of such a monetary policy shock (ie an increase in the US interest rates) on the exchange rate is not contemporaneous; instead the USD continues to appreciate for a substantial period of time.

As to the real side of the economy, a positive production shock in the US tends to appreciate the USD, while a positive production shock in Germany depreciates the DEM. These results seem to suggest that the production shocks in the two countries are different from each other by nature.

4.1.2 Analysing inflation rate changes

In the US, shocks to the inflation rate itself mainly explain changes in inflation. As the decomposition of variance shows, 97.2 % of the variance is due to the inflation rate itself in the first month after the shock, and 77.9 % a year after the shock. The second most important factor is the German interest rate which, after a year from the shock, explains 7 % of the US inflation innovations. The US interest rate explains 4.3 % of changes in US inflation. The role of the exchange rate is explaining 3.4 % of US inflation. German inflation affects US inflation with a share of 2.7 %.

By comparing the empirical results with the theoretically derived effects of the various structural disturbances, we observe that US inflation shocks resemble or seem to be dominated by domestic (US) supply shocks. This conclusion mainly considers effects on the exchange rate and domestic production; it would be inconsistent with other sources, in particular demand shocks. Please recall that supply shocks were written in the model as autonomous changes in inflation expectations. Thus inflation shocks in the US tend to increase the inflation rate at home, and diminish it in Germany. The effect of supply shocks on the exchange rate is ambiguous from the standpoint of theory, but here we can see that a positive inflation shock in the US causes the USD to depreciate and the DEM to appreciate. Such a result would seem to rule out demand shocks as the primary mover of inflation, and instead imply that, in principle, the need for anti-inflationary policy should generally coincide with a weak currency.

The volatility in the German inflation rate is explained mainly by its own innovations: up to 94.6 % of the variance immediately after the shock and up to 83 % after a year from the shock. The second most important factor affecting the German inflation is the exchange rate with a share of 5.7 % a year after the shock. The variance decomposition further yields a share of 1 % for the US inflation rate, and 2 % and 2.8 % for the German and US interest rates, respectively.

Judging from the effects on the exchange rate and domestic output, German inflation shocks also resemble domestic supply shocks. However, the empirical results are such that it is difficult to identify a single type of shock that could unambiguously be identified with the German inflation impulses. An increase in the German inflation tends to appreciate the USD and to depreciate the DEM. This also has a weak, dampening effect on economic activity. The conclusions with regard to policy conflicts are thus similar to the US case.

4.1.3 Analysing interest rate changes

In both countries, up to 71.4 % of interest rate changes are explained by innovations in the interest rate itself. In the US, the second most important factor affecting the interest rate is production. Its share is 9.3 %. The share of the inflation rate is 2.8 % and that of the exchange rate 4.0 %. In Germany, the second most important factor is the US inflation rate; it explains 5.3 % of the innovations in the German interest rate. The shares of the exchange rate and the domestic inflation rate are 5.3 % and 2.8 %, respectively.

Strangely enough, an increase in the US interest rate tends to accelerate both the US inflation rate and the German inflation rate. The result that a rise of the domestic interest rate causes an increase of the inflation rate comes out significantly both in the US and in Germany. This anomalous outcome has also been obtained in other (empirical) studies. Eichenbaum (1992), Sims (1992) and Cochrane (1994), for example, obtain the result that the price level rises for over two years after a contractionary monetary policy shock.²¹ The positive correlation between the interest rate and the inflation rate is known as a price puzzle, a phenomenon of prices tending to increase temporarily after a contractionary monetary policy shock. This finding is typically explained as a reaction to the central bank's raising of interest rates in response to inflation expectations.

4.1.4 Factors affecting the real side of the economy

In the US, production shocks are mostly due to innovations in production itself. After the first month, 92.8 % are explained by past values of the production. The share then falls to 75.5 % a year after the shock. In Germany, the share of the production itself in explaining changes in the German production is 91.5 % after the first month after the shock, and still 84.2 % a year after the shock. The second most important component is the German inflation rate with a share reaching up to 2.5 % a year after the shock.

In the US, the real side of the economy seems to be mainly affected by exchange rate shocks, and possibly by foreign money demand shocks. In Germany, innovations in production resemble domestic demand shocks. Both kinds of shocks either appreciate the domestic currency and slow domestic inflation, or vice versa. Thus, both can be easily controlled through monetary policy, the effects of which are even stabilizing on the foreign country.

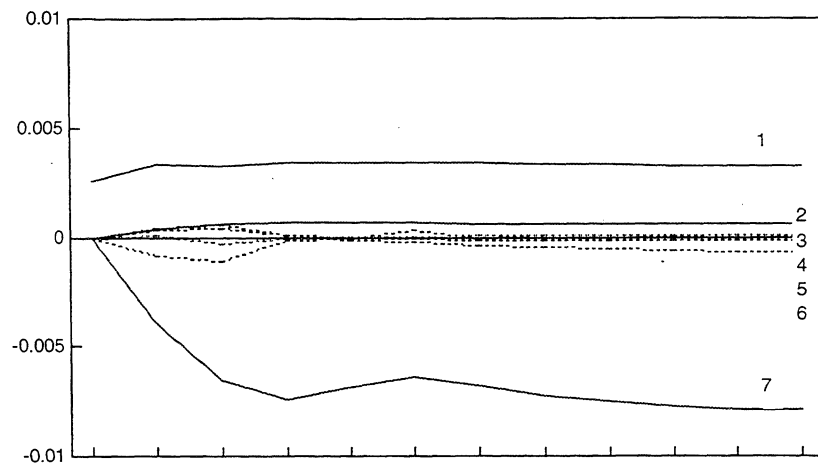
Other studies offer a rich blend of explanations. Blanchard & Quah (1989), for example, attribute virtually all short-term output variability in the US to demand shocks, while Galí (1992) finds that supply shocks dominate over all horizons. Gerlach & Smets (1995) note that aggregate demand shocks play a critical role in accounting for changes in output.

In other empirical studies, domestic supply shocks have been found to dominate in Germany. Méhitz and Weber (1996) tested the effects of demand versus supply shocks on output, inflation and the current account in Germany. They found; first, that supply shocks account for virtually all the variability of output in the long run; and second, that money supply shocks exert no significant impact on either inflation or output. They argue that this is due Germany's steady and predictable conduct of monetary policy. Gerlach & Smets (1995) also found in their empirical study of the monetary transmission mechanism that discretionary shifts in German monetary policy play only a very limited role in determining recent output and price developments.

²¹Sims & Zhou (1994) and Christiano et al. (1996) avoid this in their studies by assuming that the monetary authority responds to commodity prices in setting monetary policy.

Figure 4.1

The effects of the US interest rate shock

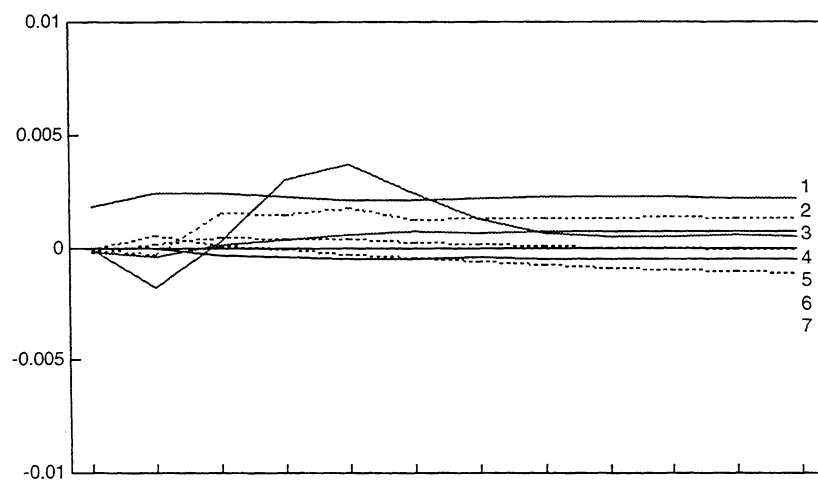


- 1 US interest rate
- 2 US inflation rate
- 3 German interest rate
- 4 German production
- 5 German inflation rate
- 6 US production
- 7 Exchange rate (USD/DEM)

Continuous lines indicate cases where the variable in question has a significant (at 10 % level) coefficient.

Figure 4.2

The effects of US inflation shock

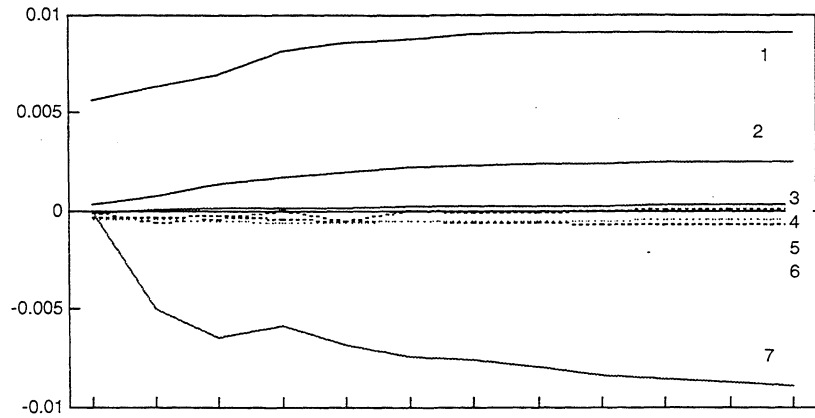


- 1 US inflation rate
- 2 German production
- 3 German interest rate
- 4 Exchange rate (USD/DEM)
- 5 US interest rate
- 6 German inflation rate
- 7 US production

Continuous lines indicate cases where the variable in question has a significant (at 10 % level) coefficient.

Figure 4.3

The effects of US production shock

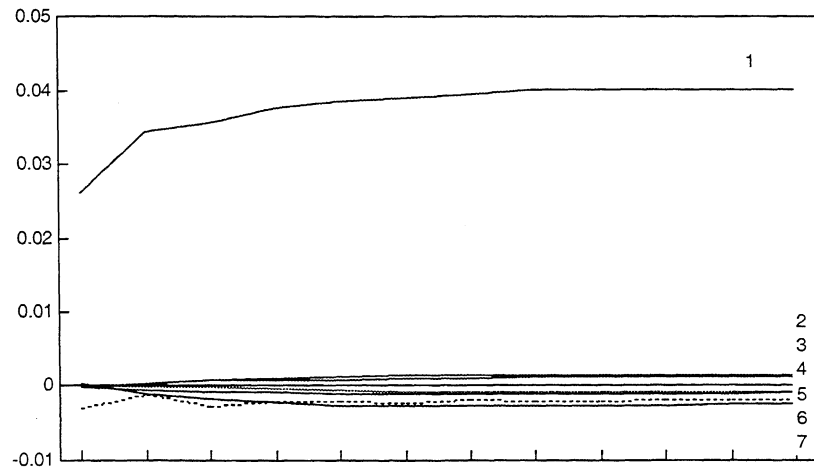


- 1 US production
- 2 US interest rate
- 3 US inflation rate
- 4 German production
- 5 German interest rate
- 6 German inflation rate
- 7 Exchange rate (USD/DEM)

Continuous lines indicate cases where the variable in question has a significant (at 10 % level) coefficient.

Figure 4.4

The effects of the exchange rate shock (DEM/USD)

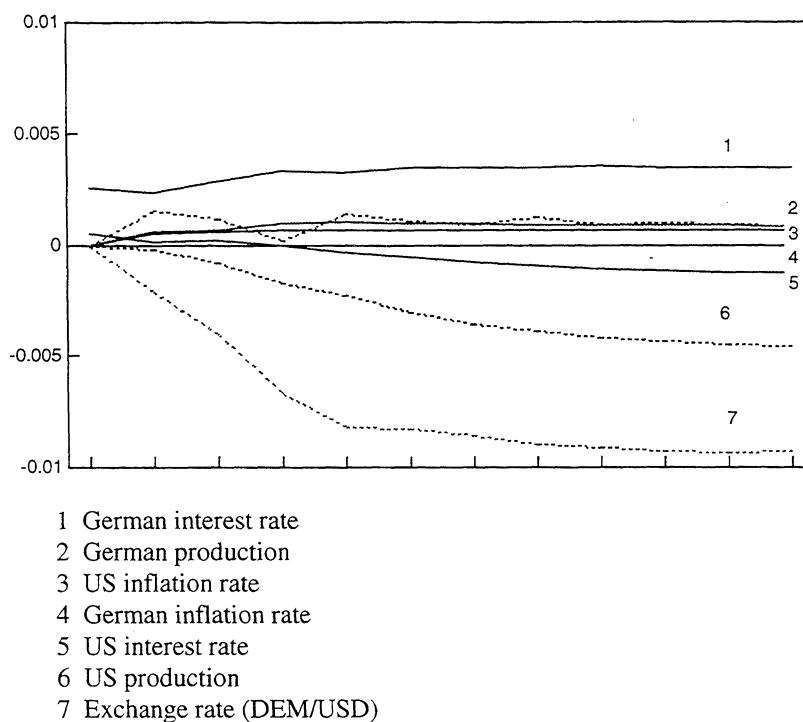


- 1 Exchange rate (DEM/USD)
- 2 German inflation rate
- 3 German interest rate
- 4 US inflation rate
- 5 US interest rate
- 6 German production
- 7 US production

Continuous lines indicate cases where the variable in question has a significant (at 10 % level) coefficient.

Figure 4.5

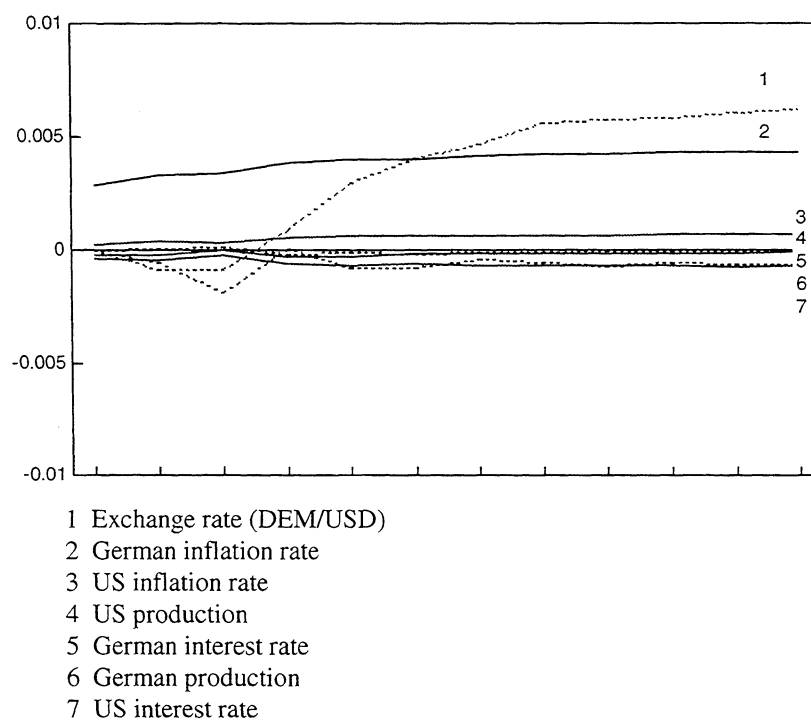
The effects of German interest rate shock



Continuous lines indicate cases where the variable in question has a significant (at 10 % level) coefficient.

Figure 4.6

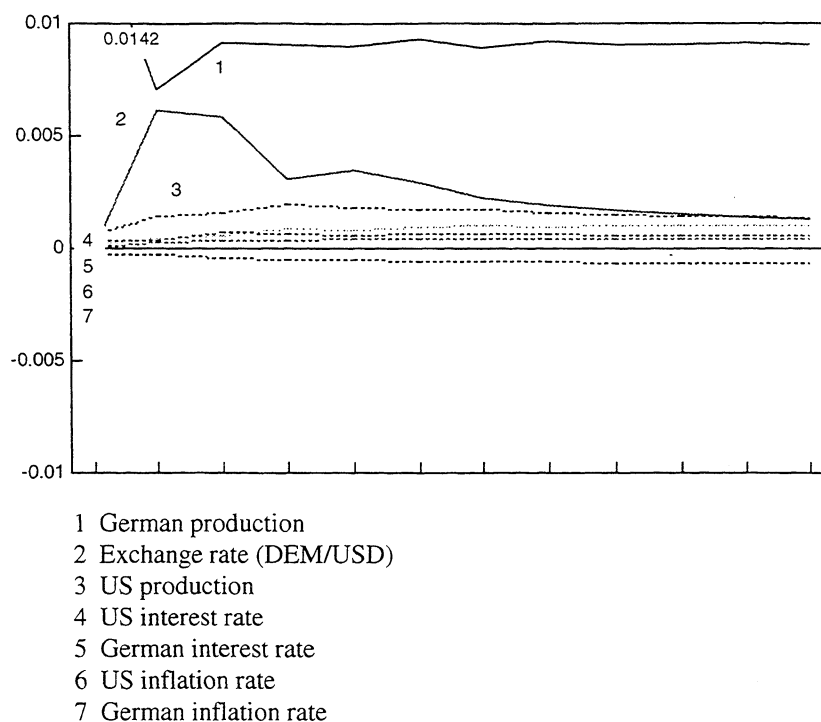
The effects of German inflation rate shock



Continuous lines indicate cases where the variable in question has a significant (at 10 % level) coefficient.

Figure 4.7

The effects of German production



Continuous lines indicate cases where the variable in question has a significant (at 10 % level) coefficient.

4.2 Policy discussion

In the empirical analysis presented above, we have seen that supply shocks seem to dominate in explaining changes in inflation. Managing a supply shock by means of monetary policy is a potential source of tensions, because the effect on the exchange rate is ambiguous. Here, the empirical results indicate that the domestic currency depreciates and the inflation rate rises as a consequence of a supply shock. There is thus no trade-off for the central bank in stabilizing both the inflation rate and the exchange rate monetary policy, since stabilizing the inflation rate simultaneously stabilizes the exchange rate. This empirical result is valid both for the US and Germany. Tightening of domestic monetary policy raises interest rates and strengthens the nominal exchange rate. That, in turn, diminishes inflationary pressures in the domestic economy.

This behaviour is contingent on the assumption that exchange rate movements are induced by inflation shocks. However, as the variance decompositions show, exchange rate volatility stems mostly from shocks to the exchange rate itself. Thus, the only way for the central bank to stabilize the exchange rate is to intervene directly in the foreign exchange markets. However, if the *only* way to achieve exchange rate stability is to concentrate totally on the exchange rate, then there is the possibility that the cost of exchange rate stability is domestic price instability.

The explanatory power of demand shocks in determining inflation and exchange rate developments seems to be very weak. Instead, the dominating

factors, ie supply shocks and exchange rate shocks, produce qualitatively similar effects on the exchange rate and inflation. If, despite exchange rate stabilization, exchange rate expectations continue to be volatile, this can be transmitted through interest rates into the domestic economy. On the other hand, the fact that exchange rate stability is a policy target can diminish the volatility of expectations if a successful policy increases the certainty that the spot exchange rate deviates from the target rate only little, rarely, and randomly.

This leaves us with the question of exchange rate management.²² Once EMU is established, there will be two large economies as in the theoretical model of the present study. The empirical findings could be expected to appear in a more pronounced manner than here, where data from Germany only are used. If the main source behind variations in the inflation rate continue to be supply shocks, the country where the supply shock originates can try to stabilize both domestic inflation and the exchange rate. The other country, on the other hand, faces a trade off between currency movements and domestic inflation. Given that a domestic demand shock or, alternatively, a supply shock occurring in the US, may be the source of a monetary policy conflict in Germany, monetary policy coordination could be in Germany's interest. From the German point of view, it may prove reasonable to concentrate on controlling domestic inflation and let the US stabilize the exchange rate. The next question is whether the US would have any special reasons itself to participate in this type of monetary policy coordination.

Clearly, achieving long-term exchange rate stability, or avoiding major long-run swings between the USD and the DEM would require that monetary policy objectives and the policies to achieve these targets were broadly similar. Considering that the exchange rate reacts to changes in money supplies, monetary policy cooperation would probably be more fruitful than unilateral attempts by one of the central banks to influence the exchange rate. An expansion in one country could be followed by an expansion in the other country, so that the effect on the exchange rate would be zero (as an expectation at least). Since shifts in expectations could, in principle, be counteracted with well defined optimal monetary policy coordination, exchange rate volatility could also be expected to diminish. Considering the empirical result obtained in Gerlach & Smets (1995) that showed that the effects of a standardized monetary policy tightening on output and inflation are very similar in Germany and the US, we can infer that long-run exchange rate stability is possible. Indeed, the US has participated in coordinated interventions on occasion, but no interest in more formal monetary policy cooperation has ever been shown.²³ Corden (1994) notes that, although at times the US has decided to play in concert, the US authorities have felt completely free to manage monetary policy in the light of domestic conditions as they perceived them without seeing much need to consider possible exchange rate effects. For two-way monetary cooperation to be feasible, US policymakers should feel they could gain from exchange rate stabilization.

²²An excellent non-technical discussion on the possible future exchange rate arrangements is provided in Corden (1994). The prospects with special regard to EMU have been analyzed carefully in the report of the ECU Institute (1995).

²³See eg Corden (1994) for an overview on US monetary policy.

Even given a mutual willingness to cooperate, cross-border exchange rate management may prove difficult. The major part of the variation of the exchange rate is autonomous – over 90 % of the exchange rate variation is explained by shocks to itself. As argued in the report of the ECU Institute (1995), full financial liberalization increases the substitutability between currencies, so it follows that exchange rates, given market perceptions on future policy, may become increasingly unstable as they become increasingly dependent on the interplay of expectations, policy and fundamentals. One can even envision a situation where the exchange rate is less dependent on economic fundamentals – the basis of traditional models of exchange rate determination – than policy.

What do these results possibly indicate for the future European Central Bank (ECB)? Certainly, conclusions about past or present experience do not necessarily apply in the future. The rise of EMU will most certainly involve structural changes that invalidate our present models. Still, here we can speculate about the interaction between the US and EMU area from the current results. Assuming that US supply shocks result in a monetary policy conflict on the European side, the ECB has reason to avoid international exchange rate cooperation. In response, the ECB could leave the job of stabilizing the exchange rate to the US, and concentrate on stabilizing inflation within EMU.²⁴ Thus, we see that because of the n-1 problem, simultaneous attempts to stabilize the exchange rate and the domestic inflation rate is not possible. The solution will involve either an asymmetric international monetary system where one country dominates or monetary policy coordination.

5 Summary

This study examines stabilization aspects of monetary policy in the case of two large economies both issuing a major international currency. We start from an assumption that once EMU is established, the international monetary system will become strongly bipolar with the USD and the EUR as the major currencies. First, we review the characteristics of an international currency and briefly discuss the possibilities of the EUR to become a key currency. Next we present arguments as to why a central bank might be interested in stabilizing both inflation and the exchange rate. Excessive exchange rate volatility, when not a reflection of actual underlying problems, might give false signals to policymakers and private agents, and thereby encourage them to take inappropriate measures. Given a motivation to control exchange rate movements, we then ask whether actions to reach such a goal conflict with actions done in the pursuit of price stability, and if so, are such conflicts related to the type of shock hitting the economy.

An IS-LM-AS model is constructed to analyse the international transmission of various shocks. Certain situations are identified where the central bank faces a

²⁴This is in accordance with the argument that since the ECB's primary objective is price stability it will concentrate on domestic issues. The report of the ECU Institute (1995) argues that due to this, the ECB will be reluctant to engage in any initiative to stabilize exchange rates. The ECB will instinctively aim for a minimum of commitments vis-à-vis third countries, particularly in the early years of its existence as it tries to build up its reputation for independence and for achieving low inflation.

trade-off in its pursuit of internal or external target. These typically occur where domestic demand shocks dominate, and may occur when supply shocks dominate, so that the exchange rate appreciates under inflationary impulses as a result of these shocks. The latter seems to be less worrisome as it has the same qualitative effect on prices and the domestic currency.

To identify the potential trade-off situations for monetary policy of the current major-currency central banks for the period 1983–1996, we estimate a VAR system to find out the dominant source of shocks to the observed changes in interest rates, inflation rates and output in both countries, as well as changes in the exchange rate.

The results indicate that the inflation rate seems to be driven by domestic supply shocks in both countries. Theoretically, the effect of a supply shock on the exchange rate is ambiguous. The empirical results suggest that US output shocks, most likely supply shocks, tend to increase the price level and to depreciate the USD. Since the price level also increases in Germany, it implies that Germany could face a combination of higher inflation and an appreciating currency. Conversely, in the US it is irrelevant whether monetary policy is directed to stabilize inflation or the exchange rate, because domestically any policy action directed to stabilize one target variable, also stabilizes the other. From the German (European) point of view, however, the exchange rate is destabilized. Hence, if the initial source of the disturbance is a US supply shock, the European side can stabilize the exchange rate only through sacrificing domestic price stability. Alternatively, the European side has to accept the destabilizing effect on the exchange rate while maintaining domestic price stability.

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Appendix

Table A.1 **Variance decomposition of US interest rate**

| Month | INTUS | INFUS | PRODUS | EXR | INTG | INFG | PRODG |
|-------|-------|-------|--------|------|------|------|-------|
| 1 | 90.32 | 0.38 | 1.64 | 0.65 | 3.23 | 2.13 | 1.66 |
| 2 | 84.01 | 1.98 | 3.11 | 3.25 | 4.29 | 1.89 | 1.47 |
| 3 | 77.49 | 2.60 | 7.11 | 4.17 | 4.07 | 2.32 | 2.24 |
| 4 | 74.81 | 2.51 | 8.25 | 4.02 | 4.63 | 3.58 | 2.20 |
| 5 | 73.40 | 2.48 | 8.87 | 3.97 | 5.49 | 3.58 | 2.20 |
| 6 | 72.55 | 2.61 | 9.19 | 3.97 | 5.89 | 3.59 | 2.20 |
| 7 | 72.05 | 2.71 | 9.23 | 3.94 | 6.25 | 3.63 | 2.19 |
| 8 | 71.75 | 2.73 | 9.27 | 3.93 | 6.51 | 3.63 | 2.19 |
| 9 | 71.57 | 2.74 | 9.26 | 3.92 | 6.70 | 3.62 | 2.19 |
| 10 | 71.49 | 2.75 | 9.26 | 3.93 | 6.78 | 3.61 | 2.19 |
| 11 | 71.43 | 2.76 | 9.25 | 3.94 | 6.82 | 3.61 | 2.19 |
| 12 | 71.41 | 2.76 | 9.25 | 3.95 | 6.84 | 3.61 | 2.19 |

Table A.2 **Variance decomposition of US inflation**

| Month | INTUS | INFUS | PRODUS | EXR | INTG | INFG | PRODG |
|-------|-------|-------|--------|------|------|------|-------|
| 1 | 0 | 97.98 | 0.56 | 0.01 | 0 | 1.37 | 0.09 |
| 2 | 3.66 | 82.73 | 1.83 | 0.73 | 7.89 | 1.78 | 1.37 |
| 3 | 4.50 | 81.59 | 1.81 | 0.84 | 7.97 | 1.91 | 1.37 |
| 4 | 4.32 | 78.47 | 1.75 | 1.91 | 9.35 | 2.90 | 1.30 |
| 5 | 4.29 | 77.70 | 1.74 | 2.88 | 9.22 | 2.89 | 1.29 |
| 6 | 4.29 | 77.25 | 1.74 | 3.41 | 9.17 | 2.87 | 1.28 |
| 7 | 4.31 | 77.16 | 1.75 | 3.48 | 9.15 | 2.87 | 1.28 |
| 8 | 4.30 | 77.10 | 1.76 | 3.49 | 9.20 | 2.86 | 1.28 |
| 9 | 4.30 | 77.07 | 1.76 | 3.50 | 9.21 | 2.87 | 1.28 |
| 10 | 4.30 | 77.06 | 1.76 | 3.50 | 9.21 | 2.88 | 1.28 |
| 11 | 4.30 | 77.05 | 1.76 | 3.51 | 9.22 | 2.88 | 1.28 |
| 12 | 4.30 | 77.04 | 1.76 | 3.51 | 9.22 | 2.88 | 1.28 |

Table A.3

Variance decomposition of US production

| Month | INTUS | INFUS | PRODUS | EXR | INTG | INFG | PRODG |
|-------|-------|-------|--------|------|------|------|-------|
| 1 | 0 | 0 | 98.20 | 0 | 0 | 0 | 1.80 |
| 2 | 0.47 | 1.01 | 90.21 | 6.10 | 0.13 | 0 | 2.09 |
| 3 | 0.54 | 1.58 | 87.58 | 7.15 | 1.09 | 0.05 | 2.00 |
| 4 | 1.04 | 1.52 | 84.88 | 7.17 | 2.86 | 0.38 | 2.15 |
| 5 | 1.12 | 1.57 | 83.58 | 7.40 | 3.61 | 0.40 | 2.33 |
| 6 | 1.13 | 1.62 | 82.44 | 7.29 | 4.83 | 0.39 | 2.30 |
| 7 | 1.16 | 1.66 | 81.85 | 7.23 | 5.42 | 0.40 | 2.28 |
| 8 | 1.19 | 1.71 | 81.55 | 7.20 | 5.65 | 0.40 | 2.31 |
| 9 | 1.20 | 1.76 | 81.30 | 7.19 | 5.84 | 0.40 | 2.31 |
| 10 | 1.21 | 1.79 | 81.18 | 7.19 | 5.92 | 0.40 | 2.32 |
| 11 | 1.21 | 1.80 | 81.13 | 7.20 | 5.94 | 0.40 | 2.32 |
| 12 | 1.22 | 1.80 | 81.09 | 7.20 | 5.96 | 0.40 | 2.32 |

Table A.4

Variance decomposition of DEM/US exchange rate

| Month | INTUS | INFUS | PRODUS | EXR | INTG | INFG | PRODG |
|-------|-------|-------|--------|-------|------|------|-------|
| 1 | 0 | 0 | 0.02 | 95.75 | 0 | 0 | 4.23 |
| 2 | 1.83 | 0.38 | 3.17 | 88.31 | 0.52 | 0.09 | 5.69 |
| 3 | 2.61 | 0.89 | 3.37 | 86.52 | 0.92 | 0.09 | 5.61 |
| 4 | 2.60 | 1.68 | 3.30 | 83.72 | 1.73 | 0.43 | 6.55 |
| 5 | 2.61 | 1.71 | 3.37 | 82.95 | 1.95 | 0.93 | 6.49 |
| 6 | 2.63 | 1.89 | 3.40 | 82.61 | 1.95 | 1.04 | 6.49 |
| 7 | 2.64 | 2.02 | 3.39 | 82.37 | 1.95 | 1.09 | 6.55 |
| 8 | 2.65 | 2.05 | 3.40 | 82.21 | 1.96 | 1.17 | 6.55 |
| 9 | 2.66 | 2.06 | 3.42 | 82.18 | 1.96 | 1.17 | 6.56 |
| 10 | 2.66 | 2.06 | 3.42 | 82.16 | 1.97 | 1.17 | 6.56 |
| 11 | 2.67 | 2.06 | 3.42 | 82.15 | 1.97 | 1.18 | 6.56 |
| 12 | 2.67 | 2.06 | 3.43 | 82.15 | 1.97 | 1.18 | 6.56 |

Table A.5

Variance decomposition of German interest rate

| Month | INTUS | INFUS | PRODUS | EXR | INTG | INFG | PRODG |
|-------|-------|-------|--------|------|-------|------|-------|
| 1 | 0 | 0.50 | 1.91 | 0.02 | 95.59 | 1.15 | 0.84 |
| 2 | 0.16 | 0.98 | 1.85 | 1.17 | 93.39 | 1.12 | 1.34 |
| 3 | 1.59 | 4.37 | 1.80 | 5.06 | 84.41 | 1.58 | 1.19 |
| 4 | 2.10 | 4.62 | 1.75 | 4.80 | 82.17 | 2.49 | 2.09 |
| 5 | 2.10 | 5.23 | 1.76 | 4.84 | 81.45 | 2.46 | 2.16 |
| 6 | 2.07 | 5.32 | 1.74 | 5.09 | 80.84 | 2.76 | 2.17 |
| 7 | 2.25 | 5.32 | 1.73 | 5.13 | 80.56 | 2.78 | 2.22 |
| 8 | 2.25 | 5.32 | 1.74 | 5.22 | 80.45 | 2.78 | 2.24 |
| 9 | 2.25 | 5.31 | 1.74 | 5.27 | 80.38 | 2.81 | 2.24 |
| 10 | 2.25 | 5.31 | 1.74 | 5.29 | 80.36 | 2.81 | 2.24 |
| 11 | 2.25 | 5.31 | 1.75 | 5.29 | 80.35 | 2.81 | 2.24 |
| 12 | 2.25 | 5.31 | 1.75 | 5.29 | 80.35 | 2.81 | 2.24 |

Table A.6

Variance decomposition of German inflation

| Month | INTUS | INFUS | PRODUS | EXR | INTG | INFG | PRODG |
|-------|-------|-------|--------|------|------|-------|-------|
| 1 | 0 | 0 | 0.69 | 0.45 | 0 | 98.38 | 0.49 |
| 2 | 1.50 | 0.01 | 0.67 | 2.74 | 2.66 | 91.86 | 0.55 |
| 3 | 1.59 | 0.96 | 0.75 | 4.48 | 2.71 | 88.50 | 1.01 |
| 4 | 2.62 | 1.01 | 0.98 | 5.16 | 2.61 | 86.23 | 1.40 |
| 5 | 2.69 | 1.05 | 1.00 | 5.44 | 2.60 | 85.83 | 1.39 |
| 6 | 2.72 | 1.05 | 1.01 | 5.56 | 2.62 | 85.58 | 1.46 |
| 7 | 2.77 | 1.06 | 1.05 | 5.59 | 2.62 | 85.44 | 1.48 |
| 8 | 2.77 | 1.06 | 1.07 | 5.59 | 2.61 | 85.42 | 1.48 |
| 9 | 2.77 | 1.06 | 1.08 | 5.60 | 2.61 | 85.40 | 1.49 |
| 10 | 2.77 | 1.06 | 1.09 | 5.60 | 2.62 | 85.38 | 1.49 |
| 11 | 2.77 | 1.06 | 1.09 | 5.60 | 2.62 | 85.37 | 1.49 |
| 12 | 2.77 | 1.06 | 1.10 | 5.60 | 2.62 | 85.37 | 1.49 |

Table A.7

Variance decomposition of US interest rate

| Month | INTUS | INFUS | PRODUS | EXR | INTG | INFG | PRODG |
|-------|-------|-------|--------|------|------|------|-------|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 2 | 0.25 | 0.03 | 0.10 | 0.06 | 0.88 | 0.10 | 98.57 |
| 3 | 0.26 | 1.26 | 0.11 | 0.44 | 0.89 | 0.75 | 96.28 |
| 4 | 0.61 | 1.23 | 0.18 | 0.54 | 1.22 | 2.07 | 94.16 |
| 5 | 0.60 | 1.25 | 0.27 | 0.53 | 1.71 | 2.32 | 93.31 |
| 6 | 0.66 | 1.35 | 0.36 | 0.54 | 1.73 | 2.31 | 93.06 |
| 7 | 0.70 | 1.35 | 0.36 | 0.58 | 1.74 | 2.35 | 92.92 |
| 8 | 0.70 | 1.35 | 0.36 | 0.58 | 1.76 | 2.36 | 92.89 |
| 9 | 0.70 | 1.35 | 0.37 | 0.58 | 1.78 | 2.36 | 92.85 |
| 10 | 0.71 | 1.35 | 0.37 | 0.58 | 1.78 | 2.37 | 92.84 |
| 11 | 0.71 | 1.35 | 0.37 | 0.58 | 1.78 | 2.37 | 92.84 |
| 12 | 0.71 | 1.35 | 0.37 | 0.58 | 1.79 | 2.37 | 92.83 |

Table A.8

Criterion for lags

| lags | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-------------------------|-------|-------|-------|-------|-------|-------|-------|
| Schwarz-Bayes criterion | -70.2 | -69.3 | -68.4 | -67.4 | -66.6 | -65.7 | -65.0 |

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