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Volker Clausen and Hans-Werner Wohltmann[1]

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Abstract

This paper analyzes the dynamic effects of anticipated and unanticipated oil price increases in a small two-country monetary union, which is simultaneously characterized by asymmetric wage adjustments and asymmetric interest rate sensitivities of private absorption. Common external oil price disturbances lead in this asymmetric macroeconomic setup to temporary divergences in output developments across the monetary union. In the case of anticipated oil price increases the relative cyclical position is reversed in the course of the adjustment process. Complete stabilization of the output variables throughout the overall adjustment process requires a restrictive monetary policy being time inconsistent from a quantitative but time consistent from a qualitative point of view. That means that the central bank credibly announces a future reduction in the growth rate of the nominal money stock but actually implements a reduction, which is less restrictive than the original announcement.

JEL Classification: E63, F41

Keywords: EMU; international policy transmission; oil price shock; time inconsistency; monetary policy

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1. Introduction

The establishment of European Monetary Union (EMU) in 1999 marks a fundamental change in the monetary regime in Europe. The transfer of responsibility for the conduct of monetary policy from the national central banks to the European Central Bank (ECB) implied that the former lost their ability to respond to country-specific cyclical developments. The ECB, in contrast, primarily monitors the macroeconomic situation at the aggregate European level in order to decide about the appropriate stance of the common monetary policy. Nevertheless, it also considers the country-specific output and inflation developments to be informative and relevant (see *ECB*, 2005 and 2007). Asymmetric cyclical dynamics within the monetary union clearly complicate the design of ECB policy as the common stance may not be appropriate in all member countries. This tends to create tensions in the decision-making process. A high degree of business cycle synchronization within Europe generally facilitates ECB policy-making as the common monetary stance is more likely to be appropriate also from the respective national points of view.

At about the same time with the establishment of the EMU, the longer-term trend of oil prices saw a remarkable reversal. The 1990s were mostly characterized by falling oil prices. However, beginning in 1998/99 the world has seen a substantial and persistent increase in nominal and real oil prices. Expressed in Dollar per Barrel, the price increased tenfold from about 10 dollars to currently about 100 dollars.[1] This secular oil price increase as well as the increase in oil price volatility raised professional interest in the impact of oil price changes on output and inflation as well as in the appropriate policy response by the monetary authorities in the US and in Europe. In this context, numerous papers argue that the macroeconomic impact of oil prices cannot be assessed in isolation. The overall impact has to be analysed in conjunction with the endogenous reaction of monetary policy. *Bernanke et al.* (1997) first argued that systematic monetary policy responses to the inflationary impulse *triggered* by oil price shocks were an important additional source of aggregate cyclical fluctuations in the U.S. economy. This joint assessment of oil price shocks and systematic endogenous reactions of monetary policy has been examined in many subsequent papers (such as, for example, in *Hamilton* and *Herrera* (2004) or *Carlstrom* and *Fuerst* (2006)).

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[1] In July 2008, nominal oil prices marked their historical all-time high at even 140 US-dollars. They fell to 40 US-dollars in conjunction with the severe economic downturn following the financial crisis and have more than doubled since then. Expressed in Euro per Barrel, the long-term increase is somewhat dampened by favorable exchange rate developments of the euro versus the dollar but still looks impressive. The nominal price of oil increased more than sixfold from about 10 to currently about 70 Euro per Barrel. These figures illustrate the sustained longer-term upward trend of oil prices as well the considerable short-term fluctuations of oil prices. See *ECB* (2010) for more details.

Macroeconomic asymmetries are empirically relevant. The *ECB* (2010) finds considerable heterogeneity across the EMU member countries in their macroeconomic responses to common oil price shocks. The differences between the two large countries Germany and France are particularly pronounced. Germany (next to Belgium) experiences the strongest recession from a common oil price shock hitting the euro area. France, at the other end of the spectrum, shows over the medium term almost no response of real GDP to an increase in oil prices (see p. 83, Chart 5).[2] *Peersman* and *van Robuys* (2009) also find substantial heterogeneity across the EMU member countries in their responses to oil price shocks.

Against this background this paper deals with the interesting question how the *simultaneous* presence of common external oil price shocks *and* endogenous monetary policy actions by the ECB feed through the member economies and how the member countries interact in the process of adjustment with each other and with the rest of the world. In principle, different cyclical developments within the monetary union may here arise from two sources: The member countries may respond differently to the common oil price shock and/or they may behave differently with respect to the endogenous monetary policy response by the ECB.

This raises the question about the number and type of macroeconomic asymmetries to be included in the model, which generate cyclical asymmetries in response to uniform impulses from oil prices and the common monetary policy by the ECB. On the one hand, the model intends to include empirically relevant macroeconomic asymmetries across the EMU. On the other hand, we intend to focus on a limited set of asymmetries in order to be still able to solve the model algebraically without having to recur to numerical simulations. The algebraic solution – which is provided in the technical appendix - allows for a more detailed discussion of optimal monetary policy. Furthermore, the complete adjustment dynamics as well as the concept of time inconsistency can be illustrated by means of phase diagrams.[3]

Concerning the *type* of macroeconomic asymmetries our model aims to capture existing asymmetries in the wage-price dynamics across the Euro area. A study by the *ECB* (2005) on the importance of regional factors in a heterogeneous monetary union finds that *"a substantial part of persistence in price developments may stem from differences in wage developments*

[2] This paper concentrates on the differential output dynamics following oil price shocks, excluding other macroeconomic indicators. In principle, the impact on different price indicators and the respective rates of inflation can be derived explicitly from the underlying model and also be illustrated in respective graphs. Furthermore, the behavior of cyclical unemployment in response to oil price shocks – as investigated econometrically in *Löschel* and *Oberndorfer* (2009) – can be illustrated here in relation to the output gap measure. For brevity, these results are not shown.

[3] A similar approach is taken by *Strulik* and *Trimborn* (2009) who use phase diagrams in order to illustrate the dynamic effects of temporary fiscal stimulus in a microfounded real business cycle (growth) model in continuous time.

and wage-setting mechanisms across euro area countries (including, in some countries, the automatic indexation of nominal wages to prices)" (p. 68). After more than ten years of a common monetary policy in Europe there is now additional empirical evidence that wage-price dynamics continue to differ considerably across the member countries (see, among others, *ECB* (2010) and *Carstensen et al.* (2009)). Furthermore, *Peersman* and *van Robays* (2009) find in a comprehensive study of the effects of oil price shocks that the cross-country differences in Europe are primarily rooted in different so-called "second-round" effects. In contrast, differences in "first-round effects" do not seem to be the major driving force of cyclical asymmetries in Europe. Asymmetric wage-price responses in Europe lead to different adjustment patterns in the member countries. Germany, for example, shows strong responses in wages and prices, whereas France shows almost no responses in these variables.[4]

In consequence, this paper considers two types of asymmetries: On the *supply* side, we assume asymmetric wage adjustment mechanisms. We look here at differences in the propagation mechanisms within the EMU and explicitly consider the cyclical implications of *"second-round effects"* of oil price increases stemming from asymmetric wage adjustment mechanisms. Asymmetric degrees of nominal wage flexibility are implemented by postulating different types of Phillips curves within the monetary union. On the *demand* side, the member countries are assumed to be characterized by asymmetric interest rate transmission such that the direct cyclical impact of the endogenous ECB policy differs across the EMU member countries.[5]

Our specific focus on a limited set of two empirically relevant structural asymmetries allows us to solve the model explicitly and to derive analytically the adjustment paths of the economies in response to oil price shocks as well as the appropriate reaction functions for monetary policy.[6] Furthermore, the complete adjustment dynamics can be illustrated by means of phase diagrams. The model can be interpreted as an IS/LM model augmented by a supply side with (1) a *Phillips* curve based on rational expectations of prices and exchange

[4] See *Clausen* (2002) for a more detailed discussion of labor market and other macroeconomic asymmetries in EMU member countries.

[5] See *Clausen* and *Wohltmann* (2005) for a more detailed motivation and analysis of the individual implications of this macroeconomic asymmetry. The empirical evidence on asymmetric interest rate transmission, especially comparing France and Germany, is somewhat inconclusive concerning the relative strength as some studies find a relativeley stronger impact in France, others find a relatively stronger impact in Germany (see *Peersman* (2004), table 1). We assume in the following for the sake of illustration France (Country 1) to be more strongly affected by interest rate impulses.

[6] The focus on different second-round effects and just these two asymmetries leaves out other types of demand or supply side asymmetries. In the following model setup we abstract for simplicity from asymmetries in the importance of oil in the production process across the member countries. In the definition of the consumer price index we do not allow for a direct impact of oil as a consumption good but allow only for an indirect impact via the final goods prices. Empirically, the cross-country differences in the importance of oil in the EMU member countries are limited in size (see, *ECB* 2003, p. 27).

rates and (2) imported oil in domestic production and (3) a long-run supply function.[7] We examine the short-, medium- and long-run effects of anticipated and unanticipated oil price increases on both member countries. This setup serves as a background for the analysis of monetary policy. We assume that the primary goal of monetary policy is price stability and investigate to which extent the ECB may also be able to dampen the differential cyclical developments within the monetary union caused by the common external price shock.[8]

The analysis of anticipated oil price shocks and their implications for monetary policy generates new insights concerning the notion of time consistency of monetary policy. We introduce the novel distinction between *qualitative* and *quantitative time inconsistency*. Complete stabilization of the output variables throughout the overall adjustment process requires a restrictive monetary policy being time inconsistent from a quantitative but time consistent from a qualitative point of view. That means that the central bank credibly announces a future reduction in the growth rate of the nominal money stock but actually implements a reduction, which is less restrictive than the original announcement.

Section 2 introduces our model. *Section 3* analyzes the dynamic effects of anticipated and unanticipated oil price increases*.* *Section 4* discusses the appropriate response by monetary policy to these price shocks. *Section 5* summarizes our main results. The paper includes an appendix, which contains a detailed derivation of the analytical solution.

2. A Model of a Monetary Union

We consider a monetary union, which consists of two member countries U_1 and U_2. The member countries are identical in size and the monetary union as a whole is considered as small relative to the rest of the world. Both member countries use imported oil for domestic production:

(1) $$q_1 = (a_{01} + a_1 y_1 - a_{21}(i_1 - \dot{p}_1^c)) + g_1 + (b_0 - b_1 y_1 + b_2 y_2 + b_3 y^* - b_4(p_1 - p_2) - b_5 \tau_1)$$

(2) $$q_2 = (a_{02} + a_1 y_2 - a_{22}(i_2 - \dot{p}_2^c)) + g_2 + (b_0 - b_1 y_2 + b_2 y_1 + b_3 y^* - b_4(p_2 - p_1) - b_5 \tau_2)$$

(3) $$\tau_1 = p_1 - (p^* + e)$$

7 The macroeconomic setup draws on earlier specifications in *Wohltmann* (1993 a and b) and *Wohltmann* and *Clausen* (2001a and b). In principle, the model equations can also be formulated in discrete time and simulated with MATLAB-DYNARE (as done, for example, in *Wohltmann* and *Winkler* (2006)). They also provide a more detailed discussion on the microeconomic foundations of the model equations used in this paper. In this paper, we focus on the qualitative adjustment mechanisms in an asymmetric monetary union, which can be properly illustrated with a countinuous time specification.

8 The implications of this paper go well beyond the role of imported raw materials in an open economy. It may also be applied to all intermediate goods produced abroad and used for domestic production. We therefore use in this paper the terms oil imports, raw material imports or imports of intermediate goods interchangeably.

(4) $\tau_2 = p_2 - (p^* + e)$

(5) $m = (p_1^c + l_0 + l_1 q_1 - l_2 i_1) + (p_2^c + l_0 + l_1 q_2 - l_2 i_2)$

(6) $i_1 = i_2 = i^* + \dot{e}$

(7) $y_1 = q_1 - \psi(p_R^* + e - p_1) - c_0$

(8) $y_2 = q_2 - \psi(p_R^* + e - p_2) - c_0$

(9) $\dot{p}_1 = \mu \dot{w}_1 + (1-\mu)(\dot{p}_R^* + \dot{e}) \qquad (0 < \mu < 1)$

(10) $\dot{p}_2 = \mu \dot{w}_2 + (1-\mu)(\dot{p}_R^* + \dot{e})$

(11) $\dot{w}_1 = \pi_1 + \delta(q_1 - \bar{q}_1) \qquad (\pi_1 = \frac{1}{2}\dot{m})$

(12) $\dot{w}_2 = \pi_2 + \delta(q_2 - \bar{q}_2) \qquad (\pi_2 = \dot{p}_2^c)$

(13) $p_1^c = \alpha_1 p_1 + \alpha_2 p_2 + \alpha_3(p^* + e) \qquad (\alpha_1 + \alpha_2 + \alpha_3 = 1)$

(14) $p_2^c = \alpha_1 p_2 + \alpha_2 p_1 + \alpha_3(p^* + e)$

(15) $\bar{q}_1 = f_0 + f_1\bar{\tau}_1 + f_2(\overline{p_1 - p_2}) + f_3(\overline{p_1 - (p_R^* + e)})$

(16) $\bar{q}_2 = f_0 + f_1\bar{\tau}_2 + f_2(\overline{p_2 - p_1}) + f_3(\overline{p_2 - (p_R^* + e)})$

The notation is as follows:[9] q = real output, y = real income, i = nominal interest rate, $i - \dot{p}^c$ = real interest rate, g = real government expenditure, p = producer price level of the domestically produced good, τ = final goods terms of trade, e = nominal exchange rate of the union with respect to the rest of the world expressed in units of domestic currency for one unit of foreign currency, m = nominal money stock in the union[10], w = nominal wage, π = trend or core rate of inflation, p^c = consumer price index, $\bar{q}$ = steady state level of q (natural level of output), p_R^* = price of oil or of other intermediate good, $p_R^* + e - p$ = real oil price, $p - (p_R^* + e)$ = intermediate goods terms of trade.

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[9] All variables – except for the interest rates i_1, i_2 and i^* - are logarithmized. The variables of member country U_1 (U_2) are labeled with the lower case index „1“ („2“). Variables with a „*“ describe foreign variables. A dot above a variable indicates the right-hand side derivative with respect to time; a bar indicates a steady state or long-run equilibrium value of the respective variable. All structural parameters in the equations (1)-(16) are taken to be positive. They can be interpreted as elasticities or semi-elasticities, respectively.

[10] The monetary aggregate m is derived from the underlying LM equation through log-linearization. Denoting the underlying levels of the aggregate money stock with M and of money demand with $P_j^c L_j (j = 1,2)$, money market equilibrium implies $M = P_1^c L_1 + P_2^c L_2$. Provided that the initial values of money demand are identical in both member countries and using the approximation $dM / M_0 \approx \ln M - \ln M_0$ it is possible to derive m = 2(ln$M$-ln 2).

The IS equations (1) and (2) describe aggregate demand in the two member countries of the monetary union. Goods market equilibrium in country U_j (j = 1, 2) requires domestic production (q_j) to equal the sum of real private absorption (first expression in brackets), real government expenditure (g_j) and the difference between the real ex- and import of final goods (second expression in brackets). Real private absorption is assumed to depend negatively on the real interest rate and international trade in final goods (trade balance excluding imports of raw materials) negatively with respect to the terms of trade. Equations (3) and (4) define the terms of trade with respect to final goods. The IS equations are assumed symmetric except for different semi-interest elasticities of private absorption. We assume private absorption in U_1 to respond more strongly to interest rates compared to U_2 ($a_{21} > a_{22}$).[11]

The LM equation (5) reflects money market equilibrium in the monetary union. Money demand in country U_j is assumed to depend on domestic production q_j, which is considered a more appropriate measure of the volume of transactions than real income y_j. The nominal money stock m is deflated by the consumer price indices (13) and (14) to allow for the fact that in open economies money is also used for the purchase of imported goods. Perfect capital mobility within the monetary union as well as between the monetary union and the rest of the world implies uncovered interest parity (6). Interest rates within the union are equalized and may deviate only by the rationally anticipated rate of depreciation $\dot{e}$ from the foreign interest rate i^*.

The equations (7) and (8) link domestic production q_j with real income or gross national product y_j. The difference originates from real intermediate imports. Real imports of raw materials (intermediate goods) can be expressed in non-logarithmized form as the product of the real price of raw materials ($P_R^* \cdot E / P_j$) and the physical import R_j.[12] Assuming for simplicity a proportional relationship between the quantity R_j and the (non-logarithmized) level of domestic production Q_j of the form $R_j = æ \cdot Q_j \quad (1 > æ > 0)$,[13] we derive after a logarithmic-linear approximation the equations (7) and (8) where $\psi = æ/(1-æ)$ provided that the initial

[11] It may be argued that the IS-equations are "myopic" as absorption depends on current income and does not follow from intertemporal optimization on part of the consumers. Note, however, that the presence of interest rates in the absorption equation implicitly captures and mimics intertemporal substitution and anticipation effects by consumers.

[12] In this paper, capital letters generally indicate non-logarithmized variables.

[13] See for more details also *Findlay* and *Rodriguez* (1977) and *Buiter* (1978).

value of the intermediate goods terms of trade $P_j/(P_R^* \cdot E)$ is normalized to unity (*Wohltmann* 1993b). [14]

The equations (9) and (10) describe price adjustment within the monetary union.[15] The rates of inflation in U_j are determined by a weighted average of domestic nominal wage inflation and of the rate of change of the real price of raw materials expressed in domestic currency. The corresponding weights μ (1-μ) reflect the average shares of wage costs (raw material costs) in the overall variable costs of a representative firm.[16] The equations (9) and (10) are dynamic versions of mark up-price setting (*Buiter* 1979).

The equations (11) and (12) describe the dynamics of wage adjustment in the monetary union. The rate of change of wages in U_j is determined by an expectations-augmented *Phillips*-curve where inflationary expectations are given by the trend or core rate of inflation (π_j).[17] We assume that wage setters in both member countries base their decisions on different time horizons. In U_1, the trade unions take a long-run perspective. Their rate of nominal wage increases is linked to the rate of growth of the money stock in the monetary union, which in turn determines the *long-run* rate of inflation. In U_2, wage setting is based on the rationally anticipated *short-run* development of consumer price inflation based on (14). Furthermore, both wage setting equations contain a component reflecting wage pressure, which is modeled according to *Okun's law* using the output gap, i.e., the difference between actual and potential output. Without this wage pressure component ($\delta = 0$), the trade unions show insider-outsider-behavior and the wage equation in U_1 corresponds with *nominal* wage rigidity while wage setting in U_2 can be interpreted as *real* wage rigidity based on the consumer price index.[18] Nominal wages are therefore more flexible in U_2 than in U_1. In U_1, nominal wages only

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[14] In production functions, which allow for factor substitution, the constant ψ depends on the elasticity of substitution between factors of production and from the share of imported inputs in aggregate production. See *Bhandari* and *Turnovsky* (1984).

[15] Another strand of the literature looks at asymmetries in the price setting equations and their implications for asymmetric price developments within a heterogeneous monetary union. Price setting in the service sector is typically slower than in other parts of the economy such that countries with a larger service sector are under otherwise unchanged circumstances characterized by larger degree of price rigidity (*ECB* 2005). We focus instead on asymmetric wage setting mechanisms and assume in our model symmetric mark-up price setting behaviour of firms.

[16] The expression 1-μ can be interpreted as a measure of the degree of openness of the economy on the supply side (*Bhandari* and *Turnovsky* 1984). In contrast, the parameter α_3 in the price adjustment equations (13) and (14) reflect the openness of the economy with respect to the large foreign country on the demand side.

[17] See for more details also *Buiter* and *Miller* (1982) and *van der Ploeg* (1990).

[18] The *OECD* (2000) finds that the EMU member countries differ considerably in their degrees of wage flexibility. For example, the degree of nominal wage flexibility in France is relatively small while being relatively large in Germany (see table 11, p. 108). In contrast, the impact of the rate of unemployment on real wages has a similar magnitude in both countries. As long as the monetary union is assumed to consist of France (U_1) and Germany (U_2) the parameter δ can be assumed to be identical in (11) and (12). More recently, *Peersman* and *van Robays* (2009, p. 625) also find the degree of nominal wage flexibility in France to be very small compared with Germany.

respond to the output gap as long as the rate of monetary growth remains unchanged. In U_2, nominal wage changes $\dot{w}_2$ react via π_2 to anticipated changes in the consumer price index. Consumer price inflation includes the anticipated rate of depreciation $\dot{e}$, which, in turn, immediately reacts to exogenous shocks. In consequence, the rate of change of nominal wages in U_2 responds directly to the anticipated rate of depreciation $\dot{e}$. In U_1, the rate of change is determined by the constant rate of growth of the money stock. In contrast, producer price inflation $\dot{p}_1$ and $\dot{p}_2$ respond in both member countries directly to $\dot{e}$. This can be directly seen from the price adjustment equations (9) and (10).

Equations (15) and (16) describe long-run supply functions within the monetary union. In the long-run assuming labor market equilibrium, a neoclassical production function and a perfectly elastic supply of raw materials, goods supply depends positively on the final and intermediate goods terms of trade and on the internal price differential (internal terms of trade).[19]

In summary, our monetary union is assumed completely symmetric except for exactly one asymmetry in both, the demand and the supply side. On the demand side, U_1 is characterized by a relatively higher interest sensitivity of private absorption. On the supply side, U_2 is characterized by a relatively higher degree of nominal wage flexibility. We show in the following that as a result of these asymmetries oil price shocks generate adjustment dynamics in both member countries, which display considerable quantitative as well as qualitative differences within the monetary union.

Using the solution method of *Aoki* (1981), the model is decomposed into an aggregate and a difference system. The aggregate system is derived by adding corresponding equations of U_1 and U_2. It describes the behavior of the monetary union as a whole. The difference system is derived by the subtraction of corresponding equations of U_1 and U_2. It describes the differential developments within the monetary union. In previous work the method by *Aoki* has been predominantly applied to symmetric models. It can only be used in our asymmetric model when we assume identical weights α_1 and α_2 in the consumer price definitions (13) and (14), i.e., that consumers in the monetary union are indifferent between domestically produced goods and imports from the respective partner country (*Clausen* and *Wohltmann* 2005). The simplifying assumption $\alpha_1=\alpha_2$ may be justified for highly integrated monetary unions and allows us to solve the aggregate system independently from the difference system. With $\alpha_1=\alpha_2$, the price indices p_1^c and p_2^c are identical. In conjunction with the uncovered interest

[19] A more detailed theoretical derivation of the role of the terms of trade in aggregate supply is given in *Wohltmann* and *Bulthaupt* (1999) and *Devereux a*nd *Purvis* (1990). The supply equations (15) and (16) can also be derived by assuming static price and wage equations with full wage indexation in the long run.

parity (6) it follows that real interest rates are equalized within the monetary union ($i_1 - \dot{p}_1^c = i_2 - \dot{p}_2^c$). In contrast, the producer price levels p_1 and p_2 and the corresponding rates of producer price inflation $\dot{p}_1$ and $\dot{p}_2$ differ across the monetary union. The arithmetic mean of the solutions to the aggregate and the difference system yields the solution paths for the output and price developments in the individual member countries. The detailed analytical derivations are provided in the appendix.

3. Effects of an Oil Price Increase

This section analyzes the dynamic effects of anticipated and unanticipated increases in the price of imported oil ($\mathrm{d}p_R^* > 0$) on both member countries. In the case of an anticipated increase in p_R^*, we assume that the price increase is credibly announced in $t = 0$ and happens at the later date $T > 0$. An unanticipated price shock comes as a surprise to the private sector and happens already at $t = 0$. Both types of shocks have identical effects in the steady state but differ in their implications for the adjustment dynamics.

Effects on the Aggregate Monetary Union

The *long-run* or *steady state* effects of an oil price increase result from the equilibrium condition $\dot{\tau} = 0 = (\dot{m} - \dot{p}) = \dot{p}_1 - \dot{p}_2$ for the dynamics of the aggregate and the difference system.[20] In long-run equilibrium, member country outputs q_1 and q_2 equal their long-run levels $\overline{q}_1$ and $\overline{q}_2$ according to the long-run supply functions (15) and (16). An oil price increase leads in the monetary union to a decline in aggregate union output $\overline{q} = \overline{q}_1 + \overline{q}_2$, which is evenly distributed across the monetary union ($\mathrm{d}\overline{q}_1 = \mathrm{d}\overline{q}_2 < 0$).[21] It follows that asymmetries in wage setting or in the interest sensitivities of aggregate demand do not affect the ultimate impact of oil price shocks on member country outputs $\overline{q}_1$ and $\overline{q}_2$. One reason is that in our model producer price inflation $\dot{p} = \dot{p}_1 + \dot{p}_2$, the rate of depreciation $\dot{e}$ and consumer price inflation $\dot{p}^c = \dot{p}_1{}^c + \dot{p}_2{}^c$ are ultimately only determined by the rate of monetary growth in the union ($\dot{m} = \dot{p} = 2\dot{e} = \dot{p}^c$). The second reason is that oil price shocks of the form $\mathrm{d}p_R^* > 0$ leave no-

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20 The long-run is considered as the imaginary period in which the dynamic adjustments of the aggregate and the difference system are completed. In the case of the aggregate variable we have τ and p: $\tau = \tau_1 + \tau_2$, $p = p_1 + p_2$.

21 In contrast, an isolated increase in the price of imported final goods ($\mathrm{d}p^*$>0) leads to an increase of $\overline{q}$. In this case, $\mathrm{d}\overline{q} / \mathrm{d}p^* = -\mathrm{d}\overline{q} / \mathrm{d}p_R^*$ holds.

minal and real interest rates as well as the internal price differential p_1-p_2 ultimately unaffected. In contrast, the external terms of trade based on final goods $\tau = \tau_1 + \tau_2$ change in the long run. Provided that

$$(17) \qquad b_5 > (a_1 - b_1 + b_2)\psi > f_3 \cdot \lambda \qquad (\lambda = 1 - a_1 + b_1 - b_2 > 0)$$

holds, the oil price increase leads to a fall in the aggregate terms of trade ($\mathrm{d}\overline{\tau} / \mathrm{d}p_R^* < 0$).[22] The first inequality in (17) ensures that the *long-run* IS curve in the $\overline{\tau} / \overline{q}$-diagram has a „normal" negative slope[23], while the second inequality ensures that the long-run IS curve in *Figure 1* moves in response to $\mathrm{d}p_R^* > 0$ further to the left than the upward-sloping long-run aggregate supply curve (AS).[24]

The jump in oil prices $\mathrm{d}p_R^* > 0$ normally leads to a permanent decline in the real money stock ($\mathrm{d}(\overline{m-p}) / \mathrm{d}p_R^* < 0$). Provided that the nominal money stock is constant ($\dot{m} = 0$) this is equivalent to a permanent increase in the aggregate producer price level $p = p_1 + p_2$.[25]

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22 As common in the analysis of small countries, we assume here that the increase in the oil price leaves the foreign price level of the foreign final good unaffected. For a relaxation of this condition see *Wohltmann* and *Winkler* (2006). Provided that (17) holds, an increase in p^* leads to $\mathrm{d}\overline{\tau} / \mathrm{d}p^* = -\mathrm{d}\overline{\tau} / \mathrm{d}p_R^* > 0$. The nominal exchange rate e can only achieve a stationary long-run equilibrium as long as the nominal money stock in the union remains constant ($\dot{m} = 0$). In this case we find, given (17), $\mathrm{d}\overline{e} / \mathrm{d}p_R^* > 0$ and, respectively, $\mathrm{d}\overline{e} / \mathrm{d}p^* < 0$, i.e., an increase in the price of imported raw materials (final goods) leads to a real and a nominal depreciation (appreciation) of the common currency. Due to $\overline{y} = \overline{q} + \psi \cdot \overline{\tau} + 2\psi(p^* - p_R^*) - 2c_0$ we also find in the case $\mathrm{d}p_R^* > 0$ ($\mathrm{d}p^* > 0$) an overproportionate fall (rsp. increase) in real income $\overline{y} = \overline{y}_1 + \overline{y}_2$ relative to real output $\overline{q}$.

23 The standard assumption of a „normal" reaction of the trade balance to changes in the final goods terms of trade τ is insufficient because an isolated increase in τ raises private absorption due to $y = q + \psi \cdot \tau + 2\psi(p^* - p_R^*) - 2c_0$.

24 Using a CES production function, the parameter f_3 can be linked to the variable factors labor and imported raw materials as follows $f_3 = (\beta + \sigma)(1 - \mu) / \mu$ (*Wohltmann* and *Bulthaupt* 1999); where β indicates the real-wage elasticity of the labor supply and σ the elasticity of substitution between labor and imported raw materials. The second inequality in (17) holds provided that the sum of both elasticities is sufficiently small.

25 We find $\mathrm{d}(\overline{m-p}) / \mathrm{d}p_R^* < 0$ if and only if $\alpha_3 (a_1 - b_1 + b_2)\psi < (l_1 b_5 + \alpha_3 \lambda) f_3 + f_1 l_1 (a_1 - b_1 + b_2)\psi$. This condition holds if $\alpha_3 - f_1 l_1 < 0$ or if b_5 is sufficiently large.

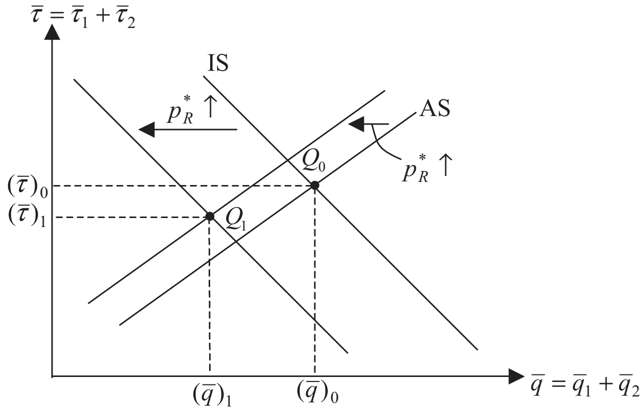

Figure 1: Long-Run Effects of an Oil Price Increase

The *dynamics of adjustment* of the aggregate monetary union to an oil price increase can be illustrated in a phase diagram including the state variables τ and *m-p* (*Figure 2*).[26] The points Q_0 and Q_1 denote the initial and the final equilibrium of the aggregate system and S_0 and S_1 the corresponding convergent saddle paths. The dynamic adjustment of the state vector (τ, *m-p*) in response to an anticipated oil price increase shows on impact a discontinuous jump from Q_0 to *B* (or *B*'). It is followed by a movement along a trajectory, which converges asymptotically to the unstable branch I_0 belonging to the saddle point Q_0 (*BC* or *B*'*C*'). After the implementation in *T*, the system moves along the unique convergent saddle path S_1 to the new long-run equilibrium Q_1.[27]

The anticipation of a future increase in oil prices leads on impact to a real depreciation of the common currency. It equals the nominal depreciation due to the assumption of short-run price rigidity. The *size* of the instantaneous fall in the terms of trade τ is inversely related to the time span *T* between the announcement and the actual implementation of the price in-

[26] We use the real variables τ and *m-p* as state variables in the phase diagram because steady state values of the nominal exchange rate *e* and the aggregate price level *p* do not exist in the presence of a positive rate of growth of the money stock. The terms of trade τ are taken as a jump variable as it includes the forward-looking variable *e*. As a result of price rigidity, the producer-oriented real money stock *m-p* is taken as predetermined. In contrast, the consumer-oriented real money stock $m\text{-}p^c$ is a non-predetermined variable because the aggregate consumer price index $p^c = p_1^c + p_2^c$ includes the jump variable *e*.

[27] It is assumed here that $\mathrm{d}\bar{\tau} / \mathrm{d}p_R^* < 0$ and $\mathrm{d}(\overline{m-p}) / \mathrm{d}p_R^* < 0$, which prevail as long as the weak condition (17) holds and provided that b_5 is sufficiently large. Moreover, it is assumed that Q_1 remains below the unstable branch I_0. The theoretical possibility that Q_1 is located above I_0, which arises for example with extremely large values of b_5 or $a_2 = \frac{1}{2}(a_{21} + a_{22})$, is considered as empirically irrelevant.

crease. We find „undershooting“ of the final goods terms of trade in point *B* in the case of a long time span *T* and „overshooting“ in *B*’ given a short span. In the extreme case of an unanticipated increase in p_R^* (*T*=0), the impact effect is given in B^* on the saddle path S_1 where the size of the impact depreciation reaches its maximum.

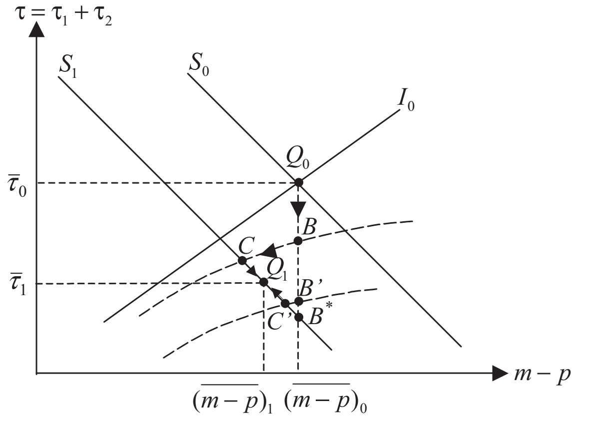

Figure 2: Effects of an Oil Price Increase on the Aggregate Monetary Union

After the immediate impact depreciation the real depreciation of the common currency continues further in the case of an anticipated price increase. This adjustment pattern differs from the case of an unanticipated price increase. Furthermore, in the adjustment process following the impact effect the real money stock *m-p* subsequently falls because the real depreciation ($\dot{\tau} < 0$) and the implicit nominal depreciation $\dot{e}$ cause nominal wage increases in U_2, which in turn raise the aggregate rate of producer inflation beyond the level determined by the initial rate of monetary growth ($\dot{p} > \dot{m}_0$). The parallel development of the terms of trade τ and of the real money stock *m-p* ends at the date of implementation *T*. In the case of a “large” *T*, i.e., that the time span between the anticipation and the implementation is relatively long, we find for *t*>*T* a continuation of the real depreciation, which leads in conjunction with the discontinuous fall in the rate of inflation in *T* to an increase in the real money stock (adjustment path CQ_1). For “small” values of *T* (and, in particular, in the special case $T = 0$) we find after the implementation in *T* a real appreciation, which is accompanied by a further reduction in the real money stock (adjustment path $C'Q_1$). The adjustment dynamics ultimately settle at the new final equilibrium Q_1 on the saddle path S_1 irrespective whether *T* is “small” or “large”.

The aggregate real interest rate and the rate of real appreciation $\dot{\tau}$ behave inversely due to

$$(18)\qquad (i_1 - \dot{p}_1^c) + (i_2 - \dot{p}_2^c) = i - \dot{p}^c = 2i^* - (1-\alpha_3)\dot{\tau} \qquad (i = i_1 + i_2,\ \dot{p}^c = \dot{p}_1^c + \dot{p}_2^c)$$

and because the foreign interest rate i^* is considered exogenous. A real depreciation of the common currency ($\dot{\tau} < 0$) implies that real interest rates in Europe $i - \dot{p}^c$ exceed their steady state level and vice versa. In *Figure 2*, the rate of real appreciation $\dot{\tau}$ is negative throughout the period up to T such that the aggregate real interest rate $i - \dot{p}^c$ exceeds its steady state level ($2i^*$).[28] The increase in $i - \dot{p}^c$ is accomplished despite the initial increase in the rate of inflation $\dot{p}^c$ by an even stronger increase in the short-term nominal interest rate i.[29] At the date of implementation T, the rate of appreciation $\dot{\tau}$ increases discontinuously, which implies a simultaneous fall in the aggregate real interest rate. For „small" T, the aggregate real interest rate remains for $t > T$ below its long run level $2i^*$, while remaining above this level for „large" T. In the long-run, the real interest rate returns to its initial steady state level ($2i^*$).

The effect on aggregate demand and output $q = q_1 + q_2$ in the period $0 < t < T$ is characterized by two opposing influences. The real depreciation of the common currency increasingly improves the unions trade balance and increases due to (17) aggregate demand. On the other hand, the increase in the aggregate real interest rate reduces real private absorption. Provided that the weak condition

$$(19)\qquad ((1+\alpha_3)\mu + 2(1-\mu))l_2(b_5 - (a_1 - b_1 + b_2)\psi) > (1-\alpha_3)\mu\, a_2\alpha_3$$

holds, the impact effect of an anticipated oil price increase on aggregate output $q = q_1 + q_2$ is on balance positive: $q(0+) > \bar{q}_0$.[30] Given (19), the anticipation of a future oil price increase leads to an immediate expansion in aggregate output in the monetary union.[31]

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[28] After the impact effect, real interest rates increase continuously up to T.

[29] The rise in i follows from the uncovered interest parity (6) and the increase in the rate of depreciation $\dot{e}$.

[30] Inequality (19) holds if the terms of trade elasticity of the trade balance (b_5) is large relative to the interest sensitivity of private absorption (a_2). In this case, the expansionary terms of trade effect dominates the contractionary real interest rate effect. Condition (19) also holds if the semi-interest elasticity of money demand (l_2) is sufficiently large. In the special case without imported raw materials ($\mu = 1, \psi = 0$) condition (19) simplifies to $(1+\alpha_3)l_2 b_5 > (1-\alpha_3)a_2\alpha_3$. This condition ensures that an anticipated increase in the rate of monetary growth $\dot{m}$ leads on impact to an increase of aggregate output (*Wohltmann* and *Clausen* 2001a). Given a role for imported raw materials in domestic production, condition (19) ensures that an anticipated increase in $\dot{m}$ again leads to an expansionary impact effect on output.

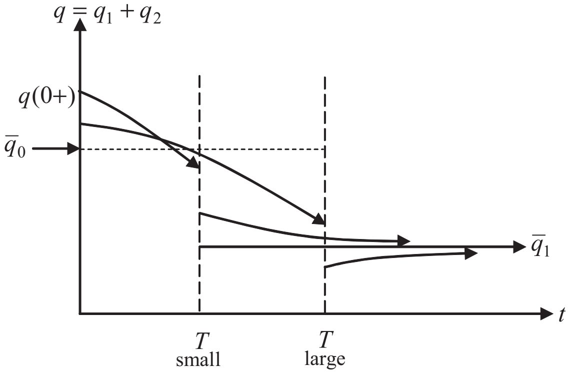

Figure 3: Aggregate output effects in the monetary union

The subsequent development of aggregate output up to *T* is theoretically ambiguous. On the one hand, the external trade balance successively improves following the discontinuous depreciation on impact and subsequent further reductions in the terms of trade τ . On the other hand, the real interest rate increases and lowers the interest-sensitive part of private absorption. With realistic empirical parameterizations, the contractionary real interest rate effect dominates the expansionary terms of trade effect such that aggregate output q falls after the initial expansion. The fall in aggregate output typically continues even below the initial equilibrium value $\overline{q}_0$ (*Figure 3*), except for very small values of *T.* In *T*, the implementation of the oil price increase leads – notwithstanding the fall in real interest rates - to a discontinuous fall in output, which can be explained using (7) and (8) by the fall in real income y in *T* and the implied fall in aggregate demand.[32] The *size* of the contraction in *T* does not depend on the time span between the anticipation and the implementation of the oil price increase.[33] For "small" values of *T*, union output experiences a convergence from above to the new steady

[31] This result critically depends on the "normal" reaction of the trade balance with respect to changes in the terms of trade based on final goods, i.e., that the assumption $b_5 > 0$ already holds in the *very* short-run. This assumption was already made in the overshooting model by *Dornbusch* (1976) and also in *Buiter* and *Miller* (1982). The case $b_5 < 0$ (abnormal reaction of the trade balance) leads to a positive determinant of the dynamic aggregate system and to the loss of the saddle path property of the system. Moreover, we continue to assume that domestic production responds immediately and perfectly elastic to changes in aggregate demand. Assuming instead a Lundberg lag in domestic production where supply responds sluggishly to changes in aggregate demand, output remains predetermined on impact and increases only gradually over time in response to an anticipated increase in imported raw materials.

[32] For $y = y_1 + y_2$, the link with domestic production is given by $y = q + \psi\tau + 2\psi(p^* - p_R^*) - 2c_0$. Contrary to q, y falls already on impact ($y(0+) < \overline{y}_0$) due to $\tau(0+) < \overline{\tau}_0$ and also in the subsequent adjustment process. As p_R^* jumps in *T*, *y* experiences another discontinuous contraction in *T*.

state value of q, which is lower than the initial equilibrium value.[34] In contrast, for sufficiently „large“ values of T, q converges to the new steady state value $\bar{q}_1$ from below (cf. Figure 3).

Output Effects in the Individual Member Countries

As a consequence of the assumed asymmetries on the supply and the demand side, the cyclical developments in response to the symmetric oil price shock $\mathrm{d}p_R^* > 0$ differ in the individual member countries. Differential output developments within the monetary union are captured by the output differential $q^d = q_1 - q_2$. The solution path of q^d in response to an anticipated oil price increase typically looks as in *Figure 4*. Anticipating in t=0 the price increase in $T > 0$, both countries experience a discontinuous and (due to our assumption $\alpha_1 = \alpha_2$) identical increase in real interest rates. This leads in U_1 to a relatively stronger fall in aggregate demand than in U_2 because of the assumed asymmetry in the interest sensitivity of private absorption ($a_{21} > a_{22}$). The immediate real depreciation of the common currency improves the trade balance and increases aggregate demand symmetrically. In consequence, on impact and in the early period of adjustment output in U_2 is higher than in U_1, In other words, the output differential is on impact *negative*: $q^d(0+) < 0$. This initial cyclical differential favoring U_2 relative to U_1 changes quantitatively and even qualitatively over time in response to changes in the internal and external terms of trade. The internal terms of trade $p^d = p_1 - p_2$ fall over time as a consequence of differential inflation developments within the monetary union.[35] This improves the internal competitiveness of U_1 compared with U_2 and the bilateral trade balance of U_1 within the union. Furthermore, U_1 experiences a decline in the respective external (final goods) terms of trade τ_1 on impact and also in the subsequent adjustment process, which goes beyond the corresponding decline of τ_2 for U_2 such that the improvement of the trade balance of U_1 with respect to the large foreign country exceeds the

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33 This result holds generally and follows from the fact that the jump variable τ remains continuous in T. In contrast, the size of the initial jump clearly depends on T. See *Turnovsky* (2000), pp. 187 ff.

34 This statement also holds in the special case $T = 0$. The initial jump in q is ambiguous in sign because the shock $\mathrm{d}p_R^* > 0$ has a negative impact on y and therefore also on private absorption while on the other hand the terms of trade worsen and the real interest rate falls. A realistic empirical parameterization suggests $q(0+) < \bar{q}_0$.

35 The initial period of adjustment is characterized by $\pi_2 > \pi_1$ and $q_2 > q_1$ and following (11) and (12) $\dot{w}_2(0+) > \dot{w}_1(0+)$. The dynamic price adjustment equations (9) and (10) then imply $\dot{p}_2(0+) > \dot{p}_1(0+)$.

one of U_2.[36] Viewed in isolation, the developments of the internal and external terms of trade following the impact effect result in a larger expansionary effect on q_1 than on q_2. It follows that the output differential $q^d = q_1 - q_2$ *increases* after the negative impact effect. Apart from that, the rise in real interest rates exerts a negative impact on both member countries. This effect is assumed to be stronger in U_1 than in U_2 and causes therefore a *decrease* in the output differential q^d. As long as the difference between the interest sensitivities of private absorption is sufficiently small, the terms of trade effects dominate the real interest rate effect on q^d such that on balance the output differential increases after the negative impact effect. The increase in q^d is rooted in the fall in the producer price differential p^d, whose development is driven by the respective inflation differential. The rate of producer price inflation in U_1 is relatively lower ($\dot{p}_1 < \dot{p}_2$) due to different wage dynamics in the anticipation period $0 < t < T$. This follows from two factors: First, the rate of consumer price inflation $\dot{p}^c$ exceeds on impact for $0 < t < T$ the constant rate of monetary growth $\dot{m}$ and increases even thereafter.[37] Second, the output gap in U_1 (i.e., the difference $q_1 - \overline{q}_1$) and the corresponding rate of wage inflation are higher than the corresponding values in U_2.

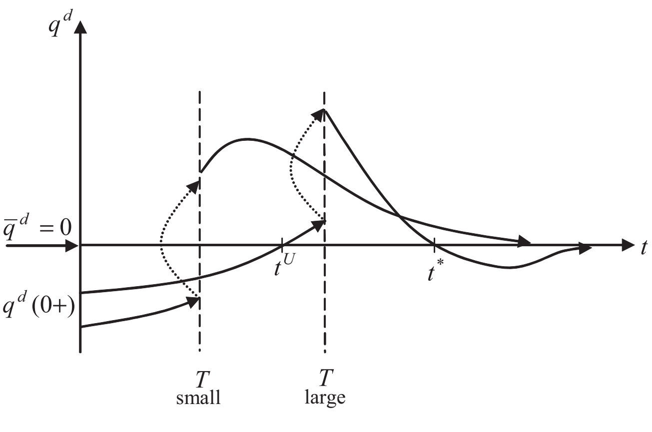

Figure 4: Development of the output differential

[36] In the period $0 < t < T$, the relationship $\tau_1 = 0{,}5(\tau + p^d)$ and the fall in τ and p^d imply that τ_1 also falls. For $\tau_2 = 0{,}5(\tau - p^d)$ we find $\tau_2 > \tau_1$ where after the initial discontinuous fall in t = 0+ it can not be ruled out theoretically that τ_2 subsequently increases.

[37] Not only $\dot{p}^c$ but also $\dot{p} = \dot{p}_1 + \dot{p}_2$ increases continuously in the interval $0 < t < T$. The effect on $\dot{p}$ is smaller (underproportional) than on $\dot{p}^c$ due to $\dot{p} - \dot{p}^c = \alpha_3 \dot{\tau} < 0$. In contrast, q generally falls after the (typically)

The country-specific developments in the internal and external terms of trade lead in the course of the adjustment process to a reversal in the relative cyclical impact of the oil price shock across the monetary union. Technically speaking, they lead to a sign change in the solution time path of the output differential, which occurs at the latest at the date of implementation T. More formally, we find a date of a *cyclical reversal* t^U with $0 < t^U \leq T$ such that $q^d < 0$ (or $q_1 < q_2$) holds for $t < t^U$ and $q^d > 0$ (or $q_1 > q_2$) holds for (at least sufficiently small) $t > t^U$. The reversal date t^U occurs before the date of implementation T as long as the period between the anticipation and the implementation of the oil price shock is sufficiently long (cf. *Figure 4*). In the case that the period is very short, t^U coincides with T.[38] The special case $T = 0$ with an unanticipated price shock always leads to $q^d > 0$.

At the date of implementation T, the output differential q^d increases discontinuously because the real interest rate rises and lowers by assumption private absorption in U_1 more strongly than in U_2. The rise in the output differential in T is associated with a discontinuous increase in the inflation differential $\dot{p}^d = \dot{p}_1 - \dot{p}_2$, which was negative up to T. The subsequent development of q^d depends on the time span between the anticipation and the implementation of the oil price increase. For "small" values of T, q^d increases somewhat even beyond T because the rate of inflation in U_2 remains in this case initially above the one in U_1 ($\dot{p}_2 > \dot{p}_1$). The inflation differential $\dot{p}^d$ continues to be negative and the price differential $p^d = p_1 - p_2$ falls accordingly. In the long run, the price differential p^d returns to its initial level $\bar{p}^d = 0$ such that p^d needs to increase for sufficiently large $t > T$, which requires a positive inflation differential ($\dot{p}^d = \dot{p}_1 - \dot{p}_2 > 0$). Simultaneously, the external terms of trade of U_1, τ_1, improve and U_1 experiences a decline in international competitiveness. The output differential q^d needs to fall for sufficiently large $t > T$ in order to return toward the end of the adjustment process to the initial value $\bar{q}^d = 0$.

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positive impact effect such that as the result of the anticipation of a future price increase in imported raw materials the monetary union experiences *stagflation.*

38 The solution path of q^d has a reversal date t^N in the interval $0 < t < T$, which is *independent* from T. For sufficiently "large" T, we find $t^N < T$ and therefore $t^U(=t^N) < T$. If, in contrast, T is sufficiently "small", $T < t^N$ holds such that a reversal date t^U does not exist in the interval $0 < t < T$. We then find $q^d < 0$ for all $t < T$ but $q^d > 0$ for $t > T$ (provided t is not too large), as q^d increases discontinuously in T, and because the jump in T is independent from T and always larger than $\left|q^d(t)\right|$ for any $t < T$. The real income differential $y^d = y_1 - y_2$ also experiences for $T > 0$ a reversal at $t^K \leq T$. Due to $y^d = q^d + \psi p^d$ and $p^d < 0$ for $0 < t < T$, we find $t^K > t^U$ if $t^U < T$ and $t^K = t^U$ if $t^U = T$.

For sufficiently "large" T, q^d starts to fall immediately after the initial increase in T because producer inflation in U_1 is higher than in U_2 ($\dot{p}_1 > \dot{p}_2$) and the price differential p^d increases correspondingly for $t > T$. In contrast with the case of a "small" T, the system may experience another date of reversal $t^* > T$ where the output differential again changes sign (it turns negative). Given a "large" T, the price differential may increase for sufficiently large t beyond the steady state level $\overline{p}^d = 0$ due to strong asymmetries in nominal wage developments across the monetary union. The member country U_1 experiences a loss in international competitiveness. At the reversal date t^*, the output differential q^d turns again negative and converges therefore for $t > t^*$ toward $\overline{q}^d = 0$ from below. This case is presented in *Figure 4*.[39]

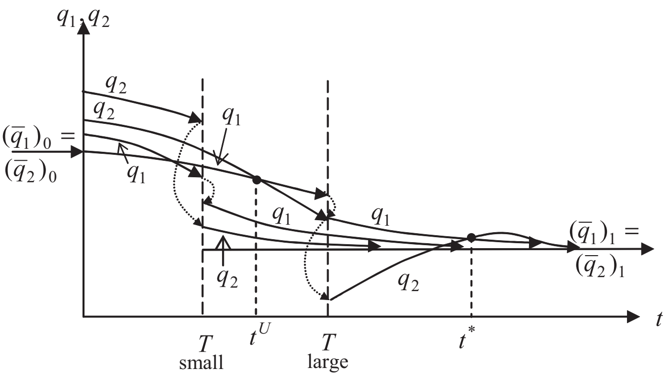

Figure 5: Output developments in individual member countries

Output developments in the individual member countries are given in *Figure 5*.[40] They represent linear combinations of the solution paths for aggregate and differential output. We showed for empirically realistic parameterizations that aggregate output $q = q_1 + q_2$ experiences a discontinuous increase on impact and a monotonic decline in $0 < t < T$. The output variable q_2 therefore increases on impact and subsequently falls. In contrast with q_2, q_1 does *not* necessarily increase in the early phase of the adjustment process because the difference variable $q^d = q_1 - q_2$ falls. Furthermore, q_1 does not necessarily experience a contraction in the interval $0 < t < T$ due to the fall of the price differential p^d and of τ. In *Figure 5*, we

39 The second date of reversal t^* only exists for sufficiently large values of T. For "intermediate" values of T, q^d converges monotonically for $t > T$ from above toward the steady state value $\overline{q}^d = 0$.

40 The qualitative developments of real output and real income y_1 and y_2 are identical.

present the most realistic case that q_1 falls on impact as well as in the subsequent adjustment process. However, the size of the subsequent contraction in U_1 is smaller than in U_2 such that after the date of reversal t^U, q_1 stays above q_2. At the date of implementation T, both countries experience a discontinuous contraction, which turns out to be larger for U_2 than for U_1. In the case $t^U = T$, i.e., for T being „small", both countries experience a monotonic convergence of their output levels from above to their respective new steady state levels, which are below the initial value. Output q_1 remains hereby consistently above q_2. In contrast, with $t^U < T$, i.e., T is sufficiently „large", q_1 and q_2 experience divergent developments in the adjustment process following the discontinuous contraction in T. While q_1 continues to fall, q_2 experiences an expansionary process because the price differential $p^d = p_1 - p_2$ increases for $t > T$ while the terms of trade $\tau_2 = 0{,}5(\tau - p^d)$ simultaneously fall such that the international competitiveness of U_2 improves. For sufficiently large t, i.e., after the second date of reversal t^*, q_2 stays above q_1. In the long run, output levels in both member countries converge to the same equilibrium level.

4. Reaction of Monetary Policy to Oil Price Increases

This section investigates the ability of monetary policy to facilitate the absorption of anticipated and unanticipated oil price shocks in an asymmetric monetary union. Related to EMU, the primary concern of the ECB is the achievement of price stability, which we interpret in our model as to minimize consumer price inflation. Furthermore, according to the Treaty of Maastricht and to the stability pact the ECB is expected to support the general economic policy of the member countries. Monetary policy actions are here considered conducive to this goal when they dampen business cycles at the aggregate level and also cyclical divergences within the monetary union caused by exogenous shocks.

The analytical solutions to the aggregate and difference system determine the conditions to be met and the policies needed for stabilization.[41] More formally, business cycles at the aggregate level of the monetary union as well as asymmetric developments within the monetary union can be avoided if the constants A_1, A_2 and $\widetilde{A}_2$ in the solution for the state vector $(\tau, \quad (m-p))'$ are *all* set equal to zero. Setting $A_1 = A_2 = 0$ removes any anticipation effects, i.e., the overall system remains up to the date of implementation T in the initial steady state. Setting in addition $\widetilde{A}_2 = 0$, anticipated oil price increases do *not* lead to further adjustment

[41] See the appendix.

dynamics of the aggregate and difference variables, i.e., the system jumps in T immediately into the new steady state.

In the special case $T = 0$, i.e., of an *unanticipated* increase in oil prices, complete stabilization of the aggregate and the difference system is achieved as long as monetary policy sets $\tilde{A}_2 = -\mathrm{d}(\overline{m-p}) = 0$. Taking the rate of growth of the aggregate money stock $\dot{m}$ as the monetary instrument, the common central bank has to change $\dot{m}$ such that the steady state value of the real money stock remains unchanged.[42] An increase in oil prices leads in isolation to a permanent fall of the real money stock.[43] An increase in $\dot{m}$ by one unit leads ultimately to a *fall* in the real money stock where the size is determined by the semi-interest elasticity of money demand (l_2). The total differential

$$(20) \qquad \mathrm{d}(\overline{m-p}) = -l_2 \mathrm{d}\dot{m} + \frac{\partial(\overline{m-p})}{\partial p_R^*} \mathrm{d}p_R^* = 0$$

defines the following reaction function for monetary policy

$$(21) \qquad \mathrm{d}\dot{m} = \frac{1}{l_2} \frac{\partial(\overline{m-p})}{\partial p_R^*} \mathrm{d}p_R^* < 0 .$$

This contractionary monetary policy implies that both member countries achieve *immediately* without any further dynamic adjustments the new (lower) steady state level of the outputs q_1 and q_2 *and* cyclical divergences within the monetary union are prevented because the common real interest rate remains with this policy tied to its initial level.[44] The reduction in the rate of monetary growth in response to the exogenous oil price shock does not only prevent temporary inflationary processes in the member countries but also lead to a permanent reduction in the rates of inflation $\dot{p}_1^c$ and $\dot{p}_2^c$. The restrictive monetary policy (21) is there-

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[42] In contrast to changes in the *growth rate* of the money stock $\dot{m}$, one-time changes in the *level* of the money stock m do *not* have any lasting effects on the real money stock. We therefore consider only changes in the *growth rate* in the discussion of monetary stabilization.

[43] This case prevails as long as b_5 is sufficiently large.

[44] Setting $\tilde{A}_2 = 0$ implies the following behavior of the aggregate $q = q_1 + q_2$ and the difference variable $q^d = q_1 - q_2$: $q \equiv \bar{q}_1 (< \bar{q}_0)$, $q^d \equiv \bar{q}^d = 0$ for all $t > 0$. Furthermore, $\dot{\tau} \equiv 0$ such that following (18) real interest rates also remain constant. This implicitly assumes that the *foreign* interest rate i^* remains unaffected by the price increase. An increase in the foreign interest rate i^* in response to the materials price increase leads in isolation to a permanent rise in the level of nominal and real interest rates in the union. This causes a permanent output

fore also consistent with the primary goal of ECB monetary policy of achieving price stability based on the consumer price index.

The stabilizing impact of the contractionary monetary policy (21) with respect to the aggregate system is illustrated in *Figure 6*. Viewed in isolation, an unanticipated oil price increase leads to the adjustment process $Q_0B^*Q_1$ while the stabilizing monetary policy (21) creates the opposite development of the state variables τ and *m-p* (adjustment path $Q_0\hat{B}Q_1'$). With the simultaneous and unanticipated occurrence of both shocks ($\mathrm{d}p_R^* < 0$, $\mathrm{d}\dot{m} < 0$), the aggregate system moves instantaneously into the new steady state Q_2. Q_2 is vertically below the initial equilibrium Q_0. In comparison, Q_2 is characterized by a fall in the terms of trade τ at an unchanged equilibrium real money stock *m-p*.

Figure 6 also illustrates the combined effects of the monetary policy reaction to *anticipated* oil price increases (T >0). In contrast with the case $T = 0$ monetary policy has to react *twice* in order to achieve stabilization of the complete system throughout the entire adjustment process. This is due to the fact that with anticipated shocks adjustment dynamics in the aggregate and difference system not only occur for $t>T$ but also *prior* to the implementation at T. Full system stabilization in the period $0 < t < T$ requires the credible announcement of a monetary policy, which exactly neutralizes the anticipation effects of the future price shock.[45] The anticipation of the future increase in p_R^* leads in the phase diagram (*Figure 6*) to the time path Q_0BC (for T "large") or $Q_0B'C'$ (for T "small"); the central bank designs its monetary policy such that the corresponding adjustment runs exactly opposite to Q_0BC (or $Q_0B'C'$), which is $Q_0\tilde{B}\tilde{C}$ (or $Q_0B''C''$). This requires at the date of anticipation $t = 0$ the credible announcement or the expectation by the private sector of a *restrictive* monetary policy at T of the following form:[46]

$$(22) \qquad \mathrm{d}\dot{m}^{ann.} = -\frac{1}{h_{12}l_2}\mathrm{d}\overline{\tau} + \frac{1}{l_2}\frac{\partial\overline{(m-p)}}{\partial p_R^*}\mathrm{d}p_R^* < 0$$

differential between the member country with the lower interest sensitivity of private absorption ($\mathrm{d}\overline{q}^d < 0$ or, respectively, $\mathrm{d}\overline{q}_1 < \mathrm{d}\overline{q}_2$) (see *Wohltmann* and *Clausen* 2001a).

45 More formally, in the solution of the state vector $(\tau, \ (m-p))'$ the constant A_2 (= $-A_1$) is set equal to zero.

46 (22) is more contractionary than (21) because the element h_{12} of the corresponding eigenvector is negative and due to $\mathrm{d}\overline{\tau} = \frac{\partial\overline{\tau}}{\partial p_R^*}\mathrm{d}p_R^* < 0$.

As long as this reaction of monetary policy in T is considered credible and therefore anticipated by the private sector, the aggregate as well as the difference system remain up to T in the initial steady state Q_0. The output variables $q = q_1 + q_2$ and $q^d = q_1 - q_2$ satisfy in the period $0 \le t < T$: $q = \bar{q}_0$ and $q^d = 0$. Moreover, inflation remains constant in this period ($\dot{p} = \dot{p}^c = \dot{m}_0$) such that the anticipation of the monetary policy reaction (22) avoids stagflationary developments within the monetary union, which are otherwise caused by the anticipation of the future increase in oil prices.

If the central bank *fully* implements the announced reduction in monetary growth and given that the oil price increases in T, the system moves in the period $t > T$ continuously according to the state vector $(\tau, \quad (m-p))'$ along the initial saddle path S_0 belonging to Q_0 to the new equilibrium in Q_0'. In comparison with the new steady state Q_1 in the case of a passive monetary policy ($\mathrm{d}\dot{m} = 0$), we find here a permanent *increase* in the real money stock.[47] In contrast with the case $\mathrm{d}\dot{m} = 0$, the real interest rate now increases in T[48] such that aggregate output $q = q_1 + q_2$ falls on impact below the new steady state level $\bar{q}_1 (< \bar{q}_0)$ and converges subsequently to $\bar{q}_1$ from below. The output differential $q^d = q_1 - q_2$ immediately falls in T due to the interest rate increase and the relatively stronger response of private absorption in U_1.[49] In contrast with the case of a passive monetary policy where the negative output differential already occurs at the date of anticipation $t = 0$, it is shifted here to the date implementation T. A complete stabilization in the period $t > T$, i.e., the removal of any adjustment dynamics, will only be achieved if monetary policy does *not* fully reduce the growth rate of the money stock as previously announced but conducts instead in T a *less restrictive* monetary policy. The required reduction in $\dot{m}$ is determined by the condition that both impulses taken together – the price shock and the policy response - do not change the equilibrium real money stock. Drawing on (20) and (21), the size of the reduction in $\dot{m}$ equals the case $T = 0$.

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47 Taken individually, the restrictive monetary policy announced in $t = 0$ and implemented in $T > 0$ generates the adjustment path $Q_0 \tilde{B} \tilde{C} \tilde{Q}_1$ (for T large) or $Q_0 B'' C'' \tilde{Q}_1$ (for T small). The necessary fall in the rate of growth of the money stock is *larger* than the policy response to an unanticipated shock (T=0). Correspondingly, the steady state-increase in the equilibrium money stock turns out to be higher ($\tilde{Q}_1$ in comparison with Q_1').

48 The movement of the aggregate system from Q_0 to Q_0' along the saddle path S_0 implies a continuous decline in the terms of trade τ ($\dot{\tau} < 0$). Eq. (18) then implies that the real interest rate exceeds throughout this period its steady state level $2i^*$.

49 A passive monetary policy ($\mathrm{d}\dot{m} = 0$) would lead in T to a fall in interest rates and therefore to a discontinuous increase in q^d.

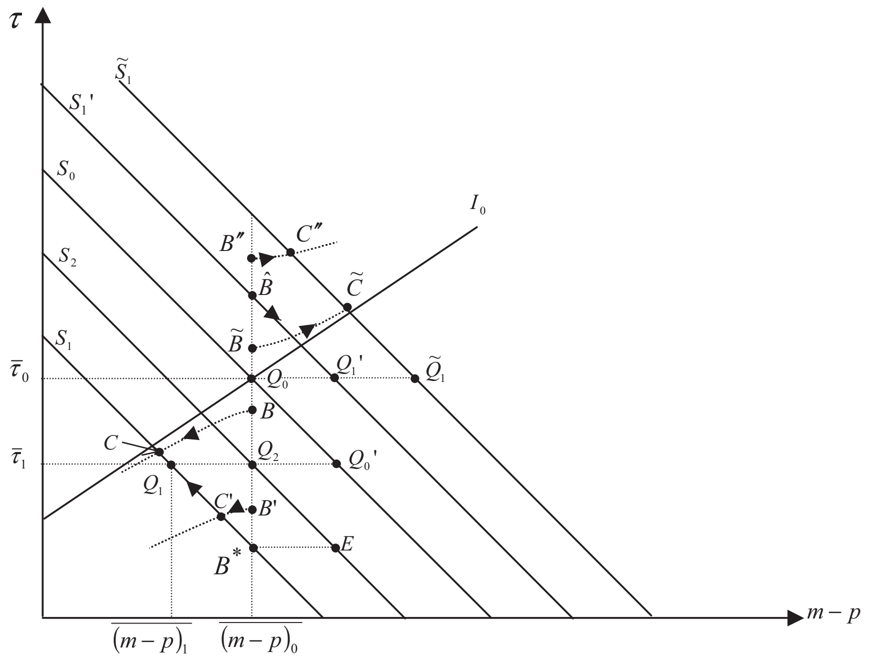

Figure 6: Monetary policy reactions to oil price increases

The phase diagram (*Figure 6*) shows that the deviation from the previously announced and therefore anticipated contractionary monetary policy implies that the state vector $(\tau, \quad (m-p))'$ jumps in T in response to both, the oil price increase and the correction of expectations by the private sector, vertically onto the saddle path S_1 into point B^*. The unanticipated changeover to a less restrictive monetary policy in T causes another vertical jump but now in opposite direction into Q_2. The aggregate variables remain constant afterwards and no further adjustment dynamics take place such that the point Q_2 – like in the special case $T = 0$ – represents the new final equilibrium of the system.[50] This two-stage monetary policy design also stabilizes the difference system completely, i.e., avoids any cyclical differences in output or price developments within the monetary union. Moreover, the rate of inflation within the monetary union is permanently reduced.

[50] Taken in isolation, the increase in the price of imported raw materials generates an adjustment path from B^* to Q_1 along the saddle path S_1. In contrast, the contractionary monetary policy (21) causes after the initial jump B^*Q_2 the mirror image adjustment process Q_2E along the somewhat higher located saddle path S_2. With both shocks occurring simultaneously, the aggregate system jumps immediately into the new steady state Q_2 and remains there thereafter.

The announcement or anticipation of the contractionary monetary policy (22) and the actual implementation of a *less* restrictive monetary policy means that in *quantitative* terms the behavior of monetary policy is *time inconsistent*. In contrast, monetary policy remains *time consistent* in *qualitative* terms because the previously announced and the actual course of monetary policy still move in the same direction. The quantitative deviation of the actual policy from the announced reaction function (22) does not seriously undermine the *reputation* of monetary policy (this holds the more as price stability as the primary goal of monetary policy is still achieved). Finally, the regime switch from the previously announced or expected monetary policy reaction (22) to the actual course followed (21) achieves complete stabilization. Business cycles at the aggregate level as well as cyclical differences within the monetary union resulting from anticipated increases in oil prices can be *completely* avoided.

The derivation of the policy decision rules (21) and (22) assumed that the increase in the oil price leads to price changes within the monetary union but leaves the foreign price level p^* unchanged. This assumption is unrealistic as, for example, the oil price hikes initiated by the OPEC countries caused increased inflation worldwide. Viewed in isolation, an anticipated and an unanticipated increase in the price of imported final goods ($\mathrm{d}p^* > 0$) incur adjustment dynamics at the aggregate level of the monetary union, which run opposite to previous effects of an oil price increase.[51] The *steady state* effects on real variables and relative prices in the system are quantitatively identical but opposite in sign provided that $dp^* = dp_R^*$.[52] In contrast to the case of oil imports, a price increase in imported final goods leads to jumps in the external terms of trade τ not only at the anticipation date but also at the date of implementation *T*. This stems from the fact that an increase in p^* leads per se due to $\tau = p - 2(p^* + e)$ to a discontinuous fall in τ.

Monetary stabilization in the *simultaneous* presence of price increases in intermediate and final goods requires the following: given the realistic assumptions that the oil price increase leads to an *underproportional* increase in the foreign price level ($\mathrm{d}p^* / \mathrm{d}p_R^* < 1$ or, re-

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[51] In contrast with the previous case $\mathrm{d}p_R^* > 0$, the constants A_1, A_2 and $\widetilde{A}_2$ now change their sign in the solution form of the state vector. The absolute values of the constants are *not* equal to those in the case $\mathrm{d}p_R^* > 0$. It follows that the adjustment dynamics in response to $\mathrm{d}p^* > 0$ are *not* an exact mirror image to the effects caused by an identical increase in the price of imported raw materials.

[52] In the case of sluggish price adjustment it follows that $\frac{\partial \overline{q}}{\partial p^*} = -\frac{\partial \overline{q}}{\partial p_R^*} > 0$, $\frac{\partial \overline{\tau}}{\partial p^*} = -\frac{\partial \overline{\tau}}{\partial p_R^*} > 0$ and $\partial(\overline{m-p}) / \partial p^* = -\partial(\overline{m-p}) / \partial p_R^* > 0$. Analogous results can be derived for the case of immediate price adjustment for the state variables τ_w and *m-w*.

spectively, $0 < \mathrm{d}p^* < \mathrm{d}p_R^*$) and lagged adjustment in the domestic price level, unanticipated *combined* foreign price shocks can be perfectly neutralized at the aggregate and the difference level by an adequate reduction in the rate of growth of the money stock. The policy reaction (21) is modified by replacing the isolated price shock $\mathrm{d}p_R^* > 0$ by the (quantitatively smaller) combined shock $\mathrm{d}p_R^* - \mathrm{d}p^* (> 0)$.[53] The required fall in the rate of growth of the money stock in response an unanticipated combined foreign price shock is *smaller* than with an isolated increase in oil prices.[54] With anticipated combined foreign price shocks ($T > 0$) the system can be stabilized in the period between the anticipation and the implementation of the foreign price increases by the credible announcement in $t = 0$ of a policy implemented in $T > 0$:[55]

$$\text{(23)} \qquad \mathrm{d}\dot{m}^{ann.} = -\frac{1}{h_{12} l_2}\left(\frac{\partial \overline{\tau}}{\partial p_R^*}(\mathrm{d}p_R^* - \mathrm{d}p^*) + 2\mathrm{d}p^*\right) + \frac{1}{l_2}\frac{\partial(\overline{m-p})}{\partial p_R^*}(\mathrm{d}p_R^* - \mathrm{d}p^*)$$

This policy rule for monetary growth implies a contractionary stance ($\mathrm{d}\dot{m}^{ann.} < 0$) when the oil price increase has a relatively *small* impact on the foreign price level p^*, i.e., as long as $\mathrm{d}p^* / \mathrm{d}p_R^*$ is sufficiently small. In this case, both terms in (23) are negative[56] and the monetary policy rule is *time consistent* in *qualitative* terms. If monetary policy pursues in T in order to stabilize the system *after T* a *less* contractionary stance than previously announced[57], the direction of monetary policy remains *unchanged*. In contrast, if $\mathrm{d}p^*$ is large relative to $\mathrm{d}p_R^*$ or the difference $\mathrm{d}p_R^* - \mathrm{d}p^*$ sufficiently small, we find $\mathrm{d}\dot{m}^{ann.} > 0$. The stabilization of the complete system requires the announcement of an expansionary but the later conduct of a contrac-

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53 The rule (21) is replaced by $\mathrm{d}\dot{m} = \frac{1}{l_2}\left(\frac{\partial(\overline{m-p})}{\partial p_R^*}\mathrm{d}p_R^* + \frac{\partial(\overline{m-p})}{\partial p^*}\mathrm{d}p^*\right) = \frac{1}{l_2}\frac{\partial(\overline{m-p})}{\partial p_R^*}(\mathrm{d}p_R^* - \mathrm{d}p^*) < 0,$ if $\mathrm{d}p_R^* > \mathrm{d}p^*$.

54 This is due to the fact that the adjustment dynamics following a foreign price increase in final goods $\mathrm{d}p^* > 0$ mirror those arising from $\mathrm{d}p_R^* > 0$, and, furthermore, due to our assumption $\mathrm{d}p_R^* > \mathrm{d}p^*$.

55 (23) simplifies with $\mathrm{d}p^* = 0$ to (22). The first expression in brackets in (23) can be rearranged to $\mathrm{d}\overline{\tau} + 2\mathrm{d}p^* = \left(\frac{\partial(\overline{p-2e})}{\partial p_R^*}\mathrm{d}p_R^* + \frac{\partial(\overline{p-2e})}{\partial p^*}\mathrm{d}p^*\right)$. The two multipliers $\frac{\partial(\overline{p-2e})}{\partial p_R^*}$ and $\frac{\partial(\overline{p-2e})}{\partial p^*}$ are quantitatively *not* identical.

56 The first expression in brackets in (23) is only negative, if $\mathrm{d}p^*$ is sufficiently small or, respectively, $\mathrm{d}p_R^* - \mathrm{d}p^*$ is sufficiently large.

57 The monetary policy actually conducted in T is identical to the case $T = 0$ and equals the second term in (23).

tionary monetary policy. Policy is time inconsistent in both, in quantitative and qualitative terms. This undermines the credibility of monetary policy and causes the central bank to lose reputation.

5. Summary and Implications

This paper investigates the dynamic effects of anticipated oil price increases in an asymmetric two-country model of a small monetary union. The union is characterized on the supply side by different wage setting behavior of trade unions and on the demand side by different interest sensitivities of private absorption. Wage setting behavior in U_1 is supposed to consider the growth of money supply in the union and is therefore fairly rigid with respect to other types of shocks (here taken as France), whereas wage growth in U_2 is linked to the short-run variation of the consumer price index with a higher degree of wage-price flexibility (here taken as Germany). Furthermore, private consumption in France (member country U_1) is supposed to respond more strongly to the interest rate than in Germany (country U_2). It is shown that a stagflationary process for the whole union starts even before the oil price increase takes place. Furthermore, as a result of the macroeconomic asymmetries cyclical divergences occur within the monetary union throughout the entire adjustment process. The direction of the cyclical divergence depends on the short-run reaction of the real interest rate. On impact, real interest rates increase and from the perspective of U_1 we find a negative cyclical differential within the monetary union.[58] In the subsequent adjustment process, the changes in the internal and external terms of trade of U_1 strengthen its international competitiveness and improve its relative cyclical position within the monetary union. At some stage during the adjustment process, even a complete reversal of the cyclical differential takes place. It happens at the latest when the price increase is implemented.

In the special case of an unanticipated price increase, the monetary union does *not* experience a cyclical reversal between the member countries. In the case of sluggish price adjustment, the output level q_1 in U_1 remains due to a relatively larger interest sensitivity of aggregate demand and to the fall in the level of real interest rates consistently *above* the output level q_2 in U_2.[59]

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[58] It can be shown that on impact the direction of the real interest rate change and, consequently, the direction of the cyclical divergence within the monetary union crucially depend on the asymmetry on the supply side. Given a symmetric setup in which wage setting in both countries is linked to consumer price inflation we find that the anticipation of a future price increase in imported raw materials leads on impact to a *fall* in the real interest rate and from the perspective of U_1 to a positive output differential.

[59] In the case of full price flexibility, real interest rates increase and q_1 remains *below* q_2 throughout the *entire* adjustment process. See for more details *Wohltmann* and *Clausen* (2003).

It is shown that the adjustment dynamics following of oil price increase (in particular, the stagflationary consequences) as well as cyclical divergences within the monetary union can be avoided by a countercyclical monetary policy.[60] In the case of an *unanticipated* increase in the oil price, sluggish price adjustment and the condition that the price level of imported final goods increases less than proportionately it is necessary to reduce the rate of monetary growth in the union. This policy response ensures that the output variable and the external terms of trade immediately attain their new (lower) long-run equilibrium values and a permanently lower rate of inflation in the union.

In the case of an *anticipated* increase in the oil price, complete stabilization in both periods, i.e., the period between the anticipation and the implementation as well as the period after the implementation, requires a *qualitatively time consistent* monetary policy, which on impact credibly announces for the date of implementation of the price increase a contractionary monetary policy taking the form of a reduction in the rate of monetary growth but reduces at the actual implementation date the monetary growth by a relatively *smaller* amount than the original announcement. The *direction* of the actual policy is consistent with the announced change such that the credibility of monetary policy remains intact. However, monetary policy encounters a time-inconsistency problem in the presence of anticipated oil price increases if it is accompanied by a sufficiently large increase in the price of imported final goods.

Overall, we show that even in the presence of asymmetric degrees of wage flexibility within the monetary union the competitiveness channel continues to work as an important equilibrating mechanism. Cyclical differentials within the monetary union incur differential wage and price developments, which render cyclical asymmetries to be self-correcting over time. This competitiveness channel is considered by the ECB as the main mechanism to correct cyclical imbalances within the monetary union (*ECB*, 2007, p. 80f). We show that despite the heterogeneity in the macroeconomic structures within the monetary union the competitiveness channel still contributes to the cyclical synchronization within the monetary union. This helps to explain the relatively small dispersion of output growth differentials within the euro area after the introduction of the euro (again see *ECB*, 2007).

Whether cyclical *reversals* take place in the course of the adjustment process, i.e., changes in the *relative* cyclical position of union member countries, generally depends (1) on the type

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[60] One attractive feature of our model is that the specification allows us to one-time changes in long-run price level and permanent changes in rate of monetary growth and inflation. It is evident that a one-time permanent increase in the oil price can ultimately only generate one-time changes in the long-run equilibrium price level, but not persistent stagflation. Our more general model in the tradition of *Buiter* and *Miller* (1982) allows for both, one-time changes in the price level and transitory effects on inflation but also for permanent changes in the rate of monetary growth and inflation.

of the underlying disturbance and (2) on the nature and composition of asymmetries in the transmission mechanism. It depends on the nature of disturbance because anticipated and unanticipated both imply cyclical differentials, but only anticipated oil price shocks lead to a cyclical reversal in the course of the adjustment process. After an unanticipated oil price increase, in contrast, output remains higher in country 1 relative to country 2 throughout the whole adjustment process. The dependence on the nature and composition of asymmetries can be illustrated by the following example. Unanticipated monetary policy leads in the simpler model with just asymmetric interest rate transmission by *Clausen* and *Wohltmann* (2005) *always* to a cyclical reversal. In this extended model including asymmetries on the supply as well as on the demand side, we find that unanticipated monetary policy does *not* lead to a cyclical reversal.

The fundamental adjustment mechanisms that govern the cyclical dynamics in response to common oil price shocks continue to operate in more realistic settings allowing for a larger set of different macroeconomic asymmetries across the Euro area member countries. However, the integration of further asymmetries requires numerical simulations, which go beyond the purpose and scope of the present paper. Another important issue not covered in this paper concerns the nature of the shock, supply versus demand. While the oil shocks in the 70s predominantly originated from the supply side, more recent price hikes emerge from strong growth in emerging economies, especially China. Obviously, the EMU member countries are not only affected by the oil price hikes per se but simultaneously also by other changes in the economic conditions in the global economy. The analysis of this question is left for future research.

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Appendix

Aggregate and Difference system

Using the decomposition method by *Aoki* (1981) the model (1)-(16) is transformed into the following set of equations using either aggregate or difference variables:

(A1) $\lambda \cdot q = g - 2a_2 i^* + 2b_3 y^* + a_2(1-\alpha_3)\dot{\tau} - (b_5 - (a_1 - b_1 + b_2)\psi)\tau$

$- 2(a_1 - b_1 + b_2)\psi(p_R^* - p^*) + k$

(A2) $y = q + \psi \cdot \tau + 2\psi(p^* - p_R^*) - 2c_0$

(A3) $m - p^c = 2l_0 + l_1 q - 2l_2(i^* + \dot{e})$

(A4) $p^c = p - \alpha_3 \cdot \tau$

(A5) $\dot{p} = \frac{1}{2}\mu(\dot{m} + \dot{p}^c) + \mu\delta(q - \overline{q}) + 2(1-\mu)(\dot{p}_R^* + \dot{e})$

(A6) $\overline{q} = 2f_0 + f_1\overline{\tau} + f_3\overline{(p - 2(p_R^* + e))}$

(A7) $æ_1 q^d = \tilde{a}_2(1-\alpha_3)\dot{\tau} - 2\tilde{a}_2 i^* + (g_1 - g_2) + (a_{01} - a_{02})$

$- ((2b_4 + b_5) - (a_1 - b_1 - b_2)\psi)p^d$

(A8) $y^d = q^d + \psi \cdot p^d$

(A9) $\dot{p}^d = \frac{1}{2}\mu(\dot{m} - \dot{p}^c) + \mu\delta(q^d - \overline{q}^d)$

(A10) $\overline{q}^d = (f_1 + 2f_2 + f_3)\overline{p}^d$

with

$\lambda = (1 - a_1 + b_1 - b_2)$, $æ_1 = (1 - a_1 + b_1 + b_2)$, $a_2 = \frac{1}{2}(a_{21} + a_{22})$,

$\tilde{a}_2 = \frac{1}{2}(a_{21} - a_{22}) > 0$, $k = a_{01} + a_{02} + 2b_0 - 2(a_1 - b_1 + b_2)c_0$, $\alpha_1 = \alpha_2$,

$q = q_1 + q_2$, $y = y_1 + y_2$, $\tau = \tau_1 + \tau_2$, $g = g_1 + g_2$, $p^c = p_1^c + p_2^c$,

$p_1^c = p_2^c$, $p = p_1 + p_2$, $q^d = q_1 - q_2$, $y^d = y_1 - y_2$, $p^d = p_1 - p_2$

The equations (A1)-(A6) describe the aggregate system while the equations (A7)-(A10) represent the difference system.

Model Reduction

The price adjustment equation (A5) yields in conjunction with (A4) the output equation

(A11) $$q-\overline{q}=\frac{1}{\mu\delta}\left(\left(\frac{1}{2}\mu\alpha_3+(1-\mu)\right)\dot{\tau}-\frac{1}{2}\mu(\dot{m}-\dot{p})+2(1-\mu)(\dot{p}^*-\dot{p}_R^*)\right)$$

The LM equation (A3) can be reformulated as

(A12) $$(m-p)-\overline{(m-p)}+\alpha_3(\tau-\overline{\tau})=l_2\dot{\tau}+l_2(\dot{m}-\dot{p})+l_1(q-\overline{q})$$

Using (A1), (A11) and (A12) we find the following state equations for the aggregate system

(A13) $$\begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}\begin{pmatrix} \dot{\tau} \\ \dot{m}-\dot{p} \end{pmatrix}=\begin{pmatrix} -\mu\widetilde{b}_5 & 0 \\ \alpha_3 & 1 \end{pmatrix}\begin{pmatrix} \tau-\overline{\tau} \\ (m-p)-\overline{(m-p)} \end{pmatrix}$$

where

$$b_{11}=\frac{\lambda}{\delta}\left(\frac{1}{2}\mu\alpha_3+(1-\mu)-\frac{\mu\delta}{\lambda}a_2(1-\alpha_3)\right),$$

$$b_{12}=-\frac{1}{2}\mu\frac{\lambda}{\delta},\qquad b_{21}=l_2+\frac{l_1}{\mu\delta}\left(\frac{1}{2}\mu\alpha_3+(1-\mu)\right),$$

$$b_{22}=l_2-\frac{1}{2}\frac{l_1}{\delta},\qquad \widetilde{b}_5=b_5-(a_1-b_1+b_2)\psi$$

The determinant of (A13) $\Delta=b_{11}b_{22}-b_{12}b_{21}$ is

(A14) $$\Delta=\frac{1}{2}\frac{\lambda}{\delta}\mu l_2(1+\alpha_3)+(1-\alpha_3)\mu a_2\left(\frac{1}{2}\frac{l_1}{\delta}-l_2\right)+\frac{\lambda}{\delta}(1-\mu)l_2$$

The explicit form of the state equations for the aggregate system (A13) is given by

(A15) $$\begin{pmatrix} \dot{\tau} \\ \dot{m}-\dot{p} \end{pmatrix}=\begin{pmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{pmatrix}\begin{pmatrix} \tau-\overline{\tau} \\ (m-p)-\overline{(m-p)} \end{pmatrix}$$

with

$$d_{11}=\frac{\mu}{\Delta}\left(\left(\frac{1}{2}\frac{l_1}{\delta}-l_2\right)\widetilde{b}_5+\frac{1}{2}\frac{\lambda}{\delta}\alpha_3\right),$$

$$d_{12} = \frac{1}{2}\frac{\mu}{\Delta}\frac{\lambda}{\delta} > 0,$$

$$d_{21} = \frac{1}{\Delta}\left(\left(\mu l_2 + \frac{l_1}{\delta}\left(\frac{1}{2}\mu\alpha_3 + (1-\mu)\right)\right)\widetilde{b}_5 + \alpha_3\mu\left(\frac{1}{2}\frac{\lambda}{\delta}\alpha_3 - a_2(1-\alpha_3)\right) + \frac{\alpha_3\lambda}{\delta}(1-\mu)\right),$$

$$d_{22} = \frac{1}{\Delta}\left(\mu\left(\frac{1}{2}\frac{\lambda}{\delta}\alpha_3 - a_2(1-\alpha_3)\right) + \frac{\lambda}{\delta}(1-\mu)\right)$$

The determinant $\Delta_1 = d_{11}d_{22} - d_{12}d_{21}$ of (A15) reduces to $\Delta_1 = -\mu\widetilde{b}_5 / \Delta$. In the case $\widetilde{b}_5 > 0$ and $\Delta > 0$, we obtain a negative determinant Δ_1 and the system (A15) displays the saddle path property. The real eigenvalues r_1 and r_2 belonging to the matrix (d_{ij}) follow from the well-known formula

(A16) $$r_{1,2} = \frac{1}{2}(d_{11} + d_{22}) \pm \sqrt{\frac{1}{4}(d_{11} + d_{22})^2 - \Delta_1}$$

Assuming $\Delta_1 < 0$ implies one unstable and one stable root, which we define as $r_1 > 0 > r_2$. The corresponding eigenvectors h_1 and h_2 are normalized as

(A17) $$h_1 = \begin{pmatrix} h_{11} \\ 1 \end{pmatrix}, \qquad h_2 = \begin{pmatrix} h_{12} \\ 1 \end{pmatrix}$$

with

$$h_{11} = \frac{d_{12}}{r_1 - d_{11}}, \; h_{12} = \frac{d_{12}}{r_2 - d_{11}}$$

We assume that $h_{11} > 0$ and $h_{12} < 0$.

An increase in the price of imported raw materials/intermediate goods ($\mathrm{d}p_R^* > 0$) or in imported final goods ($\mathrm{d}p^* > 0$), which is announced in $t = 0$ and implemented in $T > 0$, results in the following state vector $(\tau, \;\; m-p)'$, which describes the unique convergent time path from the initial equilibrium $(\bar{\tau}_0, \;\; \overline{(m-p)}_0)$ to the new long-run equilibrium $(\bar{\tau}_1, \;\; \overline{(m-p)}_1)$:[61]

[61] See *Wohltmann* and *Clausen* (2001a). The expression $e^{r_j t}$ in (A18) and (A19) represents $\exp(r_j t) \quad (j = 1,2)$.

(A18) $$\begin{pmatrix} \tau \\ m-p \end{pmatrix} = \begin{pmatrix} \overline{\tau}_0 \\ \overline{(m-p)}_0 \end{pmatrix} + A_1 h_1 e^{r_1 t} + A_2 h_2 e^{r_2 t} \qquad \text{for } 0 < t < T,$$

(A19) $$\begin{pmatrix} \tau \\ m-p \end{pmatrix} = \begin{pmatrix} \overline{\tau}_1 \\ \overline{(m-p)}_1 \end{pmatrix} + \widetilde{A}_2 h_2 e^{r_2 t} \qquad \text{for } t > T$$

with

(A20) $$\begin{aligned} A_2 &= \frac{1}{\chi} e^{r_2 T} \left(-(\mathrm{d}\overline{\tau} + 2\mathrm{d}p^*) + h_{12}\mathrm{d}\overline{(m-p)} \right) = -A_1 \\ \widetilde{A}_2 &= A_2 + \frac{1}{\chi} e^{r_1 T} \left((\mathrm{d}\overline{\tau} + 2\mathrm{d}p^*) - h_{11}\mathrm{d}\overline{(m-p)} \right) \\ \chi &= (h_{11} - h_{12}) e^{(r_1 + r_2)T} > 0 \end{aligned}$$

The constants A_1, A_2 and $\widetilde{A}_2$ are determined by three conditions: assuming price rigidity, the variable $m-p$ is predetermined and therefore required to remain continuous at $t = 0$ and $t = T$ while the jump variable τ satisfies at the date of implementation T the condition $\tau(T+) - \tau(T-) = -2\mathrm{d}p^*$.[62] In the special case $T = 0$, i.e., with unanticipated foreign price shocks, the solution time path is only given by (A19) where $\widetilde{A}_2 = -\mathrm{d}\overline{(m-p)}$. The steady state solution to the system (A15) is determined by $\dot{\tau} = 0 = \dot{m} - \dot{p}$. The steady state responses $\mathrm{d}\overline{(m-p)} = \overline{(m-p)}_1 - \overline{(m-p)}_0$ and $\mathrm{d}\overline{\tau} = \overline{\tau}_1 - \overline{\tau}_0$ to foreign price increases ($\mathrm{d}p_R^* > 0, \mathrm{d}p^* > 0$) can be derived from the total differential of the IS equation, the long-run supply function and the LM equation:

(A21) $$\begin{aligned} \lambda \mathrm{d}\overline{q} &= -\widetilde{b}_5 \mathrm{d}\overline{\tau} - 2(a_1 - b_1 + b_2)\psi(\mathrm{d}p_R^* - \mathrm{d}p^*) \\ \mathrm{d}\overline{q} &= (f_1 + f_3)\mathrm{d}\overline{\tau} + 2 f_3 (\mathrm{d}p^* - \mathrm{d}p_R^*) \\ \mathrm{d}\overline{(m-p)} &= -\alpha_3 \mathrm{d}\overline{\tau} + l_1 \mathrm{d}\overline{q} \end{aligned}$$

An isolated price increase in imported raw materials ($\mathrm{d}p_R^* > 0, \mathrm{d}p^* = 0$) leads in the steady state to $\mathrm{d}\overline{\tau} < 0$ and $\mathrm{d}\overline{(m-p)} < 0$. In this case we find $A_2 > 0$ while $\widetilde{A}_2$ turns out to be posi-

[62] The nominal exchange rate e is a component of τ and responds discontinuously only at the time of announcement $t = 0$. In the case $\mathrm{d}p^* = 0$, τ remains continuous in T.

tive (negative) for sufficiently small (large) values of T. In contrast, an isolated price increase in imported final goods ($\mathrm{d}p_R^* = 0, \mathrm{d}p^* > 0$) ultimately leads to $\mathrm{d}\overline{\tau} > 0$ and $\mathrm{d}\overline{(m-p)} > 0$. Correspondingly, $A_2 < 0$ and $\widetilde{A}_2 < 0$ ($\widetilde{A}_2 > 0$) for T sufficiently small (large).

Using (A19), the unique convergent saddle path for the aggregate system S follows as:

(A22) $\tau - \overline{\tau} = h_{12}\left((m-p) - \overline{(m-p)}\right)$

Due to $h_{12} < 0$ the saddle path has a negative slope in the phase diagram.

The difference system (A7)-(A10) can be reduced to the following dynamic equation governing the predetermined variable $p^d = p_1 - p_2$:

(A23) $\dot{p}^d = r_0(p^d - \overline{p}^d) + \frac{1}{2}\mu(\dot{m} - \dot{p}) + \mu\gamma_1\dot{\tau}$

with

$$r_0 = -\frac{\mu\delta}{æ_1}(2b_4 + b_5 - (a_1 - b_1 - b_2)\psi) < 0$$

$$\gamma_1 = \frac{1}{2}\alpha_3 + \frac{\delta}{æ_1}\widetilde{a}_2(1-\alpha_3) > 0$$

The state equation (A23) has the following solution:

(A24) $$p^d = \overline{p}_0^d + \mu(\gamma_1 h_{11} + \frac{1}{2})r_1 A_1 \frac{1}{r_1 - r_0}(e^{r_1 t} - e^{r_0 t}) + \mu(\gamma_1 h_{12} + \frac{1}{2})r_2 A_2 \frac{1}{r_2 - r_0}(e^{r_2 t} - e^{r_0 t}) \qquad \text{for } 0 < t < T$$

(A25) $$p^d = \overline{p}_0^d e^{r_0(t-T)} + \overline{p}_1^d(1 - e^{r_0(t-T)}) + \mu(\gamma_1 h_{11} + \frac{1}{2})r_1 A_1 \frac{1}{r_1 - r_0}e^{r_0 t}(e^{(r_1 - r_0)T} - 1) + \mu(\gamma_1 h_{12} + \frac{1}{2})r_2 A_2 \frac{1}{r_2 - r_0}e^{r_0 t}(e^{(r_2 - r_0)T} - 1) + \mu(\gamma_1 h_{12} + \frac{1}{2})r_2 \widetilde{A}_2 \frac{1}{r_2 - r_0}e^{r_0 t}(e^{(r_2 - r_0)t} - e^{(r_2 - r_0)T}) \qquad \text{for } t > T$$

where $\overline{p}_1^d = \overline{p}_0^d + \mathrm{d}\overline{p}^d$. This solution path is everywhere continuous.[63] In the case $\mathrm{d}p_R^* > 0$ or $\mathrm{d}p^* > 0$ we have $\mathrm{d}\overline{p}^d = 0$ because foreign price changes affect both member countries symmetrically in the long run.[64] We assume the initial values of corresponding variables in both member countries to be identical such that $\overline{p}_0{}^d = \overline{y}_0{}^d = 0$. As a result of asymmetric parameters in interest rate transmission ($\widetilde{a}_2 > 0$) the difference of IS equations (A7) requires in conjunction with $\overline{y}_0{}^d = 0$ the additional assumption $a_{01} > a_{02}$.

Cyclical differences within the union are described by the output differential $q^d = q_1 - q_2$. It follows from (A7) and $\dot{\tau}(0+) < 0$ (given $T > 0$) so that q^d falls on impact discontinuously:[65]

(A26) $$q^d(0+) = \frac{\widetilde{a}_2(1-\alpha_3)}{æ_1}\dot{\tau}(0+) < 0$$

The subsequent decline in the price level differential $p^d = p_1 - p_2$ generates a continuous increase in q^d.[66] The decline of the internal price differential p^d can be inferred from (A23):

(A27) $$\dot{p}^d(0+) = \frac{1}{2}\mu(\dot{m} - \dot{p})(0+) + \mu\gamma_1\dot{\tau}(0+) < 0$$

[63] See *Wohltmann* and *Clausen* (2001a) for the case without imported raw materials ($\mu = 1, \psi = 0$).

[64] In contrast, an increase in the level of foreign interest rates ($\mathrm{d}i^* > 0$) leads due to $\widetilde{a}_2 > 0$ and following (A7) and (A10) to $\mathrm{d}\overline{p}^d < 0$ and $\mathrm{d}\overline{q}^d < 0$.

[65] In the special case $T = 0$ we find $q^d(0+) > 0$ as a result of $\dot{\tau}(0+) > 0$.

[66] In the case that the difference in the semi-interest elasticities a_{21} and a_{22} is very large, q^d may even decline somewhat further after the initial discontinuous fall on impact. This case, however, is empirically very unrealistic and therefore considered irrelevant.