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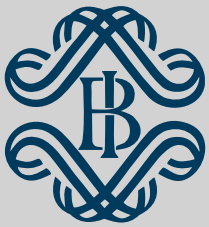

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CONVERGENCE OF INFLATION, PREREQUISITE FOR EMU

by

Lorenzo Bini Smaghi(*) and Paolo Del Giovane(*)

Abstract

This paper assesses the rationale of inflation convergence as a criterion for the passage to the final stage of EMU. It analyzes the consequences of irrevocably fixing exchange rates in the presence of diverging price performances. A simple two-country model is developed to examine the effects of the change in regime under different hypotheses concerning agents' expectations. Simulations are then conducted with the NIESR macroeconometric model. The results suggest that, under certain circumstances, the fixing of exchange rates may produce spillover effects from the high-inflation to the low-inflation country. If the Union's monetary authority seeks to counter these effects, the low-inflation country may suffer a reduction in its output.

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Introduction and summary of main conclusions[1]

Convergence of member countries' inflation rates is one of the prerequisites for the passage to the final stage of EMU. This paper provides a rationale for this criterion, with an analysis of the consequences of a move towards irrevocably fixed exchange rates in presence of diverging price performances.

The literature on the subject is not abundant. Numerous contributions concern the dynamic behaviour of economies under different exchange regimes, but little has been done to examine the effects of a shift from one regime to another. Some attention has been paid to the effects on a single country of joining an exchange rate agreement like the EMS, but mostly from a small-country perspective rather than a systemic view-point.

The paper analyzes the effects of locking exchange rates between large countries whose inflation rates have not fully converged. First, a very simple two-country model is developed to examine the change in regime under different hypotheses concerning agents' expectations. The results are then assessed on the basis of simulations done using the GEM macroeconometric model of the National Institute of Economic and Social Research (NIESR). Different assumptions concerning the reaction of economic agents to the change in regime are examined.

The analysis developed with the theoretical model suggests that the adjustment to the fixing of exchange rates depends on agents' behaviour in the financial and the labour

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1. We wish to thank G. Galli, J. Mélitz, F. Papadia and an anonymous referee for their comments, V. D'Ambrosio for the editing and J. Smith for revising the English version of the paper. Remaining errors are the authors'. Although the work is the result of a joint effort, L. Bini Smaghi is mainly responsible for Sections 1 and 2 and the Appedix, P. Del Giovane for the Introduction and Section 3.

markets. If agents adjust their behaviour in the two markets far enough in advance, exchange rate fixation results in an immediate convergence of inflation, with no repercussions on the two countries' real variables. However, if behaviour does not fully adjust ahead of time, inflation does not converge and the introduction of fixed exchange rates produces a shock to both economies. Specifically, given predetermined contracts, inflation could accelerate both in the high and in the low-inflation country. As a result the inflation rate of the Union rises. Only in the long run do the effects of the inflationary shock fade, and price convergence is achieved through slower economic growth in the country with initially higher inflation.

If the Union adopts a restrictive monetary policy to promote price stability and counteract the inflationary shock, output falls in both countries, and more sharply where inflation is lower. Therefore, the fixing of exchange rates between countries with differing price dynamics would tend to impose a cost in terms of economic growth on the lower-inflation one.

The simulations performed with the NIESR model tend to confirm the analytical results. We simulated the effects of fixing exchange rates between the three major European countries in January 1991, while inflation and interest rate differentials persisted. The results of this exercise depend on the behaviour of the exchange rate of the new Union's currency vis-à-vis the rest of the world, in particular the dollar. Assuming no change in this external rate, with respect to the baseline, the transition produces a progressive reduction of the rate of inflation in the high-inflation country and a slight increase in the low-inflation country. The average inflation rate for the area does not come close to that of the lowest-inflation country until five years after exchange rates are fixed. The current account balance of the whole area deteriorates..If the Union's currency is led to depreciate, because of the

current account deterioration, then the change in regime has a strong inflationary effect. In the high-inflation country, the simulation shows a higher inflation rate in the first two years. In the low-inflation country inflation rises permanently. If the Union's monetary authority responds by raising interest rates, growth in the low-inflation country is adversely affected.

The results of the simulations should be interpreted with care; they must not be considered as an attempt to quantify the degree of convergence on inflation and interest rates needed to avoid the repercussions of the transition to fixed exchange rates. The aim is rather to assess the direction of some of the effects of exchange rate fixation when inflation rates have not sufficiently converged. The results nevertheless tend to confirm that inflation and interest rate convergence is an important prerequisite for moving to irrevocably fixed exchange rates.

1. The model

A simple two-country, two-period model is developed:

Country A		Country B	
(1)	$m_t^d - p_t = -1/\lambda\ i_t$	(1′)	$m_t^{*d} - p_t^* = -1/\lambda\ i_t^*$
(2)	$y_t^s = \gamma(p_t - {}_{t-1}p_t)$	(2′)	$y_t^{*s} = \gamma(p_t^* - {}_{t-1}p_t^*)$
(3)	$y_t^d = -\sigma(i_t - ({}_tp_{t+1} - p_t)) - \delta(p_t - e_t - p_t^*)$	(3′)	$y_t^{*d} = -\sigma(i_t^* - ({}_tp_{t+1}^* - p_t^*)) + \delta(p_t - e_t - p_t^*)$
(4)	$y_t^s = y_t^d$	(4′)	$y_t^{*s} = y_t^{*d}$
(5)	$m_t^s = m_{t-1} + \mu_t$	(5′)	$m_t^{*s} = m_{t-1}^* + \mu_t^*$
(6)	$m_t^s = m_t^d$	(6′)	$m_t^{*s} = m_t^{*d}$

$$(7) \quad i_t = i_t^* + {}_te_{t+1} - e_t$$

The first equation defines the demand for money m as a function of the price level p, the rate of interest i and the long run (permanent) level of output assumed for simplicity equal to zero.[2] The second equation is a standard Lucas-supply function of income y, depending on the difference between the market-clearing level of prices p and the level anticipated in the previous period on the basis of all available information (rational expectations). Aggregate

---

2. The basic results obtained in the paper would not be changed by the introduction of income in equation (1) and (1′).

demand, defined in the third equation, is a function of the real interest rate and of the real exchange rate. The fourth equation defines the equilibrium in the goods market. The fifth equation defines the money supply process, μ being the rate of growth. Equation (6) defines the equilibrium in the money market. Equation (7) is the standard uncovered interest parity condition. All variables are expressed in logarithms, except the rate of interest. An asterisk refers to the variables of country B. For simplicity the two economies are assumed to be similar in structure, and the coefficients of the equations have the same value (all lower than one).

The basic characteristic of the model is its long-term neutrality: agents are assumed to have rational expectations, and only unexpected changes in the money supply temporarily affect the level of output. Assuming that money supplies grow at constant rates, $\mu_t=\mu$ and $\mu^*_t=\mu^*$, the price level varies homogeneously with them: prices grow at a rate equal to μ in country A and μ^* in country B. The exchange rate, which is obtained by solving equation (7), is determined in the long run by the relative ratios of money supply and demand in the two countries, in keeping with purchasing power parity. In the absence of shocks the exchange rate varies with the inflation differential between the two countries (see the Appendix for the solution of the model).

2. The effects of exchange rate fixation

The model of the previous section can be used to examine the transition from a flexible to a fixed exchange rate regime. It is assumed that until time t-1 the two economies have experienced constant rates of growth in the money supply, nil in country B ($\mu^*=0$), positive in country A ($\mu>0$). Therefore, until time t-1 inflation has been zero in country B and μ in country A; the exchange rate of currency

B, expressed in terms of currency A, has been appreciating at a rate μ. The values of p_{t-1}, p^*_{t-1} and e_{t-1} are normalized at zero for simplicity.

We can now examine the effects of a change in regime, deriving from the two countries' decision to fix the exchange rate at time t. With the fixation of exchange rates at time t, μ_t and μ^*_t become endogenous: monetary policy is determined by the monetary authorities of the Union, which are assumed to set the Union's rate of interest equal to that of the low inflation country before unification ($i_t=i^*_t=0$).[3] The effect on the two countries' economies depends crucially on the adjustment of agents' behaviour. Two hypotheses are considered in this respect: i) full convergence and ii) lack of convergence. The latter case is investigated on alternative assumptions of flexible and sticky contracts in the goods markets.

Assume first that the regime change, announced at time t-1, is fully incorporated in agents' behaviour. In particular, price expectations formed at time t-1 and afterwards take into account the fixing of the exchange rate at time t. In this case the inflation rate of country A falls to the level prevailing in country B (zero) so that when the exchange rate is fixed there is perfect convergence (see Appendix, Section 2). The same occurs for the interest rate. As a consequence of full convergence, the adjustment in the nominal variables has no effect on country A's output, since it is fully anticipated, or on country B's:

$$p_t = p^*_t = 0$$
$$y_t = y^*_t = 0 \qquad (8)$$

3. Alternative assumptions can be made on the single monetary policy of the System. However, the assumption that interest rates are equalized remains valid, since the fixed exchange rates are credible thereafter, and therefore there are no devaluation expectations.

Consider now the case in which agents' behaviour fails to converge beforehand. This might be due either to the fact that the decision to fix the exchange rate is not announced in advance or that until actually implemented it is not credible.

An assumption must be made on the degree of stickiness of contracts in the goods market. Assume first that all the contracts previously entered into (on the basis of the expectation that the exchange rate would not be fixed) expire when the fixing takes place and that the new contracts for time t+1 are set on the basis of the expectation that exchange rates are irrevocably fixed thereafter. Solving the system of equations (1)-(6) under the hypothesis that the rate of interest in country A is set equal to that of country B (Appendix, Section 3):

$$
(9) \qquad \begin{aligned} p_t &= \frac{\gamma A}{A^2-\delta^2} \quad \mu > 0 \\ y_t &= \frac{-\gamma(\sigma A+\delta(\gamma+\sigma))}{A^2-\delta^2} \quad \mu < 0 \end{aligned}
$$

where $A = (\gamma+\sigma+\delta)$.

At time t prices in country A increase; inflation therefore remains positive, although lower than before the change in regime (μ). This is due to the fact that the prices set at time t are based on expectations formed at time t-1, which do not incorporate the change in regime. However, in the long run (time t+1) price expectations adjust and country A's price level falls to its long-term equilibrium level.[4] Country A's output temporarily decreases at time t, since

4. It should be noted that money supply increases in country A at time t because of the one-off rise in money demand deriving from the reduction in the interest rate (see Appendix).

the increase in the price level at time t is lower than expected. In short, if a country enters monetary Union without fully convergent inflation, it may experience a temporary recession.

It is equally important to assess the effects of the fixation of exchange rates on country B:

$$
\begin{aligned}
p_t^* &= \frac{\gamma\,\delta}{A^2-\delta^2}\,\mu > 0 \\
y_t^* &= \frac{\gamma^2\,\delta}{A^2-\delta^2}\,\mu > 0
\end{aligned}
\tag{10}
$$

The fixing of the exchange rate produces a temporary inflationary effect in country B. Output rises because of the depreciation of the real exchange rate which increases the demand for country B goods and more than offsets the negative effect of the increase in the real interest rate. In the long run (t+1) country B's output and price level return to their pre-Union level.

Assume now that at the time the exchange rate is fixed contracts in the goods market expiring afterwards have already been negotiated (under the expectation that exchange rates would not be fixed) and cannot be revised.[5] In the model this implies that price expectations for time t+1 do not take into account the decision to fix the exchange rate. In the financial market, however, interest rates adjust instantaneously. Solving the model yields (Appendix, Section 4):

$$
\begin{aligned}
p_t &= \frac{(\gamma+2\sigma)A}{A^2-\delta^2}\,\mu > 0 \\
y_t &= \gamma\left[\frac{(\gamma+2\sigma)A}{A^2-\delta^2} - 1\right]\mu \gtrless 0
\end{aligned}
\tag{11}
$$

---

5. A similar analysis is conducted for a small-country case in Miller-Sutherland (1990), who formalize this assumption in a continuous time model with staggered wages, as in Calvo (1983).

The fixing of the exchange rate induces a rise in the price level that may be greater than without the change in regime (if $\sigma(\gamma+\sigma)>\gamma\delta$); as a result the inflation rate in country A may increase and output rise. This is a temporary effect since in the long run prices and output move back towards their pre-Union levels.

This result is similar to that obtained by Giavazzi-Spaventa (1990b) and Miller and Sutherland (1990) in the analysis of the EMS, on the assumption that financial markets adjust more rapidly than labour markets to the strong currency option.[6] The drop in real interest rates in the high-inflation country stimulates domestic demand, but this effect is counterbalanced by the adverse impact on net exports of the loss of competitiveness due to the appreciation of the real exchange rate. Although the expansionary effect may initially outweigh the contractionary, in the longer term the latter prevails and inflation rates converge.

Country B's price level and output also increase:

$$(12) \qquad p_t^* = \frac{\delta(\gamma+2\sigma)}{A^2-\delta^2}\,\mu > 0 \qquad y_t^* = \frac{\gamma\delta(\gamma+2\sigma)}{A^2-\delta^2}\,\mu > 0$$

The inflation rate of the Union, which is the average of the two countries' inflations, temporarily increases:

$$(13) \qquad p_t^u - p_{t-1}^u = 1/2\,(p_t+p_t^*) = (1/2)\,\frac{\gamma+2\sigma}{\gamma+\sigma}\,\mu > (1/2)\mu$$

---

6. The effects of EMS membership on agents' expectations and on the equilibrium inflation rate have been analyzed by Collins (1988), Giavazzi-Giovannini (1988), Giavazzi-Pagano (1988).

If the monetary authority of the Union aims at ensuring price stability, it will counter the inflationary pressure with a restrictive monetary policy. The Union's interest rate is no longer set at the level prevailing in the low inflation country before the exchange rate fixation, as in the previous cases, but at a level consistent with price stability ($p_t^u=0$). On this hypothesis, solving the model leads to the following values at time t (Appendix, Section 5):[7]

$$
(14)\qquad \begin{cases} i_t = i_t^* = 1+\gamma/(2\sigma) & \mu > 0 \\ p_t = \dfrac{\gamma+2\sigma}{2(A+\delta)} & \mu > 0 \\ p_t^* = \dfrac{-(\gamma+2\sigma)}{2(A+\delta)} & \mu < 0 \\ y_t = \dfrac{-\gamma(\gamma+4\delta)}{2(A+\delta)} & \mu < 0 \\ y_t^* = \dfrac{-\gamma(\gamma+2\sigma)}{2(A+\delta)} & \mu < 0 \end{cases}
$$

When the central monetary institution aims at ensuring price stability in the Union, the interest rate must increase; this has adverse effects on output in country B. In country A prices still increase, although by less than in the previous case, and output falls by more than in the hypothesis of no restrictive monetary policy.

In short, if the locking of exchange rates has not been fully incorporated into agents' behaviour and inflation performance is still divergent, the change in regime has repercussions on prices and output in the two countries.

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7. For simplicity, we assume that the monetary authority sets the monetary policy with the objective of stabilizing the price level at time t. This presumes, in this simple model, that it has superior information so that it can affect monetary conditions before prices are set at time t, this not being incorporated in agents' expectations at time t-1.

Inflation tends to rise in country B, and possibly in country A as well. To curb inflation the monetary authority of the Union would have to adopt a more restrictive policy, which would raise interest rates. As a result country B would suffer a temporary recession, which provides a rationale for the unwillingness on the part of country B to fix exchange rates unless country A has fully converged in terms of inflation and interest rates.

3. Empirical analysis

To assess the effects examined in the previous section we chose to conduct several simulations with a quarterly econometric model (GEM, developed by the National Institute of Economic and Social Research, NIESR).[8] GEM, having a block of about 60 equations for each of the seven major industrialized countries, is clearly a more sophisticated tool than the simplified model described in the previous sections.[9] In particular, it includes a detailed treatment of trade relationships and allows for exchange rate adjustments to correct, in the long run, current account imbalances. It also allows for different risk premia for each currency; this implies that the interest rate differentials need not coincide with the expected rates of depreciation. The model incorporates short-term nominal rigidities in the goods and labour market, while it has the usual neoclassical

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8. See NIESR (1991).

9. Other OECD countries and non-OECD countries are given less detailed treatment. GEM is used by the NIESR to make quarterly forecasts for the world economy and to run simulations. It has been used to examine possible regimes of international policy coordination using optimal control techniques (Currie-Wren-Lewis, 1989) and to analyze the implications of European Monetary Union (Barrell, 1990; Barrell-Gurney-In T'Veld, 1991) and of a wider use of a European currency (Barrell et al., 1990).

properties in the long run.

The exercises are evaluated against the technical baseline scenario, running from 1991 to 1999 which reflects consensus forecasts at the beginning of 1991 (when the version of GEM used in the paper was published): inflation convergence between France and Germany is achieved in the course of 1991; however, the interest rate differential between these two countries remains positive (by about 1 percentage point on average) in the first five years of the simulation and falls to zero afterwards; the inflation differential between Italy and Germany is around 3 percentage points in 1991 and narrows slowly to half a point at the end of the century; the interest rate differential remains about 1 percentage point higher than the inflation differential in the first five years, falling from around 4 points in 1991 to 0.5 in 1999; the exchange rates between DM, dollar and French franc are assumed constant for the whole period, while the lira is assumed to depreciate with respect to the mark about half the inflation differential between the two countries.

In the simulations described in the following sections the exchange rates between Germany, France and Italy are irrevocably fixed from the beginning of 1991 and the commitment is assumed to be fully credible for financial agents, so that interest rates in the three countries are instantaneously equalized. From the time exchange rates are fixed, a single authority is responsible for monetary policy for the whole area, and in particular for the determination of the common interest rate.[10]

We consider that the fixed exchange rates are also fully credible in labour markets but that previous contracts

---

10. For simplicity's sake, the United Kingdom, Belgium and the Netherlands are not considered in the simulations, although they are included in GEM. Exogenous variables for these countries are left unchanged with respect to the baseline. Current balance data for Germany apply to the whole of Germany, other data to western Germany only.

are not renegotiated. The change in inflation expectation is taken into account in the manufacturing wage equation for Italy, so that Italian nominal wages are set in 1991 as if they were based on expected German inflation rather than on lagged Italian inflation. Ex-post compensation is allowed for to keep real wages unchanged. The lag structure of wage and price equations is not modified, allowing for contractual rigidities.

We perform three exercises, which differ according to the assumptions regarding the exchange rate of the Union's currency vis-à-vis the rest of the world and the response of the monetary policy authorities after exchange rates are fixed.

The first simulation assumes that at the moment exchange rates are fixed interest rates in the three countries line up at the lowest level, that of Germany: interest rates decrease by 4.4 and 1.8 percentage points in Italy and France, respectively, in the first year of the simulation; the average interest rate of the area decreases by 2.1 points (Table 4). The results depend on the assumption made concerning the exchange rate of the Union's currency vis-à-vis the rest of the world. According to the simple theoretical model presented in the previous section, extended to three countries, the fixing of exchange rates between the first two countries does not imply any change in the exchange rate of the low-inflation currency vis-à-vis the third country if the latter has a similar inflation rate.[11]

We therefore start by assuming an unchanged

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11. This follows intuitively from the interest parity condition. Assume that the interest rate of the rest of the world is equal to that of country B, the low inflation country ($i^{w}_{t}=i^{*}_{t}=0$), and therefore that the exchange rate between country B and the rest of the world is constant from time t onwards: it follows that the exchange rate between country A and the latter is also constant and therefore the exchange rate of the Union's currency is constant with the rest of the world.

exchange rate of the DM with the rest of the world, in particular the dollar. The results of the simulation, shown in Table 1, suggest that in the first year of the simulation there are no major changes with respect to the baseline: inflation is unchanged in all countries, while GDP growth increases slightly in Italy. From the second year Italian output growth rises substantially, reflecting the real interest rate reduction, while the inflation rate starts falling towards that of the other two countries. The inflation rate of the Union converges to that of the baseline in Germany by the fifth year of the simulation. However, the Italian inflation rate does not fall fast enough to avoid a competitiveness loss, and the Italian current account deteriorates markedly. Germany, on the other hand, experiences a small improvement of its current balance; overall, the Union's current account deteriorates progressively (by about 20 billion dollars by the fifth year, corresponding to 0.4 per cent of the Union's GDP). This result suggests that the assumption of a constant external exchange rate might not be entirely appropriate.

In the second simulation the exchange rate of the Union's currency is assumed to depreciate, to comply with the constraint that in the long run the current account returns to the baseline value: this implies a depreciation of about 10 per cent by the end of the first year, with respect to the baseline. The results are shown in Table 2. The Italian inflation rate rises in the first two years and falls with respect to the baseline only from the third year on. In France and Germany inflation remains permanently higher than the baseline. The inflation differential between Italy and Germany shrinks to 0.1 points in the fifth year (against 1.1 percentage points in baseline) and disappears in the following years. However, this is partly due to the rise in German and French inflation rates; the Union's rate of inflation is higher than the area average in the baseline, and much higher than the baseline rate for Germany.

The rates of growth of the three economies increase significantly. In Italy the increase is slightly more marked and persistent than in the first simulation. The Italian deficit on current account is compensated by other countries' surpluses, favoured by the depreciation of the Union's currency.

The third simulation, whose results are given in Table 3, is based on the assumption that the new central monetary authority adopts a restrictive monetary policy to counter the inflationary effects described in the previous exercise. The target is to bring average inflation for the Union close to that of the lowest-inflation country. This entails a rise in the Union's rate of interest to 10.4 per cent in the first year, against 8.6 per cent in the first simulation. With respect to the baseline, this implies a rise of 1.8 points in Germany and a reduction of 2.6 points in Italy. Following the open parity condition, the Union's currency initially appreciates, by an amount equal to the cumulated interest rate differential with respect to the previous simulations, and subsequently depreciates in keeping to the uncovered interest parity condition, to return to the base level by the end of the fifth year of the simulation (Table 4).

In Germany and in France GDP growth in the first year falls by 0.8 and 0.3 points, respectively. Growth then improves, but the economy returns to the baseline level of output only after the sixth year of the simulation. Italian GDP growth is slower in the first year (by 0.1 points), but faster in the following five years (by 0.6 points on average). This is due to the exchange rate adjustment process and to the effect of the interest rate reduction on domestic demand, which grows at a rate significantly higher than in the baseline for the first three years.

In all three countries the inflation rate decreases with respect to the baseline, and the average inflation rate of the Union converges rapidly toward that of the

lowest-inflation country, as desired. The differential with respect to Germany's baseline inflation shrinks to 0.5 points in the first year (as against 0.9 in baseline), and is eliminated thereafter. The reduction in the average rate is accompanied by an acceleration of the convergence process: the inflation differential between Italy and Germany vanishes in the fifth year.

Intra-Union current account disequilibria are smaller than in the first simulation. The worsening of the Italian balance is offset by the improvement of the German and, to a lesser extent, the French current account, so that the overall Union's balance returns to the baseline value at the end of the simulation period.

In summary, the results of the simulations tend to confirm the analysis conducted with the theoretical model. In the presence of contractual rigidities that cannot be instantaneously removed at the time exchange rates are fixed, the move towards monetary union with divergent inflation rates tends to produce an inflationary shock. From an empirical point of view, the amplitude of this shock depends largely on the behaviour of the exchange rate of the Union's currency with respect to the dollar. The simple theoretical model developed in Section 1, based on the open parity condition, suggests that if inflation rates in the US and Germany are similar the locking of the intra-Union exchange rates should not affect the DM-dollar rate. However, this simple theoretical model leaves out other effects, in particular on the balance of payments of the Union, whose importance emerges from the simulations conducted with the econometric model. These effects tend to depreciate the exchange rate of the Union's currency if the change in regime occurs in conditions of imperfect convergence, exacerbating the inflationary effects of the transition. If the monetary authority adopts a restrictive policy to counter such a shock, the countries with lower inflation will suffer a temporary loss in terms of output and employment.

APPENDIX

1. Solution of the model with no regime change

First, the model is solved for the case in which no regime change occurs and the exchange rate continues to fluctuate. After simple substitutions, the equilibrium condition of supply and demand in the two countries can be rewritten as follows:

$$\gamma(p_t - {}_{t-1}p_t) = -\sigma(\lambda(p_t - m_{t-1} - \mu_t) - ({}_tp_{t+1} - p_t)) - \delta(p_t - e_t - p_t^*)$$

$$\gamma(p_t^* - {}_{t-1}p_t^*) = -\sigma(\lambda(p_t^* - m_{t-1}^* - \mu_t^*) - ({}_tp_{t+1}^* - p_t^*)) + \delta(p_t - e_t - p_t^*) \quad \text{(A1)}$$

Assuming that for any t:

$$\mu_t^* = i_t^* = 0$$

$$\mu_t = \mu \quad \text{(A2)}$$

and using the normalization at time t-1:

$$p_{t-1} = p_{t-1}^* = e_{t-1} = 0 \quad \text{(A3)}$$

the system reduces to:

$$(\gamma + \sigma(1+\lambda))p_t = \sigma\lambda m_{t-1} + \sigma\lambda\mu + \gamma_{t-1}p_t + \sigma_t p_{t+1} \quad \text{(A4)}$$

Solving with the method of undetermined coefficients, we obtain:

$$e_t = p_t = \mu$$

$$p_t^* = 0 \quad \text{(A5)}$$

This implies that $p_t - {}_{t-1}p_t = p_t^* - {}_{t-1}p_t^* = 0$ and, given equations (2) and (2'):

$$y_t = y_t^* = 0$$

2. Regime change with full convergence

If the authorities announce at time t-1 that the exchange rate will be irrevocably fixed at time t, the money supply (i.e. μ_t and μ_t^*) becomes endogenous. It is assumed for simplicity that monetary policy is determined so that $i_t = i_t^* = 0$. If agents adjust their expectations accordingly from time t-1 we have:

$$\begin{aligned} &{}_{t-1}p_t = {}_{t-1}p_t^* = 0 \\ &{}_{t}p_{t+1} = {}_{t}p_{t+1}^* = 0 \qquad \text{(A6)} \\ &{}_{t}e_{t+1} = e_t = e_{t-1} = 0 \end{aligned}$$

Substituting into (A1), we obtain:

$$\begin{aligned} &(\gamma+\sigma+\delta)\, p_t - \delta p_t^* = 0 \\ &-\delta p_t + (\gamma+\sigma+\delta)\, p_t^* = 0 \end{aligned} \qquad \text{(A7)}$$

which implies:

$$\begin{aligned} &p_t^* = p_t = 0 \\ &\mu_t = \frac{1}{\lambda}\,\mu \qquad \text{(A8)} \\ &\mu_t^* = 0 \end{aligned}$$

Substituting for $p_t - {}_{t-1}p_t = p_t^* - {}_{t-1}p_t^* = 0$ in (2) and (2'), yields

$$y_t^* = y_t = 0.$$

3. Regime change with imperfect convergence

If the exchange rate is fixed at time t while agents' behaviour has not previously adapted -- in particular if price' expectations set at time t-1 for time t are still divergent -- but adjust at time t, we have:

$$\begin{aligned} {}_{t-1}p_t &= \mu \\ {}_tp_{t+1} &= 0 \\ {}_te_{t+1} &= e_t = e_{t-1} = 0 \end{aligned} \tag{A9}$$

Substituting into (A1) we obtain:

$$\begin{aligned} (\gamma+\sigma+\delta)p_t - \delta p_t^* &= \gamma\mu \\ -\delta p_t + (\gamma+\sigma+\delta)\, p_t^* &= 0 \end{aligned} \tag{A10}$$

which can be solved for p_t, p_t^*, μ_t and μ_t^*:

$$\begin{aligned} p_t &= \frac{\gamma A}{A^2-\delta^2}\,\mu \\ p_t^* &= \frac{\gamma\delta}{A^2-\delta^2}\,\mu \\ \mu_t &= \frac{(A^2-\delta^2) + \lambda\gamma A}{\lambda(A^2-\delta^2)}\,\mu \\ \mu_t^* &= \frac{\gamma\delta}{A^2-\delta^2}\,\mu \end{aligned} \tag{A11}$$

where $A = \gamma+\sigma+\delta$.

Substituting for p_t and p_t^* into (2) and (2'), we obtain the solutions for y_t and y_t^*:

$$y_t = \frac{-\gamma(\sigma A+\delta(\gamma+\sigma))}{A^2-\delta^2}\,\mu \quad < 0$$

$$y_t^* = \frac{\gamma^2\delta}{A^2-\delta^2}\,\mu \quad > 0$$

4. Regime change with imperfect convergence and contract rigidities

If the exchange rate is fixed at time t while agents' behaviour does not adjust -- price expectations for time t and time t+1 do not incorporate the regime change -- we have:

(A12) $$ {}_tp_{t+1} = 2\mu$$

Substituting into (A1), we obtain:

(A13)
$$(\gamma+\sigma+\delta)p_t - \delta p_t^* = (\gamma+2\sigma)\mu$$
$$-\delta p_t + (\gamma+\sigma+\delta)\, p_t^* = 0$$

which can be solved for p_t, p_t^*, μ_t and μ_t^*:

(A14)
$$p_t = \frac{(\gamma+2\sigma)A}{A^2-\delta^2}\,\mu$$
$$p_t^* = \frac{\delta(\gamma+2\sigma)}{A^2-\delta^2}\,\mu$$
$$\mu_t = \frac{(A^2-\delta^2) + \lambda(\gamma+2\sigma)A}{\lambda(A^2-\delta^2)}\,\mu$$
$$\mu_t^* = \frac{\delta(\gamma+2\sigma)}{A^2-\delta^2}\,\mu$$

p_t can be greater than μ, depending on the value of the parameters of the model, i.e. $\sigma(\gamma+\sigma) \gtrless \gamma\delta$.

Note that the average inflation rate of the Union rises after the change in regime since:

$$1/2\ (p_t + p_t^*) = 1/2 \left(\frac{\gamma+2\sigma}{\gamma+\sigma}\right) \mu > 1/2\ \mu$$

Substituting for p_t and p_t^* in (2) and (2'), we obtain:

$$y_t = \gamma\left[\frac{(\gamma+2\sigma)A}{A^2-\delta^2} - 1\right] \mu \gtrless 0 \text{ depending on } p_t \gtrless \mu$$

$$y_t^* = \frac{\gamma\delta(\gamma+2\sigma)}{A^2-\delta^2}\ \mu > 0$$

5. Change in regime with restrictive monetary policy

Following the results of the previous case, if the authorities aim at stabilizing the price level of the Union after the exchange rates have been fixed, the following assumptions are made:

(A15) $$p_t + p_t^* = 0$$

Substituting into (A1) yields

(A16)
$$A\ p_t = (\gamma+2\sigma)\mu - \sigma i_t + \delta p_t^*$$
$$A\ p_t^* = -\sigma i_t + \delta p_t$$

which can be solved using (A15)

$$p_t = \frac{\gamma+2\sigma}{2(A+\delta)}\ \mu$$

$$p_t^* = -\frac{\gamma+2\sigma}{2(A+\delta)}\ \mu$$

(A17) $$i_t = i_t^* = (1 + \frac{\gamma}{2\sigma})\ \mu$$

$$\mu_t = \frac{\lambda\sigma(\gamma+2\sigma)-\gamma(A+\delta)}{2\lambda\sigma(A+\delta)}\ \mu$$

$$\mu_t^* = \frac{-(\gamma+2\sigma)(\lambda\sigma+A+\delta)}{2\lambda\sigma(A+\delta)}\ \mu$$

Substituting into (2) and (2′):

$$y_t = -\frac{\gamma(\gamma+4\delta)}{2(A+\delta)}\ \mu < 0$$

$$y_t^* = -\frac{\gamma(\gamma+2\sigma)}{2(A+\delta)}\ \mu < 0\ .$$

Table 0

BASELINE

Year	GDP (1)				Consumer prices (1)				Current account (2)				Unemployment rate			
	G	F	I	Weighted average (3)	G	F	I	Weighted average (3)	G	F	I	Sum (4)	G	F	I	Weighted average (5)
1	2.9	1.8	1.0	2.0	3.5	3.2	6.6	4.4	39	-8	-16	15	6.0	8.9	11.5	8.6
2	2.7	2.3	1.8	2.3	3.0	2.8	5.4	3.7	39	-7	-8	24	5.5	8.8	12.2	8.6
3	2.7	2.4	2.0	2.4	2.9	2.9	4.5	3.4	24	-9	-6	9	5.2	8.7	12.7	8.6
4	2.9	2.4	2.2	2.5	2.8	2.8	4.2	3.3	9	-12	-5	-7	4.8	8.7	13.0	8.5
5	2.9	2.4	2.5	2.6	2.7	2.7	3.8	3.1	-2	-13	-4	-19	4.4	8.6	12.9	8.3
6	2.8	2.4	2.8	2.7	2.6	2.6	3.5	2.9	-7	-14	-4	-25	4.0	8.5	12.9	8.1
7	2.7	2.3	3.1	2.7	2.5	2.5	3.3	2.8	-12	-14	-5	-31	3.5	8.4	12.5	7.8
8	2.5	2.1	3.1	2.5	2.5	2.5	3.2	2.7	-17	-11	-5	-33	3.0	8.4	12.0	7.4
9	2.0	1.9	2.9	2.2	2.5	2.5	3.1	2.7	-17	-6	-5	-28	2.4	8.3	11.5	7.0

(1) Annual growth rates.
(2) Billions of dollars.
(3) Based on the 1989 shares of GDP or private consumption of each country with respect to the whole area; source: OECD.
(4) Sum of the balances of the three countries considered.
(5) Based on the 1990 shares of labor force of each country with respect to the whole area; source: OECD.

Table 1

SIMULATION 1 – UNION'S INTEREST RATE EQUAL TO GERMANY'S BASELINE RATE; CONSTANT EXCHANGE RATE WITH EXTERNAL CURRENCIES
(difference with respect to the baseline)

Year	GDP (1)				Consumer prices (1)					Current account (2)				Unemployment rate			
	G	F	I	Union (3)	G	F	I	Union (4)	(5)	G	F	I	Union (6)	G	F	I	Union (7)
1	0.1	–	0.3	0.1	–	–	-0.1	–	0.9	1	-1	-3	-3	–	–	–	–
2	0.2	0.3	1.2	0.5	–	0.1	-0.7	-0.2	0.5	3	-1	-12	-10	-0.1	–	-0.2	-0.1
3	0.1	0.2	1.3	0.5	0.1	0.2	-0.8	-0.1	0.4	5	-1	-19	-15	-0.1	-0.1	-0.6	-0.2
4	–	0.1	1.2	0.3	0.1	0.1	-0.8	-0.2	0.3	5	-1	-23	-19	-0.1	-0.1	-1.1	-0.3
5	–	0.1	0.5	0.2	0.1	0.2	-0.8	-0.2	0.2	6	-1	-25	-20	-0.2	-0.1	-1.5	-0.4
6	–	-0.1	0.3	–	0.1	0.1	-0.7	-0.2	0.1	6	-1	-28	-23	-0.2	-0.1	-1.8	-0.6
7	-0.1	-0.1	-0.1	-0.1	0.1	0.1	-0.7	-0.2	0.1	5	1	-28	-22	-0.2	-0.1	-1.9	-0.6
8	-0.1	-0.1	-0.1	-0.1	0.1	0.1	-0.7	-0.1	0.1	6	1	-30	-23	-0.2	-0.1	-1.8	-0.5
9	–	–	-0.1	–	–	–	-0.7	-0.2	–	6	1	-32	-25	-0.3	-0.1	-1.7	-0.6

(1) Percentage points, annual growth rates.
(2) Billions of dollars.
(3) Weighted average based on the 1989 shares of GDP of each country with respect to the whole area (source: OECD).
(4) Difference between the weighted average of growth rates in the simulation and in the baseline for the three countries.
(5) Difference between the weighted average of growth rates in the simulation and the rate of growth for Germany in the baseline.
(6) Sum of the balances of the three countries considered.
(7) Based on the 1990 shares of labor force of each country with respect to the whole area; source: OECD.

Table 2

SIMULATION 2 – UNION'S INTEREST RATE EQUAL TO GERMANY'S BASELINE RATE; DEPRECIATING EXCHANGE RATE WITH EXTERNAL CURRENCIES
(difference with respect to the baseline)

Year	GDP (1)				Consumer prices (1)					Current account (2)				Unemployment rate			
	G	F	I	Union (3)	G	F	I	Union (4)	(5)	G	F	I	Union (6)	G	F	I	Union (7)
1	1.2	0.3	0.7	0.8	0.3	0.5	0.6	0.5	1.4	-6	-2	-5	-13	-0.2	–	-0.1	-0.2
2	0.6	0.5	1.7	0.9	0.9	1.3	0.3	0.8	1.5	1	3	-12	-8	-0.4	-0.1	-0.3	-0.4
3	-0.1	0.2	1.4	0.4	1.0	1.2	-0.2	0.7	1.2	8	5	-17	-4	-0.5	-0.1	-0.9	-0.7
4	-0.1	0.1	0.9	0.3	0.9	0.9	-0.2	0.5	1.0	10	7	-19	-2	-0.6	-0.1	-1.5	-0.9
5	-0.1	–	0.5	0.1	0.8	0.8	-0.2	0.4	0.8	12	7	-22	-3	-0.7	-0.2	-1.9	-1.0
6	-0.1	-0.1	0.2	-0.1	0.7	0.7	-0.2	0.4	0.7	13	8	-24	-3	-0.8	-0.2	-2.2	-1.0
7	-0.2	-0.1	-0.1	-0.2	0.6	0.5	-0.1	0.3	0.6	13	10	-25	-2	-0.9	-0.2	-2.4	-1.2
8	-0.1	-0.1	-0.2	-0.1	0.5	0.4	-0.2	0.3	0.5	14	11	-27	-2	-1.0	-0.2	-2.3	-1.2
9	0.1	–	-0.1	–	0.4	0.3	-0.3	0.1	0.3	14	11	-28	-3	-1.2	-0.2	-2.3	-1.2

(1) Percentage points, annual growth rates.
(2) Billions of dollars.
(3) Weighted average based on the 1989 shares of GDP of each country with respect to the whole area (source: OECD).
(4) Difference between the weighted average of growth rates in the simulation and in the baseline for the three countries.
(5) Difference between the weighted average of growth rates in the simulation and the rate of growth for Germany in the baseline.
(6) Sum of the balances of the three countries considered.
(7) Based on the 1990 shares of labor force of each country with respect to the whole area; source: OECD.

Table 3

SIMULATION 3 - RESTRICTIVE MONETARY POLICY IN THE UNION
(difference with respect to the baseline)

Year	GDP (1)				Consumer prices (1)					Current account (2)				Unemployment rate			
	G	F	I	Union (3)	G	F	I	Union (4)	(5)	G	F	I	Union (6)	G	F	I	Union (7)
1	-0.8	-0.3	-0.1	-0.4	-0.2	-0.4	-0.6	-0.4	0.5	5	-	-1	4	0.1	-	-	-
2	0.1	-	0.5	0.2	-0.5	-0.5	-1.0	-0.7	-	4	-1	-8	-5	0.2	0.1	-	0.1
3	0.2	-	0.7	0.3	-0.3	-0.1	-1.1	-0.5	-	6	1	-12	-5	0.2	0.1	-0.2	-
4	0.1	0.1	0.6	0.3	-0.1	-	-1.2	-0.5	-	9	2	-13	-2	0.3	-	-0.5	-
5	0.2	0.1	0.6	0.3	-0.1	-	-1.1	-0.4	-	12	3	-16	-1	0.3	-	-0.7	-0.1
6	0.2	-	0.5	0.2	-	-	-1.0	-0.3	-	13	3	-18	-2	0.2	-	-1.1	-0.2
7	0.1	-	0.2	0.1	0.1	-	-0.9	-0.3	-	13	5	-18	-	0.3	-	-1.2	-0.3
8	0.1	-	0.1	0.1	0.1	-	-0.9	-0.2	-	13	5	-20	-2	0.2	-	-1.3	-0.3
9	0.1	0.1	0.2	0.1	0.1	-	-0.8	-0.2	-	13	5	-21	-3	0.3	-	-1.3	-0.3

(1) Percentage points, annual growth rates.
(2) Billions of dollars.
(3) Weighted average based on the 1989 shares of GDP of each country with respect to the whole area (source: OECD).
(4) Difference between the weighted average of growth rates in the simulation and in the baseline for the three countries.
(5) Difference between the weighted average of growth rates in the simulation and the rate of growth for Germany in the baseline.
(6) Sum of the balances of the three countries considered.
(7) Based on the 1990 shares of labor force of each country with respect to the whole area; source: OECD.

Table 4

DM-Dollar exchange rate and interest rates (1)

Year	Baseline					Simulation 1		Simulation 2		Simulation 3	
	DM-$ exchange rate	Interest rates			average interest rate	DM-$ exchange rate	Union's interest rate	DM-$ exchange rate	Union's interest rate	DM-$ exchange rate	Union's interest rate
		G	F	I							
1	1.53	8.6	10.4	13.0	10.7	1.53	8.6	1.65	8.6	1.45	10.4
2	1.53	8.0	9.4	12.5	10.0	1.53	8.0	1.70	8.0	1.48	9.9
3	1.53	7.5	8.4	11.1	9.0	1.53	7.5	1.70	7.5	1.51	9.0
4	1.53	7.2	7.9	9.6	8.2	1.53	7.2	1.70	7.2	1.52	8.1
5	1.53	6.9	7.4	8.8	7.7	1.53	6.9	1.70	6.9	1.53	7.3
6	1.53	6.9	6.9	8.0	7.3	1.53	6.9	1.70	6.9	1.53	6.9
7	1.53	6.9	6.9	7.4	7.1	1.53	6.9	1.70	6.9	1.53	6.9
8	1.53	6.9	6.9	7.4	7.1	1.53	6.9	1.70	6.9	1.53	6.9
9	1.53	6.9	6.9	7.4	7.1	1.53	6.9	1.70	6.9	1.53	6.9

(1) Average annual data.

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