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STABILIZING MACROECONOMIC FLUCTUATIONS IN THE EMU

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Macroeconomic performance in the Economic and Monetary Union (EMU) will be impaired if national fiscal policy flexibility and monetary flexibility of the ECB is limited, goods markets adjust sluggishly, labor mobility is low, and automatic stabilization from federal taxes and government spending is low. This paper analyzes the stabilization of output fluctuations induced by symmetric and asymmetric macroeconomic shocks in the EMU. It is shown how national fiscal flexibility and flexibility of the monetary policy of the ECB can stabilize fluctuations of the average EU business cycle that are generated by symmetric shocks. Furthermore, it is demonstrated how, under EMU, national fiscal flexibility and a system of fiscal transfers are able to stabilize differences in national business cycles that are generated by asymmetric shocks.

Keywords: Monetary and Fiscal Policy, EMU, ECB, Fiscal Transfers

1. INTRODUCTION

The introduction of the Euro on January 1, 1999, marked the start of the Economic and Monetary Union (EMU). With it the national central banks transfer the design of monetary policy to the European Union (EU) level where the European Central Bank (ECB) is responsible for the design and management of the common monetary policy. Before its actual start, a decade of discussions, preparations, and evaluations passed. The European Commission (1990) studied in detail the potential costs and benefits from EMU in its seminal "One Market, One Money" study and specified in the Treaty of Maastricht the design and workings of the EMU institutions and a set of monetary and fiscal convergence criteria that the applicants were required to fulfill before admission.

The EMU is likely to induce static and dynamic efficiency gains for the participating countries. Under EMU, national policymakers will, however, be limited in their ability to actively stabilize output fluctuations in their economies induced by

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macroeconomic shocks. A monetary union first implies that individual monetary policy is replaced by the common monetary policy of the ECB and therefore lost as a policy instrument. In particular, EMU implies the loss of the possibility to adjust the nominal exchange rate in case members experience asymmetric shocks. Loss of the exchange-rate instrument as a shock absorber is, in particular, harmful if the countries that join the EMU do not constitute an "optimal currency area." Countries are less likely to form an optimal currency area if macroeconomic shocks are predominantly asymmetric, nominal rigidities prevail in the short run, labor mobility is low, and automatic stabilization from federal taxes and government spending is low.[1] The significance of asymmetric shocks, limited labor market flexibility, and low automatic stabilization from federal taxes and government expenditures casts doubts on whether the European Union[2] is actually an optimal currency area. Therefore, EMU is likely to shoulder the national fiscal authorities with a higher adjustment burden from stabilizing output fluctuations. Moreover, under EMU, national policymakers are limited in their flexibility for a second reason. The scope for national fiscal policies to stabilize business-cycle fluctuations will be limited in the EMU, namely, by the fiscal stringency requirements of the "Stability and Growth Pact." The necessity to comply with its requirements on the fiscal deficit may imply that policymakers are unable to let the automatic stabilizers inside the deficit operate in times of recession, let alone to implement active stabilization policies.

Demertzis et al. (1997) have addressed the "optimal currency area" problem associated with EMU and the role of market and policy flexibility in that perspective. Hughes Hallett and Vines (1993) compare economic performance of EMU with a regime of floating exchange rates, using simulation tools. It is pointed out that an EMU, compared to flexible exchange rates, performs poorly when hit by asymmetric shocks, featuring an independent ECB, low fiscal policy flexibility, and lack of fiscal coordination. Hughes Hallett and Ma (1996) compare outcomes under a fully coordinated monetary union with the case of noncooperative fiscal policies and the case in which the common monetary policy is assigned to price stability and fiscal policy to output growth. It is shown that national fiscal policies cause problems in the face of asymmetries between countries but few problems in case of symmetric economies. The fiscal-monetary assignments, on the other hand, cause problems, particularly in the symmetric case.

This paper extends such earlier literature on macroeconomic stabilization policies in an EMU confronted with symmetric and asymmetric shocks. It is shown how fiscal flexibility and monetary flexibility of the ECB are helpful in stabilizing EU-wide output fluctuations that are generated by symmetric shocks. In particular, a complete absence of fiscal and monetary flexibility will leave the EU economy unable to stabilize EU-wide business-cycle fluctuations generated by EU-wide macroeconomic shocks. Concerning asymmetric shocks, we consider (i) fiscal flexibility at a national level, and (ii) a system of fiscal transfers to stabilize business-cycle divergences in the European Union that are generated by asymmetric shocks. Such a transfer system might act as a substitute for the shock-absorbing capacity of exchange-rate realignments such as in the EMS and for the automatic

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stabilizing role of federal government spending and taxation that occurs in more mature fiscal federations. It is shown how such a European Fiscal Transfer System (EFTS) can increase macroeconomic efficiency in the monetary union by providing the participating countries with a cushion against asymmetric shocks. Such an EFTS was advocated by van der Ploeg (1991), who suggested that the Maastricht Treaty on EMU be supplemented with an EFTS aimed at counteracting the consequences of asymmetric macroeconomic shocks in a monetary union. Although some work has been performed on such an EFTS, notably by Italianer and van Heukelen (1993), Mélitz and Vori (1993), and von Hagen and Hammond (1995), the full implications of such a system have remained largely unexplored.

Section 2 introduces a stylized two-country EMU model that serves as our analytical device. The model enables us to analyze the role of fiscal flexibility at a national level and the flexibility of the common monetary policy implemented by the ECB. A system of fiscal transfers that aims at stabilizing differences in business-cycle fluctuations in the European Union is proposed. Section 3 solves the model and derives its analytical properties. In Section 4, numerical simulations of the model are used to study the dynamic adjustment in the EMU to symmetric and asymmetric output shocks.

2. A TWO-COUNTRY EMU MODEL

The starting point of the analysis is a situation in which EMU has been implemented, implying that national currencies and monetary policies are replaced by a common currency, the Euro, and a common central bank, the ECB. For simplicity, the transition phase in which some countries do not yet participate completely is disregarded.[3] Also, we disregard the interaction of the EU economy with the rest of the world, although EMU is likely also to have significant implications for the external relations of the European Union. In particular, it is asserted that the Euro is likely to rival the dollar as an international vehicle currency and that the European Union is likely to increase its influence in the international fora of macroeconomic policy coordination once EMU is completed.[4] In addition, flexibility of the external value of the Euro will to some extent act as a shock absorber particularly of shocks and policies from outside the EMU and could partly compensate for the loss of internal exchange-rate adjustment as a stabilization mechanism. However, in case the EMU countries vary considerably in terms of economic structure and position in the business cycle, fluctuations of the Euro are likely to affect the countries in a very different manner and may actually aggravate the divergences inside the EMU and could form an additional argument for not restricting unduly macroeconomic stabilization policies in the EMU.

Assume an EMU that consists of two countries the economies of both of which can be characterized by the relations in Table 1, where $y(t)$ denotes real output at time t, $c(t)$ is competitiveness of country 1 vis-à-vis country 2, $m(t)$ is nominal money balance, $p(t)$ is the output price level and $w(t)$ is the nominal wage, $i(t)$ and $r(t)$ are the nominal and real interest rates, and $s(t)$ is an index of the fiscal

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Table 1. A two-country EMU model

$$y(t) = \alpha c(t) - \gamma r(t) + \sigma y^*(t) + \eta s(t) + \upsilon(t) \quad \textbf{(1a)}$$

$$y^*(t) = -\alpha c(t) - \gamma r^*(t) + \sigma y(t) + \eta s^*(t) + \upsilon^*(t) \quad \textbf{(1b)}$$

$$m(t) - p(t) = \kappa y(t) - \lambda i(t) \quad \textbf{(2a)}$$

$$m^*(t) - p^*(t) = \kappa y^*(t) - \lambda i(t) \quad \textbf{(2a)}$$

$$c(t) = p^*(t) - p(t) \quad \textbf{(3)}$$

$$i(t) = r(t) + \dot{p}(t) = r^*(t) + \dot{p}^*(t) \quad \textbf{(4)}$$

$$s(t) = f(t) + n(t) \quad \textbf{(5a)}$$

$$s^*(t) = f^*(t) - n(t) \quad \textbf{(5b)}$$

$$p(t) = \delta \int_{-\infty}^{t_0} w(t) e^{-\delta(t_0 - t)}\, dt \quad \textbf{(6a)}$$

$$p^*(t) = \delta \int_{-\infty}^{t_0} w^*(t) e^{-\delta(t_0 - t)}\, dt \quad \textbf{(6b)}$$

$$w(t) = \delta \int_{t_0}^{\infty} \{p(t) + \nu y(t)\} e^{-\delta(t_0 - t)}\, dt \quad \textbf{(7a)}$$

$$w^*(t) = \delta \int_{t_0}^{\infty} \{p^*(t) + \nu y^*(t)\} e^{-\delta(t - t_0)}\, dt \quad \textbf{(7b)}$$

stance. The variables of the second country are indicated with an asterisk. Note that all variables except for the interest and inflation rates are in logarithms and refer to deviations from some exogenous equilibrium (growth path). Therefore, the analysis is entirely concerned with business-cycle fluctuations in the EMU, leaving aside all aspects associated with structural dynamics and adjustment in the European Union. To be able to solve the model later in an insightful manner, it is assumed that the countries do not differ w.r.t. the various structural parameters. A dot above a variable denotes its time derivative.

Equations (1a) and (1b) give aggregate demand as a function of competitiveness, the real interest rate, foreign output, fiscal policy, and output shocks that hit the economy. An output shock, $\upsilon(t)$, hits the economy at $t = 0$, after which its effects decay exponentially: $\upsilon(t) = \upsilon(0)e^{-\rho t}$ where ρ measures how long the shock affects the economy. If $\rho = 0$, the shock is permanent, whereas if ρ is positive, the shock has some persistence but eventually dies out. In the limiting case where ρ goes to infinity, the shock dies out instantaneously. The demand for the common currency is given by (2a) and (2b). The EU-wide nominal interest rate, $i(t)$, clears the European money market. The supply of the common currency is controlled by the ECB. Equation (3) defines the competitiveness of country 1 vis-à-vis country 2 as the difference of output prices. Each country produces a composite good which is an imperfect substitute for the other country's output, implying that different prices and competitiveness changes can occur (and persist).[5] Equation (4) defines

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the nominal interest rate as the sum of the real interest rate and the rate of producer price inflation. The fiscal stance in equations (5a) and (5b) is defined as the real fiscal deficit, $f(t)$, plus the net real fiscal transfer from country 2 to country 1, $n(t)$, as a consequence of the fiscal transfer system. Fiscal deficits directly affect both economies because of their influence on aggregate demand in both countries and indirectly through a number of other transmission mechanisms such as prices, wages, and interest rates. In particular, in a highly integrated monetary union such as the EMU, such spillover effects can be pronounced. The design of the monetary policy of the ECB, the fiscal policies of the fiscal authorities in both countries, and the fiscal transfer system are introduced in the remainder of the analysis.

Equations (6a), (6b), (7a), and (7b) describe the price and wage formation process in the presence of staggered price and wage contracts of the type introduced by Taylor (1980a) and Calvo (1983). In case of staggered contracts, only a fraction, δ, of all nominal contracts are renewed in a period. The average length of a contract, therefore, equals $1/\delta$. Equations (6a) and (6b) determine the current price level as a weighted average of all outstanding wage contracts. The price level is a predetermined variable and the economy displays Keynesian price-stickiness in the short run. Current wages in (7a) and (7b) equal the weighted average of expected future prices and excess demand. Nominal wages are forward looking and change instantaneously upon the arrival of new information. In this analysis, output shocks are deterministic rather than stochastic, and thus the assumption of rational expectations of the wage setters implies perfect foresight. Differentiating w.r.t. time gives the current rate of price inflation as a function of the real wage and the rate of wage inflation as a function of the real wage and output.[6]

Staggered wage and price setting gives rise to nominal rigidities in the economy and unemployment persistence if the economy is hit by a negative output shock. From a policy perspective, the nominal rigidities create a trade-off between price and output stability in the short run, similar to the Phillips curve.[7] The parameter δ, therefore, reflects in the model all of the institutional rigidities in the economy that limit the adjustment of prices in goods and labor markets. A higher value of δ implies that a higher fraction of all of the outstanding price and wage contracts renews at every instant. In that case, the higher price and wage flexibility dampens business-cycle fluctuations.[8] Note, finally, that the forward-looking character of nominal wages implies that (anticipated) macroeconomic policies affect the behavior of wages by altering the expectations on future prices and excess demand.

The policy reaction functions close the model. We are interested here in countercyclical policy responses that policymakers direct at stabilizing output fluctuations. We assume that national fiscal policies are aimed at stabilizing national business-cycle fluctuations and implement a countercyclical fiscal policy,

$$f(t) = -\chi y(t), \tag{8a}$$

$$f^*(t) = -\chi y^*(t). \tag{8b}$$

Equations (8a) and (8b) imply that the fiscal deficit is increased if the economy is in recession and decreased if output is above equilibrium output. Typically, this is

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achieved by letting the automatic stabilizers in the fiscal deficit have their course. In a recession, low tax revenues and high government spending, for example, on unemployment benefits increase the deficit, which will in turn stabilize output. The extent to which such automatic stabilizers are allowed to work in times of recession is determined by χ. In the model, χ also could be interpreted as a measure of the strictness with which the fiscal stringency requirements of the Maastricht Treaty and the Stability and Growth Pact of the Treaty of Amsterdam will be interpreted in practice. A strict interpretation limits fiscal flexibility considerably and would imply a low value of χ.[9]

The supply of the common currency in the monetary union, $m_E(t)$, is controlled by the European Central Bank. Equilibrium in the European money market for the common currency holds if supply equals demand. The transmission channel of ECB monetary policy is the EU-wide nominal interest rate, $i(t)$: An expansionary monetary policy induces a lower nominal interest rate to restore equilibrium in the common money market. Because prices are sticky in the short run, a decrease of the nominal interest rate implies a decrease in the real interest rate which boosts output (1) in the short run. We assume that monetary policy of the ECB[10] is also set according to a linear feedback rule,

$$m_E(t) = -\zeta y_A(t), \tag{9}$$

where $y_A = \frac{1}{2}(y + y^*)$ denotes average output in the EMU. Equation (9) implies that the money supply is expanded if the average EU economy is in recession. The resulting decrease in nominal and real interest rates boosts output in the short run.[11]

Monetary flexibility allows the ECB to stabilize output fluctuations in the EU aggregate economy that result from symmetric shocks. In the current model, ζ could be interpreted as a measure of conservativeness and independence of the ECB: A value of zero would amount to an ultraconservative/independent ECB that sticks to its monetary target under all circumstances. Prevalence of the price stability objective in ECB monetary policy is proclaimed in the Maastricht Treaty, although monetary policies are allowed to foster real economic performance, as long as it does not interfere with the price stability objective. Given the stabilizing impact of ECB monetary policy on EU aggregate output, at least in the short run because of the nominal rigidities, it cannot be ruled out that, in practice, the ECB will pursue policies that are geared to stabilize to some extent fluctuations of the real aggregate EU economy. In that case, ζ is larger than zero. Note also here that, with a higher degree of nominal rigidities, that is, a low value of δ, stabilization policies become more effective and less inflationary. A more conservative ECB implies, however, that the fiscal authorities are facing a higher adjustment burden if symmetric shocks hit the EU economy. In that case, a higher value of χ could compensate for the low stabilization effort by the ECB. A strict interpretation of the Maastricht Treaty would amount to a zero or at least a small value of the feedback parameters ζ and χ and, in that case, the EU economy might end up with an insufficient stabilization effort at a national and aggregate level.

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Consider finally the introduction of a system of fiscal transfers (EFTS) that is designed to alleviate the adjustment burden of asymmetric shocks in a monetary union. Its basic working is summarized as follows by van der Ploeg (1991, p. 144):

> The task of the EFTS is to make exchange-rate changes unnecessary by transferring income from one country to another country when there are such shifts in preferences [i.e., asymmetric shocks]. In practice, the scheme operates by transferring income from individuals of one nation to individuals of another nation and replaces, to a certain extent, the national unemployment compensation schemes. One could envisage a Community-wide tax, which in itself would act as an automatic stabilizer, whose proceeds are used to finance a Community-wide unemployment compensation scheme. It is crucial that such a version of the EFTS is budget-neutral. ...It is a pity that the Delors report does not contain any recommendations for the establishment of a EFTS, because without it regional imbalances induced by shifts in preferences may persist.

Von Hagen and Hammond (1995) construct an insurance-based system of fiscal transfers and investigate a number of desirable properties of such a system. The stabilization scheme considered in the present paper is slightly different from the system of von Hagen and Hammond (1995): It acts as an automatic output stabilizer rather than directly offsetting asymmetric shocks such as those in von Hagen and Hammond.[12] More specifically, it automatically transfers resources from countries experiencing a boom to countries that suffer from recession:

$$n(t) = -\xi y_D(t), \tag{10}$$

where $y_D \equiv y - y^*$ denotes the difference in output between both EMU countries. The transfer system aims at stabilizing intra-EU business-cycle divergences and does not affect the business-cycle of the aggregate EU economy that is only affected by ECB monetary policy and average fiscal policy in the EU. The transfer partly substitutes the automatic stabilization that the federal government budget provides in more mature fiscal federations. The transfer system is a stabilization device because output is defined in terms of deviations from a long-run equilibrium (growth path). In particular, it has no redistributive effects in a strict sense because redistribution is directed at reducing disparities in long-run equilibrium output (per capita). An extensive discussion on the allocational and redistributive effects of fiscal transfers in the EU is provided by the European Commission (1993).[13]

Equation (10) has the considerable advantage for the policymakers that there is no need to estimate the actual size of the asymmetric macroeconomic shocks. In addition, in case fiscal flexibility at the national level is very limited, due, for example, to a very strict interpretation of the Stability and Growth Pact, the EFTS remains as an effective stabilization tool in case the EMU is affected by asymmetric shocks. A disadvantage in practice could be that countries might have a strategic incentive to reduce their own stabilization effort in the knowledge that this lack of activism—implying a low value of χ—will be partly compensated by higher fiscal transfers from the EFTS. These possible "moral hazard" problems that an EFTS could generate, have been noted as its main drawback and will

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reduce the political feasibility of such a system. In our analysis, we abstract from such strategic considerations and assume implicitly that a procedure has been implemented to avoid their occurrence. The acceptability of the transfer system may be strengthened by a certain sense of solidarity: Under EMU, it will be in the interest of all other countries that the economy of a country that is hit by an adverse asymmetric shock will be stabilized. Moreover, the acceptability will be fostered by the awareness of a certain insurance component: Even if a country has not yet been hit by adverse business-cycle conditions, it may well be hit at some future time.

We can now distinguish two alternative institutional settings of EMU:

(i) A regime with $\zeta = \chi = \xi = 0$, implying that there is no automatic stabilization from the ECB monetary policy, national fiscal policies, or an EFTS. This regime might be interpreted as the regime envisaged in the Maastricht Treaty, stressing the dedication of the ECB to price stability, a strict adherence to the fiscal stringency criteria of the Stability and Growth Pact, and the absence of (significant) fiscal transfers.

(ii) A regime with $\zeta, \chi, \xi > 0$, recognizing the inefficiencies that can arise in a monetary union with the aforementioned policy assignment, in particular, if macroeconomic shocks are predominantly asymmetric, labor mobility, price and wage flexibility are low, and if there is little automatic stabilization from federal expenditures and taxation.

A combination of a conservative ECB and strict fiscal stringency criteria, implying low values of χ and ξ, leaves the aggregate EU economy without effective automatic stabilizers if symmetric shocks occur. This will lead to suboptimal average economic performance, in particular, if nominal rigidities are considerable in the short run. In addition, strict fiscal stringency criteria and a low amount of automatic stabilization from a federal budget or fiscal transfer system, implying low values of χ and ξ, leaves the EU economy without effective automatic stabilizers if asymmetric shocks occur. This may lead to pronounced divergent macroeconomic adjustment dynamics in the European Union.

Although certainly interesting because of the interdependencies and externalities in the EMU, the current analysis disregards the strategic interaction that might arise between national fiscal authorities themselves and between the ECB and national fiscal authorities on the problem of output and inflation stabilization in the EMU and the possible "moral hazard" problems associated with the operation of the fiscal transfer system. It is clear that coordination of fiscal policies or even coordination of monetary and fiscal policies can be helpful in alleviating the adjustment burden from symmetric and asymmetric shocks in the EMU.[14] Indeed, the European Commission (1990) considers coordination together with autonomy and discipline, the three main components of the budgetary regime in the EMU (p. 113).

3. EMU AVERAGES AND DIFFERENCES

As noted earlier, we assume throughout the analysis that the structural model parameters coincide in both countries and that the countries are of equal size,

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simplifying assumptions that enable us to solve the model in a straightforward manner and study macroeconomic adjustment in the two-country EMU.[15] These assumptions enable us to solve the model using the Aoki (1981) factorization of the variables into averages and differences: Average variables are defined as $x_A = \frac{1}{2}(x + x^*)$ and differences as $x_D \equiv x - x^*$. The individual country variables, consequently, are defined as $x \equiv x_A + \frac{1}{2}x_D$ and $x^* \equiv x_A - \frac{1}{2}x_D$. This method has the advantage that dynamics can be decomposed into two independent dynamic subsystems: an average system that gives the dynamics of the aggregate EU economy and a difference system that describes differences between the two EU countries. Thus, the average system is particularly suited to study macroeconomic variables at the level of the aggregate EU economy, whereas the difference system is suited to address issues of macroeconomic convergence between both parts of the EU. Table 2 provides the average and difference systems that can be derived from equations (1)–(10),

Using (1)–(10), we can write output in the average and difference systems as functions of the price level, wages, structural and policy parameters, and output shocks:

$$y_A(t) = \frac{-\left(\frac{\gamma}{\lambda} + \gamma\delta\right) p_A(t) + \gamma\delta w_A(t) + \upsilon_A(t)}{\Delta_A}, \tag{11a}$$

$$y_D(t) = \frac{-(2\alpha + \gamma\delta) p_D(t) + \gamma\delta w_D(t) + \upsilon_D(t)}{\Delta_D}, \tag{11b}$$

where $\Delta_A \equiv 1 + [\gamma(\kappa + \zeta)]/\lambda - \sigma + \eta\chi$ and $\Delta_D \equiv 1 + \sigma + \eta(\chi + 2\xi)$. Substituting (11) into (7) gives, together with (6), two dynamic systems of the price level and the wage rate, the average and difference system:

$$\begin{bmatrix} \dot{p}_i(t) \\ \dot{w}_i(t) \end{bmatrix} = A_i \begin{bmatrix} p_i(t) \\ w_i(t) \end{bmatrix} + \begin{bmatrix} 0 \\ -\frac{\upsilon\delta}{\Delta_i}\upsilon_i(0)e^{-\rho t} \end{bmatrix}, \quad i = \{A, D\}. \tag{12}$$

The transient matrices A_i, are found in the Appendix [in (A.6) and (A.11)]. The dynamic systems in (12) are saddlepoint stable[16]: They contain a backward-looking variable, the price level $p_i(t)$ and a forward-looking variable, the wage rate, $w_i(t)$, which has the ability to act as a partial shock absorber. In case of shocks, the forward-looking wage adjusts to alleviate the impact and consequences of the shock. The degree to which it can do so depends also on δ, the parameter that measures the flexibility of wages and prices. The Appendix provides a detailed analysis of the wage and price dynamics in (12).

The average and difference systems provide a good insight into the working of the EU aggregate economy and factors that create divergences between the two different countries. Intra-EU imports transmit fluctuations in output, as given by (1), in one part of the European Union to the other part with a propensity σ. Intra-EU trade, therefore, tends to amplify output fluctuations in the average

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TABLE 2. Average and difference systems of the two-country EMU model

Averages		Differences	
$y_A(t) = -\gamma r_A(t) + \sigma y_A(t) + \eta s_A(t) + \upsilon_A(t)$	**(1c)**	$y_D(t) = 2\alpha c(t) - \gamma r_D(t) - \sigma y_D(t) + \eta s_D(t) + \upsilon_D(t)$	**(1d)**
$m_A(t) - p_A(t) = \kappa y_A(t) - \lambda i(t)$	**(2c)**	$m_D(t) - p_D(t) = \kappa y_D(t)$	**(2d)**
$i(t) = r_A(t) + \dot{p}_A(t)$	**(4c)**	$c(t) = -p_D(t)$	**(3d)**
$s_A(t) = f_A(t)$	**(5c)**	$r_D(t) = -\dot{p}_D(t)$	**(4d)**
$p_A(t) = \delta \int_{-\infty}^{t_0} w_A(t) e^{-\delta(t_0 - t)}\, dt \rightarrow \dot{p}_A(t) = \delta(w_A(t) - p_A(t))$	**(6c)**	$s_D(t) = f_D(t) + 2n(t)$	**(5d)**
$w_A(t) = \delta \int_{t_0}^{\infty} \{p_A(t) + \nu y_A(t)\} e^{-\delta(t - t_0)}\, dt$		$p_D(t) = \delta \int_{-\infty}^{t_0} w_D(t) e^{-\delta(t_0 - t)}\, dt \rightarrow \dot{p}_D(t) = \delta(w_D(t) - p_D(t))$	**(6d)**
$\rightarrow \dot{w}_A(t) = \delta(w_A(t) - p_A(t) - \nu y_A(t))$	**(7c)**	$w_D(t) = \delta \int_{t_0}^{\infty} \{p_D(t) + \nu y_D(t)\} e^{-\delta(t - t_0)}\, dt$	
$f_A(t) = -\chi y_A(t)$	**(8c)**	$\rightarrow \dot{w}_D(t) = \delta(w_D(t) - p_D(t) - \nu y_D(t))$	**(7d)**
$m_A(t) = -\zeta y_A(t)$	**(9)**	$f_D(t) = -\chi y_D(t)$	**(8d)**
		$n(t) = -\xi y_D(t)$	**(10)**

system and to dampen output fluctuations in the difference system.[17] The relative competitiveness of country 1 relative to country 2 as defined in (3) and parametrized by α does not affect average output but does have an important amplifying impact on adjustment in the difference system. Similarly, the EFTS, defined in (10), does not affect average fiscal stances in (6) but affects the difference in fiscal stance and, by that, the adjustment in the difference system. Because of the nominal rigidities in the short run implied by the staggered price and wage contracts, short-run dynamic adjustment of the economies displays Keynesian features. A negative shock induces a drop of output which, however, can be counteracted by countercyclical monetary and fiscal policies. In the long run, on the other hand, the model displays neoclassical features with full adjustment of price and wages to ensure that output returns at its long-run (noninflationary) equilibrium level, which itself is independent of monetary and fiscal policy. The case for stabilization policies in the EMU becomes more pressing the larger and more prolonged the macroeconomic shocks are and if the degree of nominal rigidity in the short run increases, implying a lower value of δ.

National fiscal flexibility and monetary flexibility of the ECB counteract output fluctuations in the average system that are generated by symmetric output shocks. In that case, the fiscal deficit and the EU money supply set by the ECB simply mirror average output fluctuations since average deficits and money supply are set higher if initial output is lower. Because the EFTS only affects the adjustment dynamics of the difference system and has no effect on the dynamics of the average system, it cannot be used to stabilize the impact of symmetric shocks in the EMU. National fiscal flexibility and the EFTS enable the policymakers to smooth output fluctuations in the difference system when the EMU is hit by asymmetric shocks. Fiscal flexibility, though, causes higher differences in the fiscal deficit whereas EFTS fosters fiscal convergence as it partly redistributes the adjustment burden from asymmetric shocks from the "unfortunate" to the "fortunate" part of the European Union.

4. NUMERICAL SIMULATIONS: SYMMETRIC AND ASYMMETRIC SHOCKS IN THE EMU

Having characterized the analytical solution of the dynamics of the average and difference systems, we now turn to a simulation example to study the macroeconomic adjustment dynamics that are induced by symmetric and asymmetric output shocks that hit the EMU and to analyze the effects of alternative countercyclical fiscal and monetary policies. Table 3 gives the set of structural and policy parameters that underlie our simulation examples.

A distinction is made between a base regime (EMU1, solid lines in the figures) without fiscal and monetary flexibility ($\chi = \zeta = \xi = 0$), a regime (EMU2, dashed lines) with fiscal flexibility at the national level but without monetary flexibility ($\chi = 0.4$, and $\zeta = \xi = 0$), and, finally, a regime (EMU3, dotted lines) without fiscal flexibility at the national level but with monetary flexibility and a fiscal transfer

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TABLE 3. Structural and policy parameters

Parameter	Value	Parameter	Value
α	0.3	ν	0.25
γ	0.5	σ	0.5
δ	0.25	ζ	0/0.2
η	1	ξ	0/0.2
κ	1	χ	0/0.4
λ	1	ρ	0

system ($\chi = 0$, $\zeta = 0.2$, and $\xi = 0.2$). As noted earlier, the first regime could be regarded as a strict interpretation of the Maastricht Treaty, excluding fiscal and monetary flexibility. The second regime provides fiscal flexibility at the national level. A comparison of the first and second regime thus enables us to analyze the effects from fiscal flexibility at the national level. The third regime, on the other hand, features stabilization instruments at the supranational level—in the form of a countercyclical monetary policy of the ECB and a fiscal transfer system—while restricting national fiscal policies. A comparison between the first and third regimes thus gives insight into the stabilizing properties of supranational policy and a comparison between the second and third regimes enables us to compare the effects of national stabilization policies with those of supranational stabilization policies.

4.1. Symmetric Shocks in the EMU

Figure 1 shows the adjustment induced by a symmetric permanent negative output shock of 1% in the two-country EMU at $t = 0$, that is, $\upsilon(0) = \upsilon^*(0) = \upsilon_A(0) = -0.01$.

Output (Panels E and F) in the EMU jumps down at the impact of the symmetric negative demand shock. The nominal wage in new contracts (Panels C and D) jump down to the level consistent with long-run convergence to the new steady state. After an initial decrease, output recovers gradually due to the initial decline in real wages. Wages, prices, and output adjust to their long-run equilibrium of zero, which is approached eventually. In the second and third EMU regime, the stabilizing forces from, respectively, fiscal policy flexibility (Panels G and H) and monetary policy flexibility (Panel I) contribute to stabilization of output in the short run. Because of the symmetric structures that we have imposed, adjustment of macroeconomic variables in countries 1 and 2 is identical and the fiscal transfer system (Panel J) does not play a role in the third regime where $\xi > 0$.

4.2. Asymmetric Shocks in the EMU

Next, we consider the effects of an asymmetric output shock in the EMU and focus on the stabilizing effects of fiscal flexibility and a fiscal transfer system in the case that such asymmetric shocks hit the EMU. Figure 2 shows the adjustment induced

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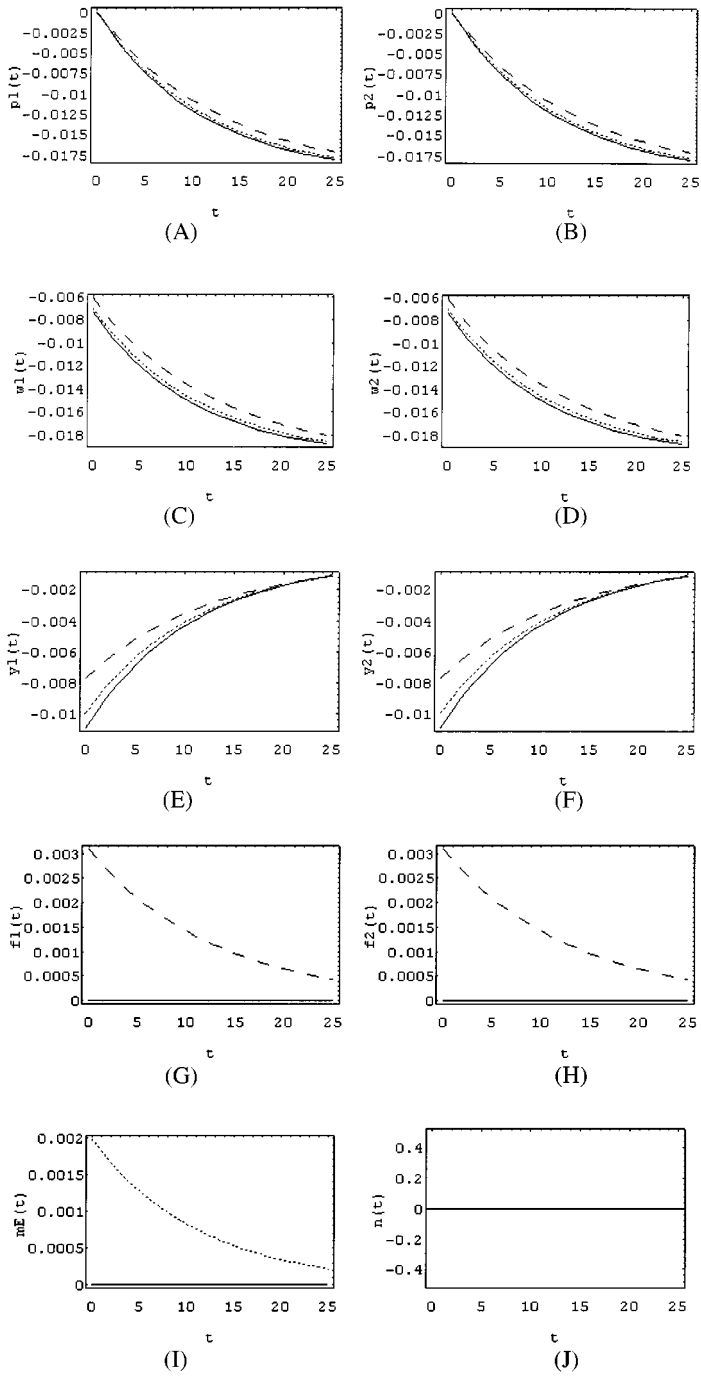


Figure 1. Symmetric output shock: (——) EMU(1), (- - - -) EMU(2), (· · · ·) EMU(3).

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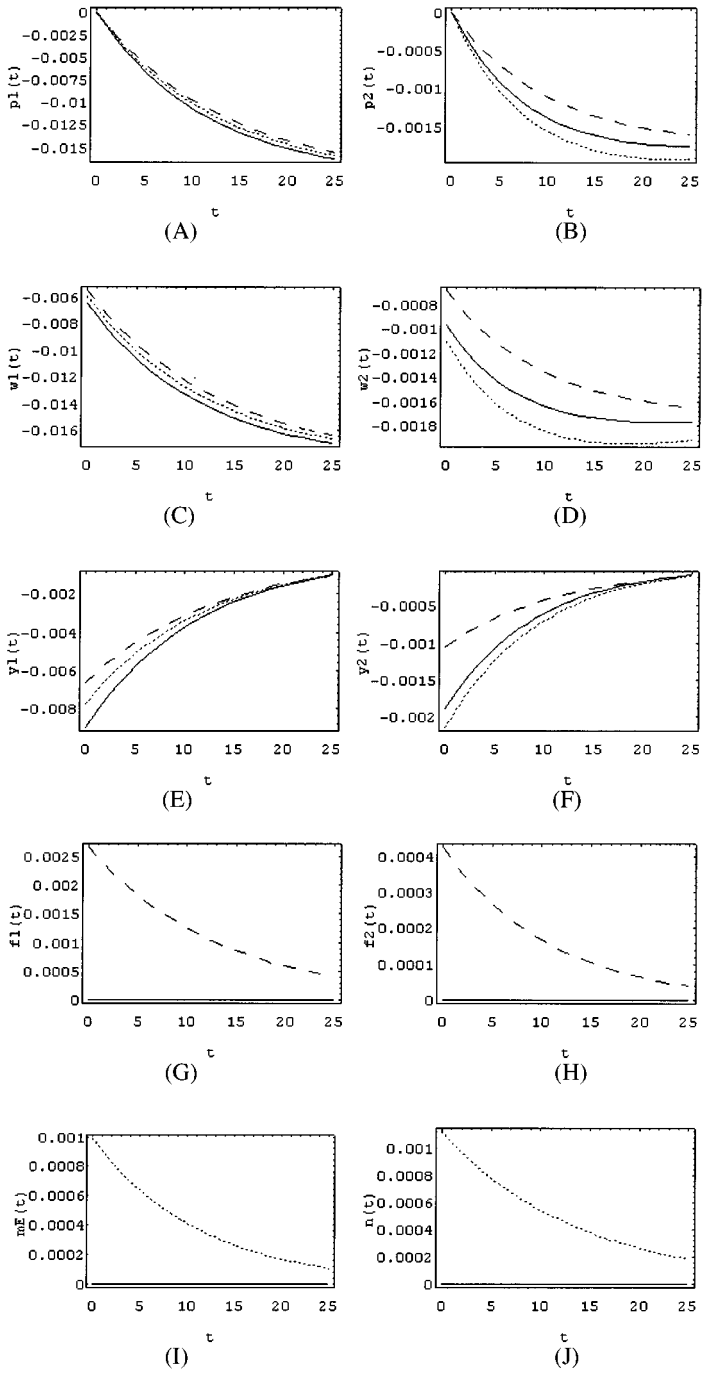


FIGURE 2. Asymmetric output shock: (——) EMU(1), (- - - -) EMU(2), (· · · ·) EMU(3).

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by an asymmetric permanent negative output shock of 1% in country 1, that is, $\upsilon(0) = \upsilon_D(0) = -0.01$.

As before, the wage rate jumps down at the impact of the output shock (Panel C). The decline in real wages in new contracts contributes to the gradual recovery of output (Panel E). Part of the shock is transmitted also to the other EMU country, inducing a recession there also, but on a smaller scale. The effects are not as strong as in the case of the symmetric shock where shocks in both countries reinforced themselves through the various spillovers between both economies. Output can be stabilized by allowing fiscal flexibility as in the EMU2 regime (Panels G and H), or by establishing an EFTS as in the EMU3 regime (Panel J). In the last case, also, a small reaction of the monetary policy of the ECB (Panel I) has some stabilizing impact. The fiscal transfer from country 2 to country 1 helps the latter to speed up adjustment at the cost of a relatively small reduction in the adjustment of country 2.

Fiscal flexibility leads to sharp divergence of fiscal deficits in the EMU if asymmetric shocks hit the European Union and fiscal stabilizers are activated (EMU2 regime). The EFTS regime not only features output stabilization but also has the additional advantage that differences in national fiscal deficits are stabilized as compared to the regime with fiscal flexibility only. Because fiscal convergence is stressed in the Maastricht criteria as a fundamental requirement to achieve nominal and real convergence in the EMU, it seems to be characteristic of the EFTS to prefer such a transfer system over national fiscal flexibility if the EMU faces asymmetric shocks.

The values of the model parameters we chose in Table 3 contain an element of arbitrariness, although they are more or less in line with the typical values that are assumed in other simulation studies.[18] A rough sensitivity analysis suggests that the adjustment patterns discussed earlier are quite general from a qualitative point of view and not highly sensitive to a small change in one of the parameter values.

Together with the openness parameters, a very important and interesting parameter is δ, which measures price and wage flexibility. As noted earlier, a higher value of δ implies that the staggered price and wage contracts have a smaller duration and that price and wage flexibility increases. Such flexibility is important because it means that the degree of nominal rigidity is reduced and the economy adjusts more quickly to shocks. To visualize this dependence of macroeconomic adjustment on the value of δ, Figure 3 displays adjustment after an asymmetric shock to country 1 (as in Figure 2) under three alternative values of δ: 0.25 as in the base scenario (solid lines), 0.35 implying a lower degree of nominal rigidity (dashed lines), and 0.15 implying a higher degree of nominal rigidity (dotted lines).

The base scenario of Table 3 with no fiscal or monetary flexibility, that is, $\chi = \zeta = \xi = 0$ has been assumed again. Therefore, we can ignore the graphs of f_1, f_2, m_E, and n, which all remain zero in that case. It is clearly seen how a lower (higher) degree of nominal rigidity speeds up (retards) the adjustment of prices, wages, and output to their equilibrium values after the asymmetric shock hits country 1. As before, part of the shock to country 1 is exported to country 2, which

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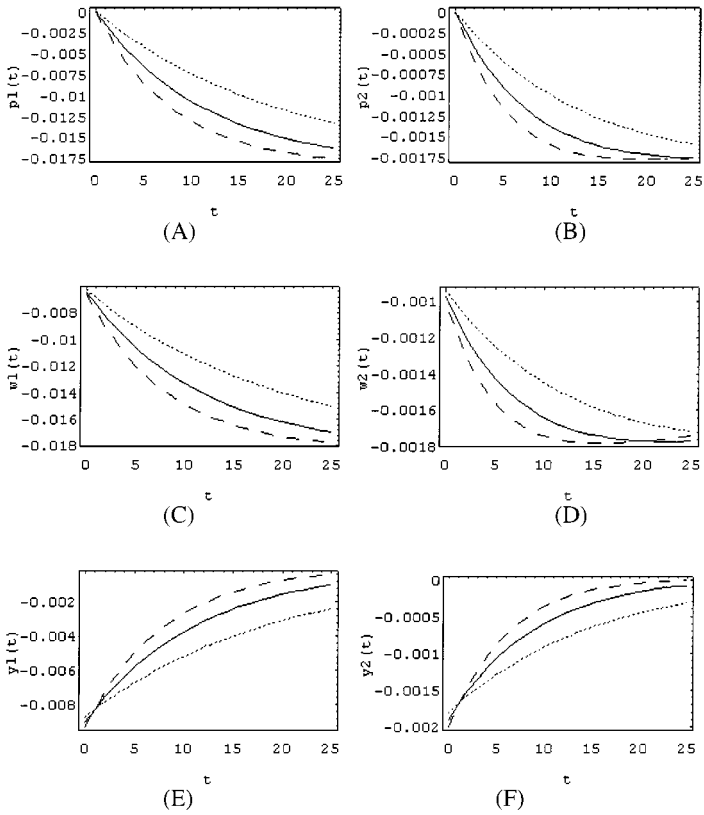


FIGURE 3. Role of nominal rigidities: (——) $\delta = 0.25$, (- - - -) $\delta = 0.35$, ($\cdots$) $\delta = 0.15$.

then also benefits (suffers) from a lower (higher) degree of nominal rigidity in the EMU. Of course, this also has policy implications: If the degree of nominal rigidity is low (high), less (more) policy flexibility is required if stabilization of output fluctuations is desired.

5. CONCLUSION

If the countries participating in the EMU do not constitute an optimal currency area, macroeconomic performance in the EMU can be seriously affected if it is hit by symmetric and asymmetric macroeconomic shocks. This paper studies flexibility of national fiscal policies, monetary policy of the ECB, and a European Fiscal Transfer System (EFTS) as stabilization devices in an EMU hit by symmetric and asymmetric shocks, featuring nominal rigidities, inflexible labor markets, and a negligible federal fiscal budget. The EFTS was defined as an intra-EMU business-cycle stabilizing device and did not serve in principle any redistributive or allocational purpose.

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With the aid of an analytical model and simulation analysis, this paper shows how fiscal flexibility stabilizes the output fluctuations induced by symmetric and asymmetric shocks. Concerning symmetric shocks, it shows that flexibility in the monetary policy of the ECB and fiscal flexibility at the national level increase the automatic stabilization capacity of the EU economy. In that perspective, a very strict interpretation of the Maastricht Treaty and the Stability and Growth Pact may reduce the shock-absorbing capacity and lead to a prolonged recession if the EU economy is hit by symmetric shocks.

In the case of asymmetric shocks, we focus on the role of national fiscal flexibility and a fiscal transfer system. Both are helpful in reducing the impact of asymmetric shocks in the EMU. The EFTS not only stabilizes output fluctuations induced by asymmetric shocks but also avoids the divergence in fiscal deficits that fiscal flexibility creates during the adjustment phase. Therefore, the EFTS also contributes to fiscal convergence in the EMU. Fiscal convergence is seen by many economists and politicians as a necessary prerequisite for long-run sustainability of the EMU as witness the prominent place of the fiscal stringency criteria in the Maastricht Treaty. Fiscal flexibility and/or the EFTS are able to substitute to a certain extent for the loss of the asymmetric shock-absorbing capacity of exchange-rate adjustment that EMU implies. The EFTS to some extent could replicate the degree of automatic stabilization of macroeconomic shocks by federal transfers that is seen in more mature fiscal federations such as the United States. From this perspective, its implementation in an EMU that does not yet constitute an optimal currency area and a mature fiscal federation deserves serious political consideration. Its political acceptability, however, is conditional upon the exclusion of the moral hazard problems that it may carry.

NOTES

1. A considerable empirical literature exists on the degree to which macroeconomic shocks in the European Union are predominantly symmetric or asymmetric. Studies by Weber (1991), Bayoumi and Eichengreen (1993), Bayoumi and Prassad (1995), and Christodoulakis et al. (1995) suggest that asymmetric shocks are fairly important in most countries of the European Union. Decressin and Fatàs (1995) analyze labor mobility in the United States and the European Union and find evidence that labor mobility is considerably smaller in the European Union than in the United States. Finally, a number of studies have analyzed the automatic stabilization from federal taxes and government spending. Sala-i-Martin and Sachs (1991), von Hagen (1991), and Goodhart and Smith (1993) show that this automatic stabilization is considerable in mature federations such as the United States and Canada. Because of the current small size of the federal EU budget (about 1.3% of the European Union GDP), such automatic stabilization from federal taxes and government spending is currently fairly small.

2. Throughout the paper, I use EMU and EU interchangeably, although, strictly speaking, EMU excludes the four EU countries that did not enter EMU at the first stage: Denmark, Greece, Sweden, and the United Kingdom. It is generally expected that some of these countries will enter EMU in the near future.

3. See, e.g., analyses by Alesina and Grilli (1993) and Martin (1995) on this initial phase in which some countries possibly do not participate completely in the EMU project and prepare for full participation.

4. See, e.g., Kenen (1993), Hartmann (1997), Eichengreen and Ghironi (1997), and Prati and Schinasi (1997) on such "external" implications of EMU.

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5. With flexible exchange rates, competitiveness equals the real exchange rate, which is defined as $c(t) \equiv e(t) + p^*(t) - p(t)$ in which $e(t)$ denotes the (log of the) nominal exchange rate between country 1 and 2. Normalizing the final conversion rate, $E(t)$, to one implies that the real exchange rate under EMU is $c(t) \equiv p^*(t) - p(t)$, since $e(t) = \ln[E(t)] = 0$ in that case. The choice of the final conversion rates of national currencies to the new common currency is by no means a trivial issue in practice, as the analysis of Giovannini (1992) shows.

6. Differentiating (6) and (7) w.r.t. time gives

$$\dot{p}(t) = \delta \left[-\delta \int_{-\infty}^{t_0} w(t) e^{-\delta(t_0 - t)}\, dt + w(t) \right] = \delta[w(t) - p(t)],$$

$$\dot{w}(t) = \delta \left[\delta \int_{t_0}^{\infty} \{p(t) + \nu y(t)\} e^{-\delta(t - t_0)}\, dt - p(t) - \nu y(t) \right] = \delta[w(t) - p(t) - \nu y(t)].$$

7. See Taylor (1980b) for an empirical analysis of staggered contracts and the output–inflation trade-off in industrial countries.

8. The European Commission (1990) recognizes the importance of a higher degree of price and wage flexibility in the EU: "wage-price flexibility remains the basic adjustment channel as a substitute for the exchange rate. However, in so far as nominal rigidities hamper market adjustments, fiscal policy measures can alleviate temporary country-specific disequilibria. This is indeed the traditional role of fiscal policy as a tool for stabilization." (p. 102).

9. The framework of the Stability and Growth Pact is more complicated in reality than the very stylized representation in our model. In particular, the deficit in the pact is defined as a fraction of GDP. Fluctuations of the latter will automatically affect the deficit in that definition because of a denominator effect.

10. For a detailed and insightful discussion of the many practical issues in the design of monetary policies of the ECB, see Begg (1997) and von Hagen (1997).

11. In case that the EMU countries are not symmetric in the model parameters, the common monetary policy will have asymmetric effects in the different countries. This interesting possibility is not addressed in our analysis as we have assumed a setting of symmetric countries. For a detailed account of possible asymmetric transmissions of the common monetary policy, see Hughes Hallett et al. (1998).

12. In the context of our two-country EMU model, the transfer system of von Hagen and Hammond might be defined as $n(t) = -\xi \upsilon_D(t)$, implying that a negative asymmetric output shock in country 1, will be counteracted by an automatic fiscal transfer from country 2 to country 1.

13. For an empirical analysis of stabilization and redistribution by fiscal flows in the United States, Canada, and the European Union, see Bayoumi and Masson (1995).

14. See also Hughes Hallett and Vines (1993) and Hughes Hallet and Ma (1996) on such policy coordination issues in the EMU. Demertzis et al. (1999) confront an independent Central Bank with an elected government to show that the perceived lack of correlation between monetary autonomy and output variability is actually caused by the stabilizing role of fiscal policy when faced with rigid monetary objectives. Cooperation between the policymakers enables them to avoid such policy conflicts. In the context of EMU, similar conflicts are likely to emerge in the absence of coordination between the ECB and national policymakers.

15. If both countries differ in their structural parameters, the adjustment processes in both economies will differ even if they are hit by a symmetric shock. In that case, it becomes difficult, if not impossible, in the case of asymmetric shocks to determine how much of the outcomes are due to shock asymmetries and how much is due to structural asymmetries.

16. Saddlepoint stability requires A_i to have a positive and a negative eigenvalue. The eigenvalues are given by

$$e\nu_{1,2} = -\frac{\mathrm{Tr}(A_i) \pm \sqrt{\mathrm{Tr}(A_i)^2 - 4\,\mathrm{Det}(A_i)}}{2},$$

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where

$$\mathrm{Tr}(A_A) = -\frac{\nu\gamma\delta^2}{\Delta_A},$$

$$\mathrm{Tr}(A_D) = -\frac{\nu\gamma\delta^2}{\Delta_D},$$

$$\mathrm{Det}(A_A) = -\frac{\nu\gamma\delta^2}{\lambda\Delta_A},$$

and

$$\mathrm{Det}(A_D) = -\frac{2\alpha\nu\delta^2}{\Delta_D}.$$

The stable, negative eigenvalue, h_i, determines the adjustment speed of the system dynamics: The adjustment speed, $-h_i$, is defined as the absolute value of the stable eigenvalue of A_i. The adjustment toward the steady state is monotonic if the discriminant $D_i = \mathrm{Tr}(A_i)^2 - 4\,\mathrm{Det}(A_i)$ is positive and oscillatory if it is negative. A necessary and sufficient condition for (12) to display saddlepoint stability is that the determinant of A_i, which equals the product of the eigenvalues, is negative. This is the case if $\Delta_i > 0$.

17. See van Aarle (1996) for an empirical analysis of intra-EU trade and foreign direct investment. According to calculations by the author, 55.7% of total exports of the EU-12 countries had other countries in the EU-12 as destination in 1980. In 1994, this number had increased to 63.3%, indicating the increasing integration of goods markets in the EU.

18. See, in particular, Bryant et al. (1988) for a comparison of different simulation models and the typical parameter values that are assumed.

19. The Laplace transform of a function $f(t)$, $F(s)$, is defined as

$$F(s) = \int_{t_0}^{\infty} f(t)e^{-s(t-t_0)}\,dt.$$

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APPENDIX: DYNAMICS OF WAGES AND PRICES

The $\{p_i(t), w_i(t)\}$ systems that describe the dynamics of the average and difference system are linear dynamic systems of the form

$$\dot{x}_i(t) = A_i x_i(t) + \upsilon_i(t), \quad x_i = \begin{bmatrix} p_i(t) \\ w_i(t) \end{bmatrix} \quad \upsilon_i(t) = \begin{bmatrix} \upsilon_i^1(t) \\ \upsilon_i^2(t) \end{bmatrix} \quad i = \{A, D\}. \qquad \textbf{(A.1)}$$

In both cases the current price level $p_i(t)$ is a predetermined variable, whereas the current wage rate $w_i(t)$ is forward looking. If the dynamic systems are saddlepoint stable, the forward-looking variables, that is, $w_i(t)$, will take unique initial values, $w_i(0)$, such that the system is placed on its unique converging dynamic trajectory, given the initial price level $p_i(0)$. The average and difference systems displays saddlepoint stability if the number of predetermined variables equals the number of stable eigenvalues and the number of nonpredetermined variables equals the number of unstable eigenvalues [see Buiter (1984)]. A necessary and sufficient condition for both systems to display saddlepoint stability is that the determinant of A_i is negative.

Given the initial value $x_i(0)$, the stable eigenvalue, h_i, and the steady state, $x_i(\infty)$, the solution to (A.1) reads

$$x_i(t) = x_i(0)e^{h_i t} + x_i(\infty)(1 - e^{h_i t}). \qquad \textbf{(A.2)}$$

The steady state of the system, $x_i(\infty)$, is found by solving

$$x_i(\infty) = -A_i^{-1}\upsilon_i(0)e^{-\rho\infty}. \qquad \textbf{(A.3)}$$

The initial value of the forward-looking variables, $w_i(0)$, is found by applying the method proposed by Judd (1982) that entails the following steps:

1. Take the Laplace[19] transform $L[(\cdot), s]$ of the dynamic system, $\dot{x}(t) = Ax(t) + \upsilon_i(t)$:

$$L[\dot{x}_i, s] = A_i L[x_i, s] + L[\upsilon_i, s]. \qquad \textbf{(A.4)}$$

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2. Use the fact that $L[\dot{x}_i, s] = sL[x_i, s] - x_i(0)$. Equating both expressions for $L[\dot{x}_i, s]$ yields

$$L[x_i, s] = (sI - A_i)^{-1}[L[\upsilon_i, s] + x_i(0)]. \tag{A.5}$$

3. Impose the condition that the nonpredetermined variables, that is, $w_i(0)$, adjust in such a manner that saddlepoint stability of the dynamic system is ensured, given the initial value of the predetermined variable, that is, $p_i(0)$. This requires that $L[\upsilon_i, z] + x_i(0) = 0$, where $s = z_i$ with z_i being the unstable eigenvalue of A_i. Imposing this convergence requirement— also known as the "singularity condition"—gives the unique value of the nonpredetermined variables, consistent with long-run convergence of the dynamic system to a finite steady state. If we assume, for example, that the exogenous shock decays exponentially, that is, $\upsilon_i(t) = \upsilon_i(0)e^{-\rho t}$, $x_i(0)$ is found easily because the Laplace transform of an exponentially decaying impulse equals $\upsilon_i(0)/(z_i + \rho)$.

A.1. THE AVERAGE SYSTEM

The average system is given by

$$\begin{bmatrix} \dot{p}_A(t) \\ \dot{w}_A(t) \end{bmatrix} = \begin{bmatrix} -\delta & \delta \\ -\delta\left(1 - \dfrac{\nu\gamma\left(\frac{1}{\lambda} + \delta\right)}{\Delta_A}\right) & \delta\left(1 - \dfrac{\nu\gamma\delta}{\Delta_A}\right) \end{bmatrix} \begin{bmatrix} p_A(t) \\ w_A(t) \end{bmatrix} + \begin{bmatrix} 0 \\ -\dfrac{\nu\delta}{\Delta_A}\upsilon_A(0)e^{-\rho t} \end{bmatrix}. \tag{A.6}$$

The inverse of the matrix A_A is

$$A_A^{-1} = \frac{1}{|A_D|}\begin{bmatrix} \delta\left(1 - \dfrac{\nu\gamma\delta}{\Delta_A}\right) & -\delta \\ \delta\left(1 - \dfrac{\nu\gamma\left(\frac{1}{\lambda} + \delta\right)}{\Delta_A}\right) & -\delta \end{bmatrix}, \tag{A.7}$$

with

$$\Delta_A = 1 + \frac{\gamma(\kappa + \zeta)}{\lambda} - \sigma + \eta\chi.$$

The determinant of A_A, $|A_A|$, which equals $-(\delta^2\nu\gamma)/(\lambda\Delta_A)$, is equal to the product of the eigenvalues. A necessary and sufficient condition for the average system to display saddlepoint stability is that $|A_A|$ be negative, which is the case if $\Delta_A > 0$. The eigenvalues of the average system are

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$$h_A = -\frac{1}{2}\left[\frac{\nu\gamma\delta^2}{\Delta_A} + \sqrt{\left(\frac{\nu\gamma\delta^2}{\Delta_A}\right)^2 + 4\left(\frac{\nu\gamma\delta^2}{\lambda\Delta_A}\right)}\right], \tag{A.8a}$$

$$z_A = -\frac{1}{2}\left[\frac{\nu\gamma\delta^2}{\Delta_A} - \sqrt{\left(\frac{\nu\gamma\delta^2}{\Delta_A}\right)^2 + 4\left(\frac{\nu\gamma\delta^2}{\lambda\Delta_A}\right)}\right]. \tag{A.8b}$$

We can write the adjustment of the dynamic system toward its steady state as a function of the initial state, the adjustment speed, and the steady state:

$$p_A(t) = p_A(0)e^{h_A t} + p_A(\infty)(1 - e^{h_A t}), \tag{A.9a}$$

$$w_A(t) = w_A(0)e^{h_A t} + w_A(\infty)(1 - e^{h_A t}), \tag{A.9b}$$

where h_A denotes the stable eigenvalue of A_A. Steady-state average prices and wages are written as

$$p_A(\infty) = w_A(\infty) = \frac{\lambda}{\gamma}\upsilon_A(0)e^{-\rho\infty}. \tag{A.10}$$

The initial value of the price level is given because the price level is a predetermined variable. The initial value of the forward-looking nominal wage follows from the condition that wages adjust at $t = 0$ such as to place the dynamic system on its unique saddlepoint stable trajectory. To determine the initial state of the average system, take the Laplace transform of (A.6) and use (A.5) to write

$$\begin{bmatrix} L(p_A, s) \\ L(w_A, s) \end{bmatrix} = \frac{1}{|sI - A_A|}\begin{bmatrix} s - \delta\left(1 - \dfrac{\nu\gamma\delta}{\Delta_A}\right) & \delta \\ \delta\left(1 - \dfrac{\nu\gamma\left(\frac{1}{\gamma} - \delta\right)}{\Delta_A}\right) & s + \delta \end{bmatrix}\begin{bmatrix} p_A(0) \\ L\left(-\dfrac{\nu\delta}{\Delta_A}\upsilon_A(0)e^{-\rho s}, s\right) + w_A(0) \end{bmatrix}. \tag{A.11}$$

Taking z_A for s and using the Laplace transform of an exponentially decaying impulse, implying

$$L\left(\upsilon_A(0)e^{-\rho z_A}, z_A\right) = \frac{\upsilon_A(0)}{z_A + \rho},$$

the convergence condition requires

$$\left[z_A - \delta\left(1 - \frac{\nu\gamma\delta}{\Delta_A}\right)\right]p_A(0) + \delta\left[-\frac{\nu\delta}{\Delta_A}\frac{\upsilon_A(0)}{z_A + \rho} + w_A(0)\right] = 0$$

$$\Leftrightarrow w_A(0) = -\frac{\left[z_A - \delta\left(1 - \dfrac{\nu\gamma\delta}{\Delta_A}\right)\right]}{\delta}p_A(0) + \frac{\nu\delta}{\Delta_A}\frac{\upsilon_A(0)}{z_A + \rho} \tag{A.12}$$

for a solution to (A.6) to remain bounded.

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A.2. THE DIFFERENCE SYSTEM

The difference system is given by

$$\begin{bmatrix} \dot{p}_D(t) \\ \dot{w}_D(t) \end{bmatrix} = \begin{bmatrix} -\delta & \delta \\ -\delta\left(1 - \dfrac{\nu(2\alpha+\gamma\delta)}{\Delta_D}\right) & \delta\left(1 - \dfrac{\nu\gamma\delta}{\Delta_D}\right) \end{bmatrix} \begin{bmatrix} p_D(t) \\ w_D(t) \end{bmatrix} + \begin{bmatrix} 0 \\ -\dfrac{\nu\delta}{\Delta_D}\upsilon_D(0)e^{-\rho t} \end{bmatrix}. \tag{A.13}$$

The inverse of the matrix A_D is

$$A_D^{-1} = \frac{1}{|A_D|}\begin{bmatrix} \delta\left(1 - \dfrac{\nu\gamma\delta}{\Delta_D}\right) & -\delta \\ \delta\left(1 - \dfrac{\nu(2\alpha+\gamma\delta)}{\Delta_D}\right) & -\delta \end{bmatrix}, \tag{A.14}$$

with $\Delta_D = 1 + \sigma + \eta(\chi + 2\xi)$. The determinant of A_D, $|A_D|$, which equals $-(\delta^2\nu 2\alpha)/\Delta_D$, is equal to the product of the eigenvalues. The necessary and sufficient condition for the difference system to display saddlepoint stability, $|A_D| < 0$, therefore, is satisfied in all cases. The eigenvalues of the difference system are

$$h_D = -\frac{1}{2}\left[\frac{\nu\gamma\delta^2}{\Delta_D} + \sqrt{\left(\frac{\nu\gamma\delta^2}{\Delta_D}\right)^2 + 4\left(\frac{\delta^2\nu 2\alpha}{\Delta_D}\right)}\right], \tag{A.15a}$$

$$z_D = -\frac{1}{2}\left[\frac{\nu\gamma\delta^2}{\Delta_D} - \sqrt{\left(\frac{\nu\gamma\delta^2}{\Delta_D}\right)^2 + 4\left(\frac{\delta^2\nu 2\alpha}{\Delta_D}\right)}\right]. \tag{A.15b}$$

We can write the adjustment of the dynamic system toward its steady state as a function of the initial state, the adjustment speed, and the steady state:

$$p_D(t) = p_D(0)e^{h_D t} + p_D(\infty)(1 - e^{h_D t}), \tag{A.16a}$$

$$w_D(t) = w_D(0)e^{h_D t} + w_D(\infty)(1 - e^{h_D t}), \tag{A.16b}$$

where h_D denotes the stable eigenvalue of A_D. Steady-state average prices and wages are

$$p_D(\infty) = w_D(\infty) = \frac{1}{2\alpha}\upsilon_D(0)e^{-\rho\infty}. \tag{A.17}$$

The initial value of the price level is given because the price level is a predetermined variable. The initial value of the forward-looking nominal wage follows from the condition that wages adjust at $t = 0$ such as to place the dynamic system on its unique saddlepoint

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stable trajectory. To determine the initial state of the difference system, take the Laplace transform of (A.13) and use (A.5) to write

$$\begin{bmatrix} L(p_D, s) \\ L(w_D, s) \end{bmatrix}$$

$$= \frac{1}{|sI - A_D|} \begin{bmatrix} s - \delta\left(1 - \dfrac{\nu\gamma\delta}{\Delta_D}\right) & \delta \\ \delta\left(1 - \dfrac{\nu(2\alpha + \gamma\delta)}{\Delta_D}\right) & s + \delta \end{bmatrix} \begin{bmatrix} p_D(0) \\ L\left(-\dfrac{\nu\delta}{\Delta_D} \upsilon_D(0) e^{-\rho s}, s\right) + w_D(0) \end{bmatrix}. \tag{A.18}$$

Taking z_D for s and using the Laplace transform of an exponentially decaying impulse, the convergence condition requires that

$$\left[z_D - \delta\left(1 - \frac{\nu\gamma\delta}{\Delta_D}\right)\right] p_D(0) + \delta\left[-\frac{\nu\delta}{\Delta_D}\frac{\upsilon_D(0)}{z_D + \rho} + w_D(0)\right] = 0$$

$$\Leftrightarrow w_D(0) = -\frac{\left[z_D - \delta\left(1 - \dfrac{\nu\gamma\delta}{\Delta_D}\right)\right]}{\delta} p_D(0) + \frac{\nu\delta}{\Delta_D}\frac{\upsilon_D(0)}{z_D + \rho} \tag{A.19}$$

for a solution to (A.13) to remain bounded.

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