# EMU, Monetary Policy Interactions and Exchange Rate Stability

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**Abstract**

This memorandum discusses the possible impact of a monetary union in Europe on transatlantic exchange rate stability. EMU leads to the elimination of coordination failures within the euro area. Whether this translates into more stable exchange rates, depends on the origin of the shock. Martin´s (1997) conclusion that EMU will lead to more stable exchange rates is shown to hold for both symmetric and asymmetric shocks in Europe, but not for shocks that originate outside Europe. The results remain valid when taking into account that the pre-EMU era was characterised by a Bundesbank-led ERM, rather than a free float. Finally, the results are tested for a future expansion of the euro area.

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# 1 Introduction

This memorandum considers the changes in monetary policy makers' incentives as a result of economic and monetary union (EMU) and studies their possible impact on exchange rate stability between the euro and the dollar.

Most of the existing literature predicts that the exchange rate volatility of the euro will increase as a result of EMU. See, for instance, Alosgoufis and Portes (1997), Coeuré and Pisani-Ferry (1999), Demertzis and Hughes Hallet (1998), McCauley (1997).[1] These papers basically make two intuitive points that are related to the fact that the euro area is relatively closed when compared to the individual participating countries. The first point is that the ECB will give priority to internal price stability over the external value of the euro. Therefore, EMU may lead to benign neglect of the exchange rate in Europe, which could lead to higher exchange rate volatility than before. The second point is that the external adjustment channel has become narrower and a larger exchange rate adjustment is required to restore internal price stability after a shock (Krugman, 1989, Obstfeld and Rogoff, 1995, Bénassy-Quéré, Mojon and Pisani-Ferry, 1997, Hau, 2000).

A study by Martin (1997) is interesting in that it concludes that exchange rate volatility is likely to decline when compared to a situation of floating rates. Martin uses a simple two-country model with random supply shocks, which stresses that the incentive to conduct an active exchange rate policy is related to relative country size.[2] The relative size of the two countries in the model determines to which extent output is affected by domestic shocks and the exchange rate, respectively. The larger the country, the less its output depends on the exchange rate. Therefore, in setting monetary policy very small countries will give priority to fixing the exchange rate, while very large countries will hardly care about the exchange rate. Martin finds that medium-sized countries are most likely to use the exchange rate as an instrument to buffer economic shocks. EMU leads to the creation of a currency bloc comparable to the US in size. This means that the incentives to change the exchange rate have become more similar for policy makers in the two blocs. Thus, Martin concludes that a more symmetric system will lead to a more stable transatlantic exchange rate.

This memorandum differs from Martin (1997) in several respects. First, it stresses the importance of the internalisation of monetary policy spillovers in the euro area as a result of EMU. The intuition behind this point will be discussed below. A second aspect not addressed by Martin is that EMU involves monetary cooperation between only a subset of all central banks in the world. This could be important. A classic article on the inter-

[1] Some other studies are inconclusive: Begg, Giavazzi and Wyplosz (1997), Cohen (1997), Masson and Turtelboom (1997).

[2] Openness is not an explicit variable in the model, but country size could be interpreted as a proxy for (the inverse of) openness.

nalisation of externalities by Rogoff (1985) shows that cooperation between two players in a three-player game may be counterproductive (i.e. welfare-decreasing). Rogoff proves this by giving an example where cooperation between central banks exacerbates the credibility problem of central banks vis-à-vis the private sector. In his example, international monetary cooperation raises the rate of wage inflation because wage setters recognise that a non-cooperative regime contains a built-in check on each central bank´s incentives to inflate.[3] Cooperation may remove this disincentive to inflate, so that the central bank´s credibility deteriorates.

In this memorandum, I extend Martin's model to a three-country version in order to address the internalisation of externalities between two countries in the presence of a third country. A three-country model also allows me to look explicitly at the impact of asymmetric shocks in the euro area on exchange rate stability. Following Martin (1997), I use the standard Barro-Gordon (1983) setting, apart from that policy makers are assumed to have an output target which does not exceed the natural rate. This means that the time-inconsistency problem does not arise. Taking an output target above the natural rate (thus taking the time-inconsistency problem on board) would not affect the main results of this memorandum.

I look at supply shocks only. Supply shocks pose a bigger dilemma for central banks in terms of the trade-off between inflation and output than demand shocks. In the case of demand shocks, a monetary policy that aims at price stability automatically dampens output fluctuations. In the case of supply shocks, prices and output are negatively correlated, so that a monetary policy geared at short-run price stability could adversely affect the output gap. The bigger monetary policy dilemma means that supply shocks are the more interesting case. Moreover, Bayoumi and Eichengreen (1993) find empirically that international spill-overs on the demand side are unimportant when compared to spill-overs on the supply side.[4]

[3] In Rogoff's model, an increase in the money supply leads to a decline in the interest rate and to an increase in the price of the domestically produced good. Since uncovered interest parity is assumed to hold, the decline in the interest rate leads to an increase in the nominal exchange rate (= a depreciation of the home currency). This nominal depreciation is assumed to be larger than the increase of the price of the home good, so that the real exchange rate increases as well. As a result, the consumer price index, which includes the price of the foreign good, increases more strongly than the price of the home good. Nominal wages are indexed to the consumer price index (CPI). Therefore, they increase more strongly than the price of the home good. As a result, the demand for labour will decline. Thus, if the money supply is increased unilaterally, a real depreciation of the home currency, lower employment and higher CPI inflation are the result. Therefore, a non-cooperative regime provides for a built-in check on each central bank's incentive to inflate.

[4] Bayoumi and Eichengreen state that: 'With respect to supply shocks, in both Europe and the US there is a core' region [..] where the shocks are highly correlated [..]. With respect to demand shocks [in Europe] [..] the correlation with Germany is much lower, even for the other countries of the European core.'

Examples of negative supply shocks are the oil price shocks of the 1970s and adverse weather conditions, which may negatively affect labour productivity in the agricultural and construction sectors. Another example of a negative supply shock is a credit crunch, which may increase the cost of capital for firms. Think of the US savings and loans crisis in the early 1990s and the fears for a dramatic widening of credit spreads in the US in the aftermath of the Asian crisis, the Russian default and the LTCM problem in 1998. Examples of positive supply shocks include the 'new economy' (the effective application of information and communication technology) in the United States and the deregulation of product and labour markets in Europe.

The intuition behind the model is as follows. Surprise inflation reduces the real wage rate and attracts jobs from abroad, which gives central bankers an incentive to inflate. They correctly anticipate that other central banks do the same, but they cannot cooperate. Therefore, inflation is overly responsive to supply shocks. EMU enables European monetary policy makers to commit that they will not shift the burden of a shock to the other European country. Full monetary policy coordination takes place by the Governing Council of the ECB, where the externalities involved in unduly fierce policy responses are internalised. The ECB will keep inflation closer to zero than the national central banks in Europe did before, not because the ECB is more inflation averse, but because of the possibility of the participating central banks to commit against each other.

The more moderate response of euro area inflation to supply shocks under EMU does not necessarily lead to more transatlantic exchange rate stability. It turns out that the consequences of EMU for exchange rate stability depend on the origin of the shock. In response to a negative supply shock in Europe, the more moderate inflation response of the ECB leads to more exchange rate stability indeed.[5] But the situation is different for a supply shock in the United States. In response to a negative supply shock in the US, the Federal Reserve will engage in monetary easing. Before the start of EMU, the sensitivity of the national central banks in Europe to what happened in the United States caused them to ease their policy stance as well, which helped to dampen the resulting dollar depreciation. After the start of EMU, European monetary policy is made by the ECB, which is less sensitive to US developments. As a result, the Federal Reserve's monetary policy response to US shocks will cause a larger divergence of monetary

[5] In the case of a shock in Europe, national central banks in Europe respond more strongly than the Federal Reserve does. The coordination of monetary policy in Europe under EMU implies that the ECB will keep inflation closer to zero than the national central banks did before. The US and European monetary policy stances diverge less than if the shock had occurred before the start of EMU. As a result, the dollar-euro exchange rate responds more moderately to European shocks under EMU. This result will be shown to hold for both symmetric and asymmetric shocks in Europe.

policy stances across the Atlantic and will generate larger dollar movements than before the start of EMU.

In order to work out this argument more systematically, this article looks at four different types of supply shocks: symmetric and asymmetric shocks in Europe, shocks in the US and worldwide shocks. The analysis of world supply shocks learns that under the assumption that the average frequency and size of shocks in Europe and the US is similar, one may expect that the dollar-euro exchange rate will be more stable than the dollar-mark exchange rate.

Initially, I assume that before the start of EMU, the European currencies floated freely against each other. This assumption is commonly made in the literature. Next, I check whether the conclusions also hold when it is taken into account that Europe had an exchange rate mechanism (ERM), rather than freely floating currencies, in the pre-EMU era. The specification of the ERM account for the asymmetric character of the arrangement, in the sense that the Bundesbank had a leading role, whereas the other national central banks had an exchange rate target against the German mark. I also take into account the possibility of an ERM break-down. If ERM and EMU are compared, instead of floating rates and EMU, the above-mentioned results remain valid. This increases the practical relevance of the conclusions.

Finally, the model's country size parameter is used to test what happens if the euro area expands. This is likely to become relevant, given the foreseen enlargement of the European Union and the expected future participation of the new member states in the monetary union. It is shown that most of the results do not change. However, if the euro area were to become (significantly) larger than the US, the exchange rate may become more, not less, responsive to a symmetric worldwide shock after EMU.

The remainder of this memorandum is organised as follows. In the next section, I will relate this memorandum to the earlier literature on this subject. In section 3, I specify a three-country model which captures both country size and the changes to the monetary policy game. In section 4, I derive optimal monetary policies for the European and US monetary authorities under floating rates, ERM and EMU and evaluate the consequences for exchange rate stability. Section 5 concludes.

## 2 Literature review

Previous research suggests several possible consequences of EMU for exchange rate volatility. One starting point is that EMU may change the structure of the euro area economy. Krugman (1993) predicts that increased specialisation will lead to more asymmetric shocks in Europe. On the other hand, Frankel and Rose (1996) argue that increasingly synchronised business cycles will reduce the relative importance of asymmetric shocks. The incidence of shocks could have an impact on exchange rate stability. However, it is too early to tell on the basis of empirical evidence which of the two explanations is right. In any case, regional specialisation and/or further economic integration are likely to happen gradually. Therefore, changes in the structure of the economy as a result of EMU will have no significant impact on dollar-euro exchange rate volatility for the time being.

Another approach shows that EMU may affect exchange rate stability, even if the nature, size and frequency of economic shocks stay the same. The reason is that EMU is a new institutional setting, which has changed the rules (and possibly also the trade-offs) for monetary policy makers.

EMU has several consequences for the monetary policy game. In the first place, as discussed in the introduction, the centralisation of monetary policy decision-making may contribute to the elimination of coordination failures within Europe. For instance, when a negative symmetric supply shock occurs in a floating exchange rate regime, monetary policy makers who care about employment have an incentive to increase the inflation rate in order to alleviate the output consequences of the shock. The action of each policy maker has a negative externality on the other countries, as a more accommodative policy stance aggravates the consequences of the initial shock in the other country. Game theory predicts that monetary policy will overreact, leading to suboptimal outcomes in the absence of coordination (Canzoneri and Henderson, 1991).

Secondly, EMU reduces the number of players, as central bankers from the participating Member States now collectively determine monetary policy for the euro area in the Governing Council of the European Central Bank (ECB), which acts as a single entity. Some argue that the smaller number of players will facilitate policy coordination between the ECB and other major central banks, leading to more stable exchange rates (European Commission, 1997). Others predict a move from a unipolar dollar-oriented world towards a bipolar system around the dollar and the euro and conclude that the emergence of a more symmetric international monetary system will lead to more instability (Aloskoufis and Portes, 1997, Begg, Giavazzi and Wyplosz, 1997).

A third point is that the policy domain of the ECB is the entire euro area, whereas the German Bundesbank used to be responsible for German price stability only. The Bundesbank was of course aware of the consequences of its policy in other countries that participated in the Exchange Rate Mechanism of the European Monetary System (ERM), but it is only natural that German national interests dominated in the end. The difference in policy domain is most important in the case of asymmetric shocks. For symmetric shocks, the appropriate central bank reaction will be approximately the same for Germany and other ERM countries (Kenen, 1997).

I have related this memorandum to Martin (1997) in the introduction. My memorandum differs from the rest of the literature in that it explicitly accounts for the fact that countries compete for economic activity and that it incorporates the relative size of Europe and the US into the model. Ghironi and Giavazzi (1998) focus on country size in a similar manner, but they study a different question than I do.[6] Moreover, their model is too complex to be solved analytically. They can only interpret their results in a meaningful way after choosing specific parameter values.

An article that is also closely related to the current memorandum is Bénassy-Quéré, Mojon and Pisani-Ferry (1997). Their three-country model is much more richly specified than mine. They look at the consequences of both supply and demand shocks in Europe, but they do not study the impact of foreign (i.e. non-European) supply shocks, as I do.[7] Bénassy-Quéré et al. find that real exchange rate volatility is likely to increase as a result of EMU, but they conclude that the impact of EMU on nominal exchange rate volatility is ambiguous.[8] Also, their results for real exchange rate volatility become more ambiguous when comparing ERM and EMU, rather than floating rates and EMU. In this memorandum, purchasing power parity is assumed to hold, rendering the model unsuitable for studying the real exchange rate, but I find unambiguous results for nominal exchange rates, not only when comparing floating rates and EMU, but also when comparing ERM and EMU.

## 3 A three-country model

For the reasons given in the introduction, I will employ a three-country model, where strategic interaction among all central banks is explicitly modeled, following the Canzoneri and Henderson (1991) approach.

I will use a static (single-period) model and explore the response of the exchange rate to several types of shocks.

### 3.1 Model specification

The model is analogous to Martin (1997). The world consists of three countries. Each country produces a single good and purchasing power parity is assumed to hold.

Monetary policy makers try to steer the economy so as to keep both inflation and the output gap close to zero. Their loss function is given by:

[6] They explore the issue of the optimal size of a currency area.

[7] Bénassy-Quéré et al. mention US supply shocks in the text, but they do not report an exact result, nor do they give a possible interpretation.

[8] Bénassy-Quéré et al. find that a lower exchange rate volatility may result when output stabilisation is included in the loss function of the monetary authorities, but believe that having exchange rate stabilisation in the loss function is a more appropriate description of the behaviour of the ECB. I do not share this belief, which helps to explain the difference between their conclusion and mine.

$$L_i = \frac{1}{2}[\pi_i^2 + \beta y_i^2], \qquad i = 1, 2, 3, \tag{1}$$

where $\pi_i$ is the inflation rate, $y_i$ is the natural logarithm of per capita output and $i$ is a country index. More precisely, $\pi_i$ is the deviation of the increase in the general price level from the target value, which we normalise to zero, and $y_i$ is the deviation of per capita output from the socially optimal level, which we normalise to zero as well.[9] There is no time-inconsistency problem in this model, because the output target of policy makers is not above its natural rate. The parameter $\beta$ (>0) represents the relative weight attached to both goals by the policy maker. Clarida, Galí and Gertler (1998) empirically find that the monetary policy reaction functions for the US, Japan and the largest European countries are quite similar. This suggests that it is not unreasonable to assume that $\beta$ is equal for all central banks in this model.

Aggregate supply is a function of the real wage levels at home and abroad. In a world of $N$ identical regions, which compete with each other on the basis of real wages, the supply function in region $i$ is as follows:

$$y_i = -(w_i - p_i) + \frac{1}{N-1}\sum_{j \neq i}(w_j - p_j) + \eta_i.$$

Notice that if the nominal wage is equal to the general price level country by country, output will be equal to potential output.

Now let us take a three-country world. The country indices will henceforth refer to specific countries: 1 for Germany, 2 for France and 3 for the United States. It is no longer the case that all countries have the same size. In fact, Germany and France are of equal size (normalised to unity) and the United States has size $\alpha$, which is larger than 1. Size refers to the population of a country. The United States is large when compared to either Germany and France individually. However, the euro area (consisting of Germany and France only) may be either larger or smaller than the United States. As long as countries are of (population) size 1, aggregate output is equal to output per capita. This is no longer true in the more general case of country size $\alpha$. The step from output in N identical regions of size 1 to output per capita in three regions of different size is worked out in Appendix A. The symmetry of the European countries in the model ensures that the US is equally sensitive to real wage developments in Germany and France.

[9] The output gap can be interpreted either as a proxy for cyclical unemployment (i.e. the part of unemployment that a central bank could, in principle, exert influence on) or as a forward-looking indicator of inflation. We will use the former interpretation in the remainder of this paper. In the first place, this comes close to the trade-off which the Federal Reserve is supposed to make. Secondly, it represents the trade-off for the ECB between sticking to the goal of price stability as defined in the EU Treaty and giving in to more short-term oriented goals that politicians may press for.

Applying the size argument consistently would argue for making Germany more sensitive to US than to French real wage developments. However, the geographical proximity of Germany and France (which is strictly speaking not in my model) would argue for mitigating these differences, if not reversing them.[10] I choose equal weights for reasons of algebraic simplicity. This amounts to assuming that each of the European countries is influenced as much by real wage changes in the US as by real wage changes in the other European country.[11] Then output per capita in the three countries is given by:

$$
\begin{aligned}
y_1 &= -\alpha\,(w_1 - p_1) + \frac{\alpha}{2}\,(w_2 - p_2) + \frac{\alpha}{2}\,(w_3 - p_3) + \varepsilon_1, &\text{(2a)}\\
y_2 &= \frac{\alpha}{2}(w_1 - p_1) - \alpha\,(w_2 - p_2) + \frac{\alpha}{2}\,(w_3 - p_3) + \varepsilon_2, &\text{(2b)}\\
y_3 &= \frac{1}{2}(w_1 - p_1) + \frac{1}{2}\,(w_2 - p_2) - (w_3 - p_3) + \varepsilon_3, &\text{(2c)}
\end{aligned}
$$

where $w_i$ is the nominal wage level, $p_i$ is the price level and $\varepsilon_i$ is a country-specific random supply shock.

Several observations can be made with respect to equations (2a)-(2c). In the first place, the amount of production in a country depends on the relative real wage level. Wage moderation or surprise inflation lead to more production. Secondly, relative country size (represented by the parameter $\alpha$) turns up in the equations, since supply per capita in small countries is more sensitive to relative real wage increases abroad than supply per capita in large countries. If a firm decides to relocate production from a large country to a small one, the large country loses as much supply (in absolute terms) as the small country gains. Clearly, though, the relocation has a relatively large impact for the small country, which is reflected in the above equations for supply per capita.[12]

Workers choose the nominal wage. They do not observe either the general price level or country-specific shocks before setting wages. Workers attempt to minimise the expected square deviation of the real wage from the wage target, which is equal to zero.[13] The utility function of workers in country

[10] See Bayoumi and Eichengreen (1998) or Ghironi and Giavazzi (1998) for an application of the gravity model to international trade.

[11] Using the weights which follow from purely looking at country size, that is using the equations derived in Appendix A, does not materially change the conclusions that I present further on in this article. My conclusion that exchange rate volatility after a worldwide shock under EMU is likely to be smaller than before, becomes somewhat stronger, in the sense that it holds for all $\alpha > 1$.

[12] One may notice that if $\alpha$ goes to infinity, the impact of relative wages on output in the largest country ($y_3$) does not go to zero. However, it becomes negligible in relative terms ($\frac{y_1}{y_3} \to 0$), in line with what one would intuitively expect.

[13] A positive real wage target would force output to be lower than the level desired by policy makers. Thus a zero real wage target is necessary for having no time-inconsistency problem in our model (see Alesina and Tabellini, 1987).

$i$ is given by

$$U_i = -E(w_i - p_i)^2.$$

It is immediately clear that it is optimal for workers to choose $w_i = p_i^e$, where $x^e$ is the expected value of a variable $x$, conditional on all information available at the time of decision-making. This wage rule could also be interpreted as follows. Workers know that if they choose too high a nominal wage, firms will make a loss, production will move abroad and unemployment will be the result. If they pick too low a wage level, more firms will be attracted and overemployment will occur. Workers have a strong preference for full employment, which gives them an incentive to choose the nominal wage equal to the expected price level.

After substituting the optimal wage rule ($w_i = p_i^e$) into the supply per capita functions, I find[14]

$$y_1 = \alpha(\pi_1 - \pi_1^e) - \frac{\alpha}{2}(\pi_2 - \pi_2^e) - \frac{\alpha}{2}(\pi_3 - \pi_3^e) + \varepsilon_1, \quad (3a)$$

$$y_2 = -\frac{\alpha}{2}(\pi_1 - \pi_1^e) + \alpha(\pi_2 - \pi_2^e) - \frac{\alpha}{2}(\pi_3 - \pi_3^e) + \varepsilon_2, \quad (3b)$$

$$y_3 = -\frac{1}{2}(\pi_1 - \pi_1^e) - \frac{1}{2}(\pi_2 - \pi_2^e) + (\pi_3 - \pi_3^e) + \varepsilon_3. \quad (3c)$$

Notice that the supply curve of an individual country has a positive slope. However, the slope of the aggregate supply curve is steeper than at the national level. The intuition is that, when countries compete for employment, local surprise inflation in, say, country 1 raises supply in country 1 but reduces supply in countries 2 and 3. In my model, the supply curve for all countries as a group, given by $y_1 + y_2 + \alpha y_3$, is actually vertical. It does not depend on the inflation rates. This allows me to focus on pure international spill-overs of monetary policy (see Martin, 1995). The fact that the world supply curve is vertical simplifies the algebra and does not qualitatively affect my results.

Central banks set policy in a discretionary manner. Each central bank chooses the price level in its own country, over which it has full control. Central banks know the supply per capita functions and observe wages and country-specific supply shocks before setting monetary policy. They can use the price level as an instrument to influence the real wage level, which in turn affects the level of output. In the absence of an exchange rate arrangement or a monetary union, central banks decide according to the loss function in (1), subject to the supply curves (3a)-(3c).

Let $X_{ij}$ denote the change in the exchange rate of country $j$ expressed in the currency of country $i$. As noted above, absolute purchasing power parity is assumed to hold. This implies that the real exchange rate is constant.

[14] I have used that $\pi_i - \pi_i^e = [p_i - (p_i)_{-1}] - [p_i^e - (p_i^e)_{-1}] = p_i - p_i^e$, where the final equality follows since the expectation of a past event (a lagged variable) is equal to its actual value.

Therefore, nominal exchange rate changes must correspond to inflation differentials (i.e. relative purchasing power parity also holds): $X_{ij} = \pi_i - \pi_j$. Then (3a)-(3c) can be rewritten as

$$y_1 = \frac{\alpha}{2}(X_{12} - X_{12}^e) + \frac{\alpha}{2}(X_{13} - X_{13}^e) + \varepsilon_1, \quad (3d)$$

$$y_2 = \frac{\alpha}{2}(X_{21} - X_{21}^e) + \frac{\alpha}{2}(X_{23} - X_{23}^e) + \varepsilon_2, \quad (3e)$$

$$y_3 = \frac{1}{2}(X_{31} - X_{31}^e) + \frac{1}{2}(X_{32} - X_{32}^e) + \varepsilon_3. \quad (3f)$$

The relationships above illustrate the role of the exchange rate as a potential stabiliser (and destabiliser) of output. At the level of an individual country, exchange rate changes have an impact on output, since wages are predetermined. At the world level, the output effects of unexpected changes in the exchange rate are neutralised: one country´s gain is another country´s loss. This restriction helps to simplify the algebra and is not too restrictive for our purposes, since in this memorandum, I focus on the impact of monetary policy on the choice of location of production and not on the possibility to create surprise inflation in order to increase total world output.

# 4 Optimal monetary policy and implications for the exchange rate

I will discuss the outcome of the model in three different situations. The situations only differ in the degree of cooperation between European national central banks. There is no monetary cooperation between Europe and the US.[15] I will look at the extreme cases of floating rates and monetary union first and compare the outcomes in both situations. Then I will consider the ERM and see if my conclusions with respect to the impact of the start of EMU on exchange rate stability between Germany/Europe and the United States can be maintained.

In all cases, the timing of events and actions is as follows. First, private inflation expectations are formed. Secondly, wages are set by the unions, which endeavour to stabilise expected real wages. Third, supply shocks occur. Fourth, inflation is set by the central banks, which minimise their expected loss. Finally, output is set by firms which choose production locations in order to maximise profits.

[15] Here, cooperation means that agents make clearly defined, mutual commitments to alter their own policies, in order to pursue a common objective or help each agent to pursue its own objectives (Kenen, 1989). This is a stronger notion than cooperation as it is used in everyday language. The assumption of no cooperation between Europe and the US seems fairly realistic as a first approximation, since policy makers do not like monetary policy 'to be determined on the other side of the Atlantic'.

Under floating rates, all central banks play Nash. Under ERM, the Bundesbank and the Federal Reserve (simultaneously) move first and are followed by the Banque de France. Both the Buba and the Fed act as a Stackelberg leader versus the Banque de France, while they play Nash against each other. Under EMU, both central banks in Europe act as one decision maker (ECB), which again plays Nash against the Federal Reserve.

I will initially assume that the euro area is not larger than the United States ($\alpha \geq 2$). Later on, in subsection 4.6, I will consider the possibility that the euro area becomes larger than the US ($\alpha < 2$). This may become relevant when new countries join EMU after expansion of the European Union towards the East. Throughout the memorandum I will maintain the assumption that the US is larger than any of the two regions forming the euro area (i.e. $\alpha > 1$).

## 4.1 Optimal monetary policy under floating rates

Under floating exchange rates, all central banks play Nash, i.e. they optimise policy without being able to make cooperative commitments. Minimising the loss function (1) subject to the supply curve restrictions (3a)-(3c), taking the monetary strategies of the other countries as given, yields the following first-order conditions:[16]

$$\pi_1 = -\alpha\beta y_1, \quad (4a)$$
$$\pi_2 = -\alpha\beta y_2, \quad (4b)$$
$$\pi_3 = -\beta y_3. \quad (4c)$$

These conditions give the choice made by each central bank between inflation and output loss. In the absence of shocks, $\pi_i = y_i = 0$, for all $i$. In the case of a negative shock ($\varepsilon_i < 0$), output will be below target ($y_i < 0$) and there will be inflation ($\pi_i > 0$). The Bundesbank and the Banque de France will split a negative shock over output loss and inflation in a ratio $\frac{1}{\alpha\beta}$, which reflects both the steepness of the supply curve (proportional to country size $\alpha$) and the central banks' preferences $\beta$. The Federal Reserve will divide a negative shock over output loss and inflation in a ratio $\frac{1}{\beta}$. As $\alpha \geq 2$, it is clear that the Federal Reserve, the central bank of the large country in our model, will choose a higher output loss and lower inflation. It does this not because central banks' preferences differ (they don't), but because the size of the US makes the Fed less effective in shifting the burden of adjustment to other countries.

[16] The bordered Hessian matrix of this constrained optimisation problem is positive definite (its determinant is $-1 - \alpha^2\beta$, which is strictly negative). Therefore, the second-order conditions for a minimum are satisfied as well.

Combining the first-order conditions with the above supply curve equations yields the response functions of the central banks:[17]

$$\pi_1^* = \left(\frac{-2\alpha\beta}{2+3\alpha^2\beta}\right)\varepsilon_1 + \frac{-\alpha^2\beta^2}{2+2\beta+\alpha^2\beta}\left[\frac{\alpha(2+3\beta)}{2+3\alpha^2\beta}(\varepsilon_1+\varepsilon_2)+\varepsilon_3\right], \tag{5a}$$

$$\pi_2^* = \left(\frac{-2\alpha\beta}{2+3\alpha^2\beta}\right)\varepsilon_2 + \frac{-\alpha^2\beta^2}{2+2\beta+\alpha^2\beta}\left[\frac{\alpha(2+3\beta)}{2+3\alpha^2\beta}(\varepsilon_1+\varepsilon_2)+\varepsilon_3\right], \tag{5b}$$

$$\pi_3^* = \frac{-\beta}{2+2\beta+\alpha^2\beta}\left[\alpha\beta(\varepsilon_1+\varepsilon_2)+\left(2+\alpha^2\beta\right)\varepsilon_3\right]. \tag{5c}$$

Notice that in the case of symmetric shocks in Europe ($\varepsilon_1 = \varepsilon_2$), the monetary policies of the Bundesbank and the Banque de France will be identical. This follows from the symmetry of these countries in our model. Also notice that in the case of perfectly asymmetric shocks in Europe ($\varepsilon_1 = -\varepsilon_2$), the monetary policy of the Federal Reserve will solely be determined by US shocks, as $\varepsilon_1 + \varepsilon_2 = 0$. In case of negative supply shocks, the equilibrium inflation rates will be above target. The intuition is that central banks generate some surprise inflation in order to mitigate the output consequences of an adverse supply shock. Put differently, they endeavour to buffer the output consequences by depreciating their own currency. Each central bank is aware of the fact that the other central banks will also ease their policy. However, central banks are unable to commit to the conduct of a certain policy in the absence of formal exchange rate agreements or monetary union. As a result, all central banks let inflation increase too much after a negative supply shock. This is a familiar result in the literature on policy coordination (see Persson and Tabellini, 1995).

## 4.2 Optimal monetary policy in EMU

The start of EMU goes hand in hand with the establishment of the ECB, which is assumed to look at euro area variables only. As the inflation rate is chosen by the single monetary authority, it follows directly that $\pi_E = \pi_1 = \pi_2$. As Germany and France are assumed to be of equal size, the increase in euro area output per capita is a simple average of per capita output growth in both countries

$$y_E = \frac{1}{2}(y_1 + y_2).$$

[17] Combine the first-order conditions with the supply curve equations, in order to obtain a system of three equations in $\pi_i$, $\pi_i^e$, $\varepsilon_i$, $i = 1, 2, 3$. Take expectations on both sides and assume that expectations of wage setters are rational. This yields three non-singular equations in $\pi_i^e$, $i = 1, 2, 3$, which implies $\pi_1^e = \pi_2^e = \pi_3^e = 0$. This simplifies the original system of equations, which can be solved for inflation to obtain equations (5a)-(5c).

Plugging in (3a) and (3b) into this equation gives the supply curve for the euro area

$$y_E = \frac{\alpha}{2}(\pi_E - \pi_E^e) - \frac{\alpha}{2}(\pi_3 - \pi_3^e) + \frac{1}{2}(\varepsilon_1 + \varepsilon_2). \tag{3a'}$$

The loss function of the ECB is[18]

$$L_E = \frac{1}{2}[\pi_E^2 + \beta y_E^2].$$

The supply curve for the United States and the loss function of the Federal Reserve are unchanged.

Solving the new optimisation problem yields the following first-order conditions:

$$\pi_E = -\frac{\alpha\beta}{2} y_E, \tag{6a}$$

$$\pi_3 = -\beta y_3. \tag{6b}$$

As before, these conditions give the choice between inflation and economic growth made by each central bank. The European Central Bank will divide a negative shock over output loss and inflation in a ratio $\frac{2}{\alpha\beta}$. Thus, it will show a tendency to be less 'activist' than the Bundesbank and the Banque de France under floating rates. The creation of EMU implies that the central banks in Europe operate as one institution. EMU enables them to internalise the intra-European externalities. They no longer endeavour to shift the burden of falling employment onto another European country. However, they still try to use the exchange rate to shift the burden on the United States.

For $\alpha \geq 2$, the ECB is at least as 'activist' as the Fed. The reason is that if the United States is larger than the euro area, the ECB is better able than the Fed to shift the burden of unemployment abroad ('size effect'). However, for $\alpha < 2$, the reverse would be true.

Combining the conditions (6a)-(6b) with the new supply curve equations (3a'),(3c), I obtain a system of two equations which can be solved for inflation:[19]

$$\pi_E^* = \left(\frac{-\alpha\beta}{4 + 4\beta + \alpha^2\beta}\right)[(1 + \beta)(\varepsilon_1 + \varepsilon_2) + \alpha\beta\varepsilon_3], \tag{7a}$$

$$\pi_3^* = \left(\frac{-\beta}{4 + 4\beta + \alpha^2\beta}\right)\left[\alpha\beta(\varepsilon_1 + \varepsilon_2) + \left(4 + \alpha^2\beta\right)\varepsilon_3\right]. \tag{7b}$$

[18] Alternatively, one could have assumed the ECB to minimise $L_E = \frac{1}{2}(L_1 + L_2)$. This does not affect the resulting policy rules. See Bénassy-Quéré et al. (1997, p. 164) for proof.

[19] Again, taking expectations on both sides and assuming that expectations of wage setters are rational yields three non-singular equations in $\pi_i^e$, $i = 1, 2, 3$, which implies $\pi_1^e = \pi_2^e = \pi_3^e = 0$.

Equations (7a)-(7b) provide several insights. First, neither the ECB's nor the Federal Reserve's monetary policy stance is affected by asymmetric shocks in Europe (i.e. when $\varepsilon_1 + \varepsilon_2 = 0$). Second, the ECB is less responsive to US shocks than the national central banks in Europe used to be before the start of EMU (i.e. $\partial\pi_E/\partial\varepsilon_3 < \partial\pi_1/\partial\varepsilon_3$).[20] Third, the Federal Reserve's response function has been affected by the changed trade-off for European policy makers.[21] Fourth, in general, policy makers will keep inflation closer to zero under EMU than under floating rates.[22]

### 4.3 The exchange rate under floating rates and EMU

In the following, I will compare dollar-deutschmark (under floating rates and ERM) with dollar-euro exchange rates (under EMU). More specifically, I am interested in the impact of supply shocks on the exchange rate. Since I have assumed purchasing power parity to hold, this impact is equal to the difference between the impact of supply shocks on US inflation and their impact on euro area (German) inflation, which have been derived in subsections 4.1 and 4.2. The special cases of an asymmetric shock in Europe, a symmetric shock in Europe, a US shock and a symmetric worldwide shock are shown in Table 1.

**Table 1 Exchange rate response to different types of shocks**

| | Floating rates (dollar-mark)* | EMU (dollar-euro)* |
|---|---|---|
| 1. Asymmetric shock in EU ($\varepsilon_1 = -1; \varepsilon_2 = 1; \varepsilon_3 = 0$) | $\frac{2\alpha\beta}{2+3\alpha^2\beta}$ | $0$ |
| 2. Symmetric shock in EU ($\varepsilon_1 = \varepsilon_2 = -1; \varepsilon_3 = 0$) | $\frac{2\alpha\beta}{2+2\beta+\alpha^2\beta}$ | $\frac{2\alpha\beta}{4+4\beta+\alpha^2\beta}$ |
| 3. Shock in US ($\varepsilon_1 = \varepsilon_2 = 0; \varepsilon_3 = -1$) | $\frac{-2\beta}{2+2\beta+\alpha^2\beta}$ | $\frac{-4\beta}{4+4\beta+\alpha^2\beta}$ |
| 4. Worldwide shock ($\varepsilon_1 = \varepsilon_2 = \varepsilon_3 = -1$) | $\frac{2\beta(\alpha-1)}{2+2\beta+\alpha^2\beta}$ | $\frac{2\beta(\alpha-2)}{4+4\beta+\alpha^2\beta}$ |

*A positive (negative) entry in the Table indicates an appreciation (depreciation) of the dollar.

Consider some limiting cases first. All exchange rate response coefficients in Table 1 become zero if the parameter $\alpha$, which represents the relative size

[20] This can be seen by comparing equations (5a) and (7a).

[21] The fact that the response function (7a) is affected by the changed behaviour of European policymakers follows from the fact that the Federal Reserve faces the same domestic trade-off as before, as can be seen from comparing first-order conditions (4c) and (6b).

[22] This can be seen from comparing equations (5a)-(5c) and (7a)-(7b).

of the US and each of the European countries, goes to infinity. The intuition is that if the euro area were infinitely small compared to the US, even a tiny deviation between real wages in the US and Europe would have a larger impact on output in Europe than a domestic supply shock.[23] Therefore, even in the case of a negative shock in Europe, the best EU central bankers can do is to follow the Fed´s monetary policy decisions, since this ensures that real wages in the US and Europe will be equal. The policy of copying the Fed´s policy is equivalent to keeping the exchange rate against the dollar fixed. Thus, when $\alpha$ is infinitely large, Europe behaves as a small country, in the sense that it unilaterally pegs its currency to the dollar. As a result, the currency impact of any shock, whether in the US or in Europe, will be zero.

Next, notice that all exchange rate response coefficients in Table 1 become zero if $\beta$ goes to zero. The intuition is simple. Remember that central banks fully control the inflation rate. Therefore, if all central banks only care about price stability, they will set inflation equal to zero in all countries. PPP ensures exchange rate stability in this case.

EMU tends to mitigate the expansionary reaction of central banks to economic shocks, since the externalities that cause the unduly fierce policy responses under floating rates are largely internalised under EMU. The degree of mitigation is larger in Europe, where monetary union is formed.

The more moderate response of euro area inflation to supply shocks does not necessarily lead to lower transatlantic exchange rate stability. The consequences of EMU for exchange rate stability depend on the origin of the shock. It is easy to see from Table 1 that (the absolute size of) the exchange rate response to a shock in Europe is smaller under EMU than under floating rates. This is true for both symmetric and asymmetric shocks. Conversely, the exchange rate response to a US shock is larger under EMU than under floating rates.

Intuitively, one can think of the course of events in the four special cases mentioned in Table 1 as follows:

1. Asymmetric shock in Europe
   Neither the ECB nor the Federal Reserve will allow inflation to differ from zero in response to an asymmetric shock in Europe, implying that the exchange rate will remain unchanged after an asymmetric shock under EMU.[24] Under floating rates, however, there will be a non-trivial dollar-mark exchange rate response after an asymmetric shock in Europe. The reason is that the Bundesbank's and the Banque

[23] This can be seen by plugging in a very large number for $\alpha$ in equations (3a) and (3b).

[24] It is easy to see that, in EMU, the optimal policy for both central banks depends on $\varepsilon_1 + \varepsilon_2$ (euro area-wide shock) and $\varepsilon_3$ (US shock) only and that both these variables are equal to zero in the case of an asymmetric shock in Europe.

de France's policy domain is the national economy, rather than the euro area. It follows directly that EMU results in smaller dollar-euro exchange rate responses to asymmetric shocks in Europe.

2. Symmetric shock in Europe
   Under floating rates, the Bundesbank and the Banque de France relax their policy in case of a negative symmetric shock in Europe. In response, the Fed reacts by relaxing policy as well, but to a lesser extent. The result is dollar appreciation. Under EMU, monetary policy in Europe is coordinated. Euro area inflation will increase more moderately after European shocks than German and French inflation did before. The Fed realises that the ECB will accommodate less aggressively than the Bundesbank did and reacts more moderately as well. The impact of EMU is to mitigate all central banks' reactions to the shock, but more so in Europe than elsewhere. The difference between the ECB´s policy reaction and the Fed´s policy reaction becomes smaller, which implies a more moderate exchange rate response.

3. Shock in the US
   In response to a negative economic shock in the United States, the Federal Reserve eases its policy. The Bundesbank and the Banque de France react by easing policy as well, but to a lesser extent, which results in a dollar depreciation. German and French inflation are overly responsive under floating rates, but this has a mitigating impact on the dollar-euro exchange rate response to US shocks. Under EMU, the ECB will be less responsive to US shocks than the individual national central banks in Europe used to be before EMU. The Federal Reserve's response will be mitigated as well, but to a smaller extent. Therefore, the policy stance of the ECB and the Fed will diverge more strongly than before, with adverse implications for exchange rate stability: the exchange rate response to economic shocks in the US increases.

4. World supply shock
   A worldwide shock is defined as simultaneous symmetric shocks of equal size in Europe and in the US. In this case, relative country size plays a role. Under floating rates, the dollar-mark exchange rate will remain stable when $\alpha = 1$, that is when the three countries are of equal size. Under EMU, the dollar-euro exchange rate will remain stable when $\alpha = 2$, that is when the US and the euro area are of the same size. If there is no symmetry in size, then the central bank of the smallest country will have a larger incentive than the other to generate a depreciation of its own currency and will succeed in doing so. In reality, the euro area has roughly the same size as the US (i.e. $\alpha \approx 2$), which implies that the exchange rate response to a world supply shock will be smaller under EMU than under floating rates. Thus, under the

assumption that the average frequency and size of shocks in Europe and the US is similar, one may expect that the dollar-euro exchange rate will be more stable than the dollar-mark exchange rate.

### 4.4 Optimal monetary policy under ERM

When studying the impact of the start of monetary union in Europe, it is common to compare floating rates and EMU. This approach can be defended on the grounds that, in the long run, the relevant choice is between floating rates versus full monetary union (Persson and Tabellini, 1995). However, it seems more appropriate to compare ERM and EMU. Not only were the EMU countries required to participate in the exchange rate mechanism of the European Monetary System in the two years before the start of EMU, the so-called 'core countries' had been participating in the ERM (and its predecessor, the 'snake arrangement) for over twenty years.

The ERM had two essential characteristics. The first is that the system was asymmetric. The Bundesbank set its policy, after which the central banks of the other countries that participate in the ERM set their policy so as to stabilise the exchange rate against Germany. This element is captured by having the Bundesbank act as a Stackelberg leader against the Banque de France. The second characteristic is the possibility of an ERM break-up. I will assume that France was expected to stay in the ERM with probability $p$ and to leave the ERM with probability $1-p$. Intuitively, $p$ can be seen as the credibility of the ERM. In this counterfactual experiment, probability $p$ is determined by factors beyond the scope of the model. Such factors could be political pressure inside France to abrogate the ERM agreement or market speculation which forces the central bank to give up its exchange rate commitment. The probability $p$ is known by all players in the model.

The timing of this game is as follows. First, private inflation expectations are formed. Second, wages are set. Third, shocks occur. Fourth, the Bundesbank and the Federal Reserve set their policies. Fifth, the markets determine whether the ERM is sustained or not. Sixth, the Banque de France sets its policy.

The loss function of the Banque de France depends on the continuation or break-up of the ERM. If France stays in the ERM, the exchange rate is the overriding objective, i.e. there is no trade-off between inflation and output. If France has left the ERM, the Banque de France's loss function has the same functional form as under floating rates:

$$L_{2,ERM} = \frac{1}{2}(\pi_{2,ERM} - \pi_1)^2, \tag{8a}$$

$$L_{2,BU} = \frac{1}{2}(\pi_{2,BU}^2 + \beta y_{2,BU}^2), \tag{8b}$$

where $\pi_{2,ERM}$ stands for Banque de France policy given that France participates in ERM and $\pi_{2,BU}$ ($y_{2,BU}$) stands for Banque de France policy (output in France) given an ERM break-up. The first-order conditions are:

$$\pi_{2,ERM} = \pi_1, \tag{9a}$$
$$\pi_{2,BU} = -\alpha\beta y_{2,BU}. \tag{9b}$$

The reaction function of the Banque de France, which is conditional on the continuation or break-up of ERM, follows directly from combining the first-order conditions (9a) and (9b) and the supply function for France:

$$\pi^R_{2,ERM} = \pi_1, \tag{10a}$$
$$\pi^R_{2,BU} = \frac{\alpha^2\beta}{2(1+\alpha^2\beta)}(\pi_1+\pi_3) - \frac{\alpha\beta}{2(1+\alpha^2\beta)}\varepsilon_2, \tag{10b}$$

where $\pi^R_{2,ERM} = \pi^R_{2,ERM}(\pi_1)$ is the reaction function of the Banque de France if ERM is succesfully maintained and $\pi^R_{2,BU} = \pi^R_{2,BU}(\pi_1, \pi_3)$ is its reaction function in the case of an ERM break-up. Note that the Fed´s policy choice does not feature in the Banque de France´s inflation choice if France continues to participate in the ERM (i.e. $\partial\pi^R_{2,ERM}/\partial\pi_3 = 0$).

The Bundesbank and the Federal Reserve play Nash against each other. They both act as Stackelberg leaders against the Banque de France. By moving first, the Bundesbank and the Federal Reserve commit themselves to a certain monetary policy. They will take into account the reaction function of the Banque de France when setting their policy. However, they do not know yet whether France will stay in the ERM. They expect the Banque de France to play the strategy defined by equation (10a) with probability $p$ and to play the strategy defined by equation (10b) with probability $1-p$. The Bundesbank sets $\pi_1$ so as to minimise its loss:

$$L_1 = \frac{1}{2}\pi_1^2 + \frac{1}{2}\beta y_1^2, \tag{11}$$
$$s.t. \; y_1 = \alpha(\pi_1 - \pi_1^e) - \frac{\alpha}{2}[\pi_2^R - \pi_2^e] - \frac{\alpha}{2}(\pi_3 - \pi_3^e) + \varepsilon_1,$$

where $\pi_2^R = p\pi^R_{2,ERM} + (1-p)\pi^R_{2,BU}$. The loss function for the Federal Reserve is a similar expression. Because the Bundesbank anticipates the Banque de France's reaction to its own policy, the first-order condition for the Bundesbank is defined by:

$$\frac{\partial L_1}{\partial \pi_1} + \frac{\partial L_1}{\partial \pi_2^R}\frac{\partial \pi_2^R}{\partial \pi_1} = 0. \tag{12}$$

Using the reaction functions (10a)-(10b), this can be rewritten as:[25]

$$\pi_1 = -\alpha\beta[p\frac{1}{2}y_{1,ERM} + (1-p)Hy_{1,BU}], \tag{13}$$

where $H = \frac{4+3\alpha^2\beta}{4+4\alpha^2\beta}$.

The first-order condition for the Federal Reserve becomes:

$$\pi_3 = -\beta[py_{3,ERM} + (1-p)Hy_{3,BU}]. \tag{14}$$

As shown in Appendix B, the optimal responses are:

$$\begin{aligned}
\pi_1 &= \pi_{2,ERM} = p\frac{-\alpha\beta}{4+4\beta+\alpha^2\beta}[2(1+\beta)\varepsilon_1 + \alpha\beta\varepsilon_3] + \\
&\quad +(1-p)\frac{-H\alpha\beta}{D}[A_1\varepsilon_1 + A_2\varepsilon_2 + A_3\varepsilon_3], && (15a)\\
\pi_{2,BU} &= p\frac{-\alpha\beta}{1+\alpha^2\beta}\{\varepsilon_2 + \frac{\alpha\beta}{4+4\beta+\alpha^2\beta}[\alpha(1+2\beta)\varepsilon_1 + (2+\alpha^2\beta)\varepsilon_3]\} + \\
&\quad +(1-p)\frac{-\alpha\beta}{D}[B_1\varepsilon_1 + B_2\varepsilon_2 + B_3\varepsilon_3], && (15b)\\
\pi_3 &= p\frac{-\beta}{4+4\beta+\alpha^2\beta}[2\alpha\beta\varepsilon_1 + (4+\alpha^2\beta)\varepsilon_3] + \\
&\quad +(1-p)\frac{-H\beta}{D}[C_1\varepsilon_1 + C_2\varepsilon_2 + C_3\varepsilon_3], && (15c)
\end{aligned}$$

where all terms $(H, D, A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2, C_3)$ are positive. Thus, negative supply shocks lead to a more accommodative monetary policy stance.

For $p = 1$, the Bundesbank and the Fed know that France will stay in the ERM for sure and they fully internalise the fact that the Banque de France will copy German monetary policy. The policies under such a stable ERM will be almost equivalent to the optimal policies under EMU. The difference is that under ERM, shocks to the French economy do not affect Bundesbank policy, whereas German and French shock both matter (and are equally important in this model) for ECB policy in EMU.[26]

[25] Since the Bundesbank and the Federal Reserve move before the status of ERM is determined and since they are assumed to have full control over the domestic inflation rate, there will be a unique solution for inflation in Germany and the United States. However, output in each country will be affected by the continuation or break-up of the ERM and the consequent policy choice of the Banque de France. Thus, there are two solutions for output in each country: $y_{j,ERM}$ may differ from $y_{j,BU}$, $j = 1, 2, 3$.

[26] Note that the policy response of each individual central bank is exactly equivalent to its response under EMU only after substituting $\frac{1}{2}(\varepsilon_1 + \varepsilon_2)$ for $\varepsilon_1$ in equations (15a)-(15c). This result is in line with Benassy-Quere, Mojon and Pisani-Ferry (1997) and Canzoneri and Henderson (1991).

For $p = 0$, France will leave the ERM for sure and the Bundesbank and the Fed know this. When determining their policies, they fully internalise the fact that the Banque de France has the 'opportunistic' reaction function $\pi^R_{2,BU}$. It is straightforward to show that, under ERM, inflation will generally be closer to zero than under floating rates, but further away from zero than under EMU. This corresponds to the familiar result in game theory that losses for all policy makers tend to be lower in a Stackelberg equilibrium than in a Nash equilibrium.

For $0 < p < 1$, the absolute value of the policy responses under ERM is decreasing in $p$ in the case of symmetric shocks.[27] If $p$ is high, the existing externalities in monetary policy will be internalised to a larger extent. Intuitively, central banks on both sides of the Atlantic will keep inflation closer to zero in case of a more credible ERM (higher value of $p$).

### 4.5 The exchange rate under ERM and EMU

Recall that purchasing power parity is assumed to hold. Therefore, the exchange rate change is equal to the inflation differential, which in turn is entirely determined by the policy response. The response of the exchange rate to specific types of shocks under ERM is summarised in Table 2.

**Table 2 Exchange rate response to different types of shocks**

| | ERM (dollar-mark)* | EMU (dollar-euro)* |
|---|---|---|
| 1. Asymmetric shock in EU ($\varepsilon_1 = -1; \varepsilon_2 = 1; \varepsilon_3 = 0$) | $p\frac{2\alpha\beta}{4+4\beta+\alpha^2\beta} + (1-p)\frac{2H\alpha\beta N_1}{D}$ | $0$ |
| 2. Symmetric shock in EU ($\varepsilon_1 = \varepsilon_2 = -1; \varepsilon_3 = 0$) | $p\frac{2\alpha\beta}{4+4\beta+\alpha^2\beta} + (1-p)\frac{2H\alpha\beta N_2}{D}$ | $\frac{2\alpha\beta}{4+4\beta+\alpha^2\beta}$ |
| 3. Shock in US ($\varepsilon_1 = \varepsilon_2 = 0; \varepsilon_3 = -1$) | $p\frac{-4\beta}{4+4\beta+\alpha^2\beta} + (1-p)\frac{-2H\beta N_3}{D}$ | $\frac{-4\beta}{4+4\beta+\alpha^2\beta}$ |
| 4. World wide shock ($\varepsilon_1 = \varepsilon_2 = \varepsilon_3 = -1$) | $p\frac{2\beta(\alpha-2)}{4+4\beta+\alpha^2\beta} + (1-p)\frac{2H\beta(\alpha-1)N_4}{D}$ | $\frac{2\beta(\alpha-2)}{4+4\beta+\alpha^2\beta}$ |

A positive (negative) entry in the Table indicates an appreciation (depreciation) of the dollar.

[27] It is easy to check that $\pi_j > 0$ and $\frac{d}{dp}\pi_j < 0$, if all shocks are negative. If all shocks are positive, then $\pi_j < 0$ and $\frac{d}{dp}\pi_j > 0$. Therefore, an increase in $p$ will generally bring the absolute value of $\pi_j$ closer to zero, $j = 1, 2(ERM), 2(BU), 3$.

with

$$\begin{aligned}
N_1 &= 2 + (1 + H)\beta + \alpha^2\beta, \\
N_2 &= 2 - (1 - H)\beta + 3\alpha^2\beta, \\
N_3 &= 2 + (3 + H)\alpha^2\beta, \\
N_4 &= 2 + (1 - H)\alpha\beta + 3\alpha^2\beta,
\end{aligned}$$

and $H$ as before and $D$ as defined in Appendix B. All terms $(D, N_1, ..., N_4)$ are positive.

The results that were obtained when comparing floating rates and EMU still hold when comparing ERM and EMU. I recall these results for easy reference: EMU will result in smaller exchange rate reactions to both symmetric and asymmetric shocks in Europe, in larger exchange rate reactions to US shocks and in smaller exchange rate reactions to worldwide shocks.

In comparing ERM and EMU, I will consider the different possibilities case by case:

1. Asymmetric shocks in Europe

   Under EMU, the exchange rate will not react to an asymmetric shock in Europe at all, since neither the ECB nor the Fed will allow inflation to differ from zero. However, there will be a non-trivial move in the dollar-mark exchange rate under ERM. Therefore, the conclusion that EMU results in a smaller exchange rate reaction to asymmetric shocks in Europe is still valid.

2. Symmetric shock in Europe

   It is straightforward to show that the exchange rate reaction to a symmetric shock in Europe under ERM is larger than under floating rates (for $p = 0$) and equal to the reaction under EMU (for $p = 1$) respectively. The intuition is that if in an ERM which is likely to fail, central banks will compete less aggressively than under floating rates, but more aggressively than under EMU and that for a highly credible ERM, the policy responses are the same as those under EMU.[28] For intermediate values of $p$ (i.e. $0 < p < 1$), the size of the exchange rate reaction under the ERM scenario is a weighted average of these two extreme cases. It follows directly that the earlier results (EMU results in a smaller exchange rate reaction to symmetric shocks in Europe than floating rates) still hold when comparing EMU and ERM.

3. Shocks in the US

   The same reasoning as sub 2 leads to the conclusion that the earlier result (EMU results in a larger exchange rate reaction to a US shock

[28] The latter is only true if $\frac{1}{2}(\varepsilon_1 + \varepsilon_2) = \varepsilon_1$ (that is: if $\varepsilon_1 = \varepsilon_2$), but this condition is satisfied for a symmetric shock in Europe.

than floating rates) must still be valid when comparing EMU and ERM.[29]

4. Worldwide shocks

   The exchange rate reaction to a worldwide shock under ERM is intermediate between floating rates and EMU.[30]

To summarise this paragraph, all results that we established for the comparison of floating rates and EMU are still valid.

### 4.6 A future expansion of the euro area

So far it has been assumed that the euro area is not larger than the United States. However, if the current outs were to join EMU, and especially if the candidate member states in Central and Eastern Europe were to join not only the European Union, but also EMU, the euro area would become larger than the US. The sensitivity of the earlier results to such a future expansion of the euro area can easily be tested using the size parameter in the model.

This subsection discusses the previous results with respect to exchange rate stability for the case $1 < \alpha < 2$. I will thus maintain the assumption that, even after the expansion of the euro area, the US is larger than half of the euro area. I will first compare floating rates and EMU and then turn to the comparison of ERM and EMU.[31]

**Floating rates and EMU**

The results remain qualitatively the same in special cases 1-3 that I have looked at in earlier subsections: The exchange rate will be more stable in response to (both asymmetric and symmetric) shocks in Europe under EMU than under floating rates; the exchange rate will be less stable in response to US shocks under EMU than under floating rates, even if the euro area were to become larger than the US.

However, the relative size of the euro area and the US may affect the conclusion in special case 4: a worldwide shock. A symmetric world supply shock will lead to smaller exchange rate volatility after the start of EMU, unless the euro area were to become more than 50% larger than the United

[29] The condition $\varepsilon_1 = \varepsilon_2$ is satisfied in this case as well (as both values are zero), so that, for an ERM with $p = 1$, the policy choices are equal to those under EMU.

[30] Again, the condition of symmetry in Europe ($\varepsilon_1 = \varepsilon_2$) is satisfied, so that for an ERM with $p = 1$, the policy choices are equal to those under EMU.

[31] It is not the purpose of this subsection to look at the effect of the euro area expansion on exchange rate stability. Rather, I check whether the earlier results about the impact of EMU on exchange rate stability would still be valid if the euro area were to expand significantly.

States.[32] In the latter case, the US would obtain stronger incentives to actively use the exchange rate as an instrument. This size effect could ultimately dominate the mitigating impact of the internalisation of externalities in Europe as a result of EMU.

**ERM and EMU**

Again, the results remain qualitatively the same in special cases 1-3 that I have looked at in earlier subsections. The relative size of the euro area and the US is of qualitative importance for the conclusion only in case 4: a symmetric worldwide shock. If the euro area were to become significantly larger than the United States, then world supply shocks would lead to larger exchange rate reactions than before EMU. The more credible ERM was thought to be at the outset (i.e. the higher $p$), the more likely our result is to break down. This should come as no surprise, since in a highly credible ERM intra-European externalities are internalised to a large extent, making this situation very similar to EMU. For instance, if $p = 0$, the reversal takes place only if the euro area were to become more than 50% larger than the US. For $p = \frac{1}{2}$ the reversal would take place as soon as the euro area were more than 20% larger than the US and for $p = \frac{3}{4}$, this would occur as soon as the euro area were more than 10% larger than the US. However, in the extreme case of a fully credible ERM ($p = 1$) the exchange rate response to a worldwide shock will be equivalent to the response under EMU. Thus, no reversal takes place.[33]

To summarise this paragraph, our results for both asymmetric and symmetric shocks in Europe and for shocks in the US remain valid, even if the euro area were to become much larger than the US. Only the result for worldwide shocks (defined as a simultaneous shock of equal size in Europe and the US) may be reversed if the euro area were to become (significantly) larger than the United States in terms of population.

[32] This can be seen by comparing the absolute values of the entries in the bottom row of Table 1. The exact condition is that the exchange rate response is smaller under EMU than under floating rates if and only if $(6\alpha - 8)(\beta + 1) + (2\alpha - 3)\alpha^2\beta > 0$. It is easy to see that for this inequality to hold, it is sufficient that $\alpha > 1.5$. Numerical evaluation shows that the inequality is likely to be satisfied for $\alpha > 1.34$ (i.e. for $\frac{2}{\alpha} < 1.49$, that is if the euro area is less than roughly 50% larger than the United States). The inequality is rather insensitive to $\beta$ (maintaining our assumption that $\beta > 0$). Even if $\beta \to \infty$, the inequality will be satisfied for all $\alpha > 1.4$.

[33] The exact condition for the exchange rate response to be smaller under EMU than under ERM can be derived from comparing the absolute values of the expressions in the bottom line of Table 2. The exact condition is a rather cumbersome expression. Numerical evaluation gives the results in the main text. Intermediate values for $p$ give intermediate critical values for $\alpha$.

# 5 Conclusion

In this memorandum, I have looked at the possible impact of EMU on transatlantic exchange rate stability. The very essence of EMU is that it changes the rules of the monetary game. As a result, the start of EMU has consequences for the behaviour of monetary policy makers, which may affect the euro-dollar exchange rate.

The establishment of the ECB comes with full monetary policy coordination within the euro area, ensuring that all externalities within the euro area are internalised in the decision making process in the ECB Governing Council. As a result, the ECB will keep the economy closer to price stability in response to economic shocks than the national central banks did before the start of EMU. Even though the Federal Reserve faces the same tradeoff as before, its response function will be affected by the changes in Europe: the Fed will also tend to keep the economy closer to price stability under EMU than under floating rates.

In the run-up to EMU, it was widely expected that exchange rate volatility would increase as a result of benign neglect of the exchange rate on both sides of the Atlantic. However, using a simple two-country model which focused on country size, Martin (1997) argued that exchange rates would become more stable. I have extended his model to a three-country version. This enables me to take into account a number of changes as a result of EMU that a two-country model cannot address.

In contrast to Martin, I am able to distinguish between symmetric and asymmetric shocks in Europe and between shocks in Europe and abroad. Martin´s conclusion appears to be true for most but not all types of economic shocks:

1. Under EMU, the exchange rate will react more moderately to (both symmetric and asymmetric) European supply shocks than before. The more moderate response of the ECB implies that the policy responses of the ECB and the Fed to a euro area supply shock will be more alike than before, which results in a more stable exchange rate.

2. The impact of US shocks on the exchange rate will become stronger under EMU. The more moderate response of the ECB to a US shock implies that the policy stance of the ECB and the Fed will diverge more (!) than before. This causes the dollar to respond more strongly to a supply shock in the US.

Thus, the impact of EMU on exchange rate stability critically depends on the origin of shocks. The lower responsiveness of the ECB to European shocks will translate into more exchange rate stability, whereas the lower responsiveness of the ECB to US shocks will translate into stronger exchange rate movements. The analysis of world supply shocks suggests that on balance, a more stable euro-dollar exchange rate is likely to result, assuming that Europe and the US are, on average, hit by shocks of similar size.

The conclusions remain valid when taking into account that Europe had an exchange rate mechanism (ERM), rather than freely floating currencies, in the pre-EMU era. The specification of the ERM accounts for the fact that the ERM was an asymmetric arrangement, in the sense that the Bundesbank had a leading role, whereas the other national central banks had an exchange rate target against the German mark. It also takes into account the possibility of a break-down of the arrangement. This increases the practical relevance of my conclusions.

Finally, the model's country size parameter is used to test what happens if the euro area expands. This is likely to become relevant, given the foreseen enlargement of the European Union and the expected future participation of the new member states in the monetary union. It is shown that most of the results remain valid even in the case of a possible expansion of the euro area. Only if the euro area were to become (significantly) larger than the US, the exchange rate may become more, not less, responsive to a symmetric worldwide shock than it used to be before EMU.

Appendices

# A Supply per capita and country size

The derivation of the size coefficients follows Martin (1997). Think of a world of $N$ identical regions, which compete with each other on the basis of real wages. The supply function in region $i$ is as follows:

$$y_i = -(w_i - p_i) + \frac{1}{N-1}\sum_{j\neq i}(w_j - p_j) + \eta_i. \tag{A1}$$

Now define a partition of the world in three super regions, comprising $n_1, n_2, n_3$ regions, respectively ($n_1 + n_2 + n_3 = N$). Shocks $\eta_i$ have expected value zero and variance $\sigma^2, i = 1, ..., N$. Assume that shocks within each super region are perfectly correlated, whereas shocks in different super regions are uncorrelated. Now define $\varepsilon_k = \frac{1}{n_k}\sum_{i\in n_k}\eta_i, k = 1,2,3$. Then

$$\begin{aligned} Var(\varepsilon_k) &= (\frac{1}{n_k})^2 Var(\sum_{i\in n_k}\eta_i) = (\frac{1}{n_k})^2[\sum_{i\in n_k}[Var(\eta_i) + \sum_{\substack{i,j\in n_k\\ i\neq j}} Cov(\eta_i,\eta_j)]] = \\ &= (\frac{1}{n_k})^2[n_k[\sigma^2 + (n_k - 1)\sigma^2]] = \sigma^2, \quad k = 1,2,3. \end{aligned} \tag{A2}$$

Then per capita supply in each super region is given by

$$\begin{aligned} y_1 &= \frac{1}{n_1}\sum_{i\in n_1}\left[-(w_i - p_i) + \frac{1}{N-1}\sum_{j\neq i}(w_j - p_j) + \eta_i\right] \\ &= \frac{1}{n_1}\sum_{i\in n_1} -(w_1 - p_1) + \\ &\quad + \frac{1}{N-1}[(n_1 - 1)(w_1 - p_1) + n_2(w_2 - p_2) + n_3(w_3 - p_3)] + \eta_i] \\ &= -(\frac{N-n_1}{N-1})(w_1 - p_1) + \frac{n_2}{N-1}(w_2 - p_2) + \\ &\quad + \frac{n_3}{N-1}(w_3 - p_3) + \varepsilon_1. \end{aligned} \tag{A3}$$

Analogously:

$$y_2 = \frac{n_1}{N-1}(w_1 - p_1) - (\frac{N-n_2}{N-1})(w_2 - p_2) + + \frac{n_3}{N-1}(w_3 - p_3) + \varepsilon_2, \tag{A4}$$

$$y_3 = \frac{n_1}{N-1}(w_1 - p_1) + \frac{n_2}{N-1}(w_2 - p_2) + -(\frac{N-n_3}{N-1})(w_3 - p_3) + \varepsilon_3. \tag{A5}$$

Normalise: $n_1 = n_2 = \frac{1}{1+\alpha}; n_3 = \frac{\alpha}{1+\alpha}$. This means that $N - 1 = n_1 + n_2 + n_3 - 1 = \frac{1}{1+\alpha}$.Then:

$$y_1 = -(1+\alpha)(w_1 - p_1) + (w_2 - p_2) + \alpha(w_3 - p_3) + \varepsilon_1, \tag{A6}$$

$$y_2 = (w_1 - p_1) - (1+\alpha)(w_2 - p_2) + \alpha(w_3 - p_3) + \varepsilon_2, \tag{A7}$$

$$y_3 = (w_1 - p_1) + (w_2 - p_2) - 2(w_3 - p_3) + \varepsilon_3. \tag{A8}$$

I have adjusted the weights in the main text in order to capture the fact that Germany and France are geographically closer to each other than to the United States. This does not affect the main conclusions of this article.

# B Optimal responses under ERM

After substituting the supply curves into the first-order conditions (9a), (9b), (13) and (14), the first-order conditions can be rewritten in terms of inflation:

$$\pi_1 = -\alpha\beta\{p + 2H(1-p)\}\{[\alpha(\pi_1 - \pi_1^e) - \frac{\alpha}{2}[\frac{p}{p + 2H(1-p)}\pi_{2,ERM} + + \frac{2H(1-p)}{p+2H(1-p)}\pi_{2,BU} - \pi_2^e] - \frac{\alpha}{2}(\pi_3 - \pi_3^e) + \varepsilon_1\}, \tag{B1}$$

$$\pi_{2,ERM} = \pi_1, \tag{B2}$$

$$\pi_{2,BU} = -\alpha\beta\{-\frac{\alpha}{2}(\pi_1 - \pi_1^e) + \alpha[\pi_{2,BU} - \pi_2^e] - \frac{\alpha}{2}(\pi_3 - \pi_3^e) + \varepsilon_2\}, \tag{B3}$$

$$\pi_3 = -\beta\{p + H(1-p)\}\{-\frac{1}{2}(\pi_1 - \pi_1^e) - \frac{1}{2}[\frac{p}{p + H(1-p)}\pi_{2,ERM} + + \frac{H(1-p)}{p + H(1-p)}\pi_{2,BU} - \pi_2^e] + (\pi_3 - \pi_3^e) + \varepsilon_3\}, \tag{B4}$$

where $H = \frac{3+\alpha^2\beta}{4+\alpha^2\beta}$. Note that $p\pi_{2,ERM} + (1-p)\pi_{2,BU}$ is the policy of the Banque de France as expected by the other central banks, i.e. after shocks occur, but before the markets determine whether or not France stays in the ERM, whereas $\pi_2^e$ is the BdF policy as expected by wage setters, i.e. before shocks occur.

The assumption of rational expectations implies:

$$\begin{aligned} E(\pi_1) &= \pi_1^e, && \text{(B5)} \\ E(\pi_2) &= p\pi_{2,ERM}^e + (1-p)\pi_{2,BU}^e = \pi_2^e, && \text{(B6)} \\ E(\pi_3) &= \pi_3^e. && \text{(B7)} \end{aligned}$$

Taking expectations on both sides of (B.1)-(B.4) and applying the assumption of rational expectations results in a non-singular system of four equations in four unknowns ($\pi_1^e$, $\pi_{2,ERM}^e$, $\pi_{2,BU}^e$, $\pi_3^e$). These equations need to be satisfied for all admissable values of $\alpha$, $\beta$, and $p$, which is only the case for $\pi_1^e = \pi_{2,ERM}^e = \pi_{2,BU}^e = \pi_3^e = 0$.

This simplifies the first-order conditions, which can then be rewritten to the following reduced-form equations:

$$\begin{aligned} \pi_1 &= \pi_{2,ERM} = p\frac{-\alpha\beta}{4+4\beta+\alpha^2\beta}[2(1+\beta)\varepsilon_1 + \alpha\beta\varepsilon_3] + \\ &\quad +(1-p)\frac{-H\alpha\beta}{D}[A_1\varepsilon_1 + A_2\varepsilon_2 + A_3\varepsilon_3], && \text{(B8)} \\ \pi_{2,BU} &= p\frac{-\alpha\beta}{1+\alpha^2\beta}\{\varepsilon_2 + \frac{\alpha\beta}{4+4\beta+\alpha^2\beta}[\alpha(1+2\beta)\varepsilon_1 + (2+\alpha^2\beta)\varepsilon_3]\} + \\ &\quad +(1-p)\frac{-\alpha\beta}{D}[B_1\varepsilon_1 + B_2\varepsilon_2 + B_3\varepsilon_3], && \text{(B9)} \\ \pi_3 &= p\frac{-\beta}{4+4\beta+\alpha^2\beta}[2\alpha\beta\varepsilon_1 + (4+\alpha^2\beta)\varepsilon_3] + \\ &\quad +(1-p)\frac{-H\beta}{D}[C_1\varepsilon_1 + C_2\varepsilon_2 + C_3\varepsilon_3], && \text{(B10)} \end{aligned}$$

with

$$\begin{aligned} H &= \frac{4+3\alpha^2\beta}{4+4\alpha^2\beta}, \\ D &= 4 + 4H\beta + 4(1+H)\alpha^2\beta + 3H(1+H)\alpha^2\beta^2 + 3H\alpha^4\beta^2, \\ A_1 &= 4 + 4H\beta + 4\alpha^2\beta + 3H\alpha^2\beta^2, \\ A_2 &= 2\alpha^2\beta + 3H\alpha^2\beta^2, \\ A_3 &= 2H\alpha\beta + 3H\alpha^3\beta^2, \\ B_1 &= 2H\alpha^2\beta + 3H^2\alpha^2\beta^2, \\ B_2 &= 4 + 4H\beta + 4H\alpha^2\beta + 3H^2\alpha^2\beta^2, \\ B_3 &= 2H\alpha\beta + 3H^2\alpha^3\beta^2, \\ C_1 &= 2H\alpha\beta + 3H\alpha^3\beta^2, \\ C_2 &= 2\alpha\beta + 3H\alpha^3\beta^2, \\ C_3 &= 4 + 4(1+H)\alpha^2\beta + 3H\alpha^4\beta^2. \end{aligned}$$

All terms $(H, D, A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2, C_3)$ are positive.

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