The P-Star Model and Monetary Integration in Europe

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Abstract

The P-star concept was developed as a simple indicator of inflationary pressure. However, for countries in a system of fixed exchange rates, domestic monetary policy becomes endogenous and the equilibrium level of prices is determined by the anchor country of the exchange rate system. In this paper, an extended version of the P-star model is applied to inflation in Germany, France, the Netherlands, Belgium and Austria. Additionally, the model is tested for a European aggregate consisting of these five countries. The P-star framework can be used to test for the German dominance in the EMS. Monetary conditions in Germany are found to have an influence on prices in the Netherlands, Austria, and France. On the European level, however, the hypothesis that Germany determines the inflation rate in the whole system is rejected.

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The question of asymmetry in the European Monetary System (EMS) – in the sense that Germany determines monetary policy for the whole system – has been investigated with different results.[1] This paper adds to the literature by using the P-star framework to investigate monetary autonomy in the EMS. Especially, it is tested if Germany determines the equilibrium price level in Europe towards which prices in other countries adjust. On the one hand, goods market integration transmits German monetary conditions to prices in the other EMS countries, as the price levels in different countries are connected via purchasing power parity (PPP). A high degree of market integration leads to more intense competition and prices cannot deviate without triggering arbitrage operations, thus enforcing a quicker return to PPP. On the other hand, adjustment is enforced by high capital mobility, which gives rise to speculative pressure in the foreign exchange market if monetary policy is incompatible with the fixed exchange rate.

Alternatively, the P-star approach can be interpreted as an indicator of the degree of integration in Europe. Since in a monetary union exchange rates cease to exist, macroeconomic imbalances have to adjust by price level movements. In this context, the P-star approach assesses how flexibly the price level responds to monetary shocks and gives evidence of the desirability of a common currency.

In theory, countries participating in a fixed exchange rate system cannot use monetary policy for domestic purposes, and PPP forces inflation rates to be equal in the long run. In practice, countries have been able to retain considerable monetary independence also in a system of fixed exchange rates, as PPP is unlikely to hold in every instant.[2] This may be due to two effects. Firstly, goods and asset market arbitrage seems to be less than perfect. Secondly, fixed exchange rates impose relatively weak constraints on monetary policy as they are in general adjustable. With divergent monetary conditions therefore not the price level adjusts, but instead the exchange rate is devalued if the pressure from the markets becomes too high.

As the original P-star model relates to a closed economy, an extended version of the P-star model is presented to account for the influence of the exchange-rate system. Then the transmission of inflation in the EMS is investigated for Germany, France, Netherlands, Belgium and Austria. Especially, Germany's influence on the inflation rate in the European Union is tested.

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[1] See Artis and Nachane (1990), Fratianni and von Hagen (1990), Herz and Röger (1992) or Henry and Weidmann (1995).

[2] See e. g. Stockman (1992) and Darby (1983) for the experience during the Bretton-Woods System. Ohanian and Stockman (1996) provide a theoretical explanation for monetary independence in a fixed exchange-rate system.

Monetary conditions in Germany are found to have a significant, but quantitatively small influence on the price-level development in the Netherlands, Austria, and France. Thus it seems that the countries investigated here retained only limited scope for an independent monetary policy. The results for the model on the European level, however, show that not Germany alone determines equilibrium prices in Europe, even after accounting for shifts in the European price level through realignments. Instead, the equilibrium price level is driven by monetary conditions in all countries. Therefore, though Germany limits the monetary independence of the smaller European countries, its own price level is also influenced by monetary conditions in the other countries. German dominance with respect to monetary policy is thus rejected.

The paper is organized as follows. Section 1 gives a short introduction to the P-star model and a survey of the literature testing the P-star approach for Europe. In Section 2, the model is extended to account for the fixed exchange rates in the EMS. Section 3 presents the empirical results and, finally, Section 4 concludes.

1 The P-Star Model

The P-star model relies on the quantity theory of money, which implies that in the long run inflation is driven by money growth. It was originally proposed by Hallman, Porter, and Small (1991) as a basis for a dynamic model of inflation for the United States. In contrast to the simple version of the quantity theory, the P-star model postulates the relation between money and prices only in the long run.

$$p_t^* = m_t - y_t^* + v_t^* \tag{1}$$

Equation (1) defines the equilibrium price level, p^*, as the price level that would prevail at the actual money stock, m, if real output and velocity were on their long-run equilibrium values, y^* and v^*. In general, the actual price level will not coincide with the equilibrium price level since individual prices are influenced by a variety of other factors such as, e. g., import prices or wages. In the long run, however, the pressure generated by an expansion of the money stock will drive actual prices in the direction of the equilibrium price level.[3] The difference between the actual and the equilibrium price level is defined as the price gap, $p^* - p$. It is assumed that

[3] Hallman, Porter, and Small (1991) assume that causality runs from money to prices. Hall and Milne (1994) and Funke, Beeby, and Hall (1997) show that for Germany, the causality structure is more complex. This question not pursued further here.

the price gap has predictive power for future inflation. Inflation, π, is then explained by an error correction model.

$$\pi_t = \alpha + \beta(p^*_{t-1} - p_{t-1}) + \sum_{i=1}^{n} \delta_i \pi_{t-i} + \varepsilon_t$$

Positive evidence for the P-star model has been found for single countries[4] as well as for Europe as a whole (Hoeller and Poret, 1991; Fels and Mayer, 1995). The model has been extended to account for German monetary influences on other EMS countries (Tatom, 1992; Kool and Tatom, 1994; Beeby, Funke and Hall, 1995; Garcia-Herrero and Pradhan, 1998). Groeneveld (1995) and Groeneveld, Koedijk, and Kool (1996, 1997) combine P-star models on the national and the European level. They assume that with the equilibrium price level in Europe the equilibrium level of prices in each country is determined. In addition to a stable European money demand function this requires PPP being valid even in the short run. In this paper only long-run PPP is assumed with the central parity in the European Exchange Rate Mechanism (ERM) as the external constraint for equilibrium price levels.

2 The P-Star Model for the European Union

In a system of fixed exchange rates, a stable relation between money and prices can be derived from a simple monetary model. With integrated goods and capital markets the area-wide money supply and the area-wide money demand determine the price level in the whole system. Prices in the participating countries are linked by two different channels. Firstly, a monetary expansion is spread out over the whole system by the central banks' interventions to support the exchange rate. Secondly, PPP provides a connection between national goods markets. But as PPP is valid only in the long run, the adjustment pressure via the goods market channel is presumably low.[5]

To maintain fixed parities, the participating countries have to submit monetary policy to the goal of stabilizing the exchange rate and only one country can follow an independent monetary policy. In the literature this fact is known as the $N - 1$ problem, since only $N - 1$ countries ever need to intervene to maintain parities. Although originally intended as a symmetric system, it is often claimed that *de facto* the EMS worked asymmetrically with Germany pursuing an inde-

[4] See Bundesbank (1992), Tödter and Reimers (1994), Scharnagl (1996), Kole and Leahy (1991), Hallman, Porter, and Small (1991), Hoeller and Poret (1991).

[5] For a survey of the empirical literature on PPP, see Froot and Rogoff (1995) and the references therein.

pendent monetary policy and the other countries fixing their exchange rate *vis-a-vis* the Deutsche Mark.[6] Under this assumption, an expansionary monetary policy in Germany would be transmitted to the other members of the system by the interventions of the non-anchor countries. In contrast, if a non-anchor country expands its money stock, it would have to intervene in the foreign exchange market as soon as the pressure on its exchange rate becomes apparent and to reduce its money supply either by non-sterilized interventions or open-market operations. Therefore, the anchor country determines the price level in the system and prices in the non-anchor countries have to follow.

In the following, the P-star model is extended to analyze the EMS. Germany as the anchor country in the EMS is supposed to target the national money stock while the other countries follow an exchange rate target and use monetary policy to keep their exchange rate fixed relative to the Deutsche Mark. With a stable money demand function for Germany[7], therefore, the German equilibrium price level is given as

$$p_t^{*D} = m_t^D - y_t^{*D} + v_t^{*D} .$$

Variables for Germany are denoted with the superscript *D*. The equilibrium price level in the other countries, $\overline{p}^{*i}$, is determined – via the exchange rate target – by the equilibrium level of prices in Germany,

$$\overline{p}_t^{*i} = p_t^{*D} + \overline{e}_t^{i,D} ,$$

with $\overline{e}^{iD}$ denoting the central parity in the ERM relative to the Deutsche Mark.[8] The foreign-based price gap in the non-anchor countries thus can be written as a combination of the national price gap, the difference between the German and the national equilibrium price level, and the central parity.

$$(\overline{p}_t^{*i} - p_t^i) = (p_t^{*i} - p_t^i) + (p_t^{*D} - p_t^{*i}) + \overline{e}_t^{i,D}$$

Assuming unchanged parities, an increase in the equilibrium price level in Germany leads to a widening of the price gap in the other ERM countries. This gap can only be reduced by a movement in the price level of those countries, since with fixed exchange rates the money supply in the non-anchor countries is endogenous. If, in contrast, money growth in a non-

6 See, e. g. the references in Fratianni and von Hagen (1990).
7 Evidence for a stable money demand function for Germany is provided e. g. in Wolters, Teräsvirta and Lütkepohl (1998), Scharnagl (1996).

anchor country is too high so that its equilibrium price level is incompatible with the German equilibrium price level, the adjustment with fixed exchange rates will have to take place through a reduction of the money supply in the non-anchor country.

The inflation rate is modeled as an error correction model with the price gap and the lagged dependent variable as explanatory variables. To assess the influence of German monetary conditions on inflation in the respective country, the national price gap as well as the price gap based on the German equilibrium price level are included.[9]

$$\pi_t^i = \alpha + \beta(p_{t-1}^{*i} - p_{t-1}^i) + \gamma(\overline{p}_{t-1}^{*i} - p_{t-1}^i) + \sum_{j=1}^{n} \varphi_j \pi_{t-j}^i + \varepsilon_t \qquad (2)$$

Assuming a stable European money demand function[10], the European equilibrium price level, p^{*E}, is determined by the aggregate money stock, m^E, and the aggregate equilibrium values for output, y^{*E}, and velocity, v^{*E}.

$$p_t^{*E} = m_t^E - y_t^{*E} + v_t^{*E}$$

It is assumed that the European price gap reflects the sum of the national monetary conditions,

$$(p_t^{*E} - p_t^E) = \sum_i w_i (p_t^{*i} - p_t^i),$$

with the weights w_i summing up to unity over all countries. Alternatively, under the assumption of German leadership in the EMS the European price gap can be written as

$$\begin{aligned} (p_t^{*E} - p_t^E) &= \sum_i w_i (\overline{p}_t^{*i} - p_t^i) \\ &= p_t^{*D} - \sum_i w_i p_t^i + \sum_i w_i \overline{e}_t^{i,D}. \end{aligned} \qquad (3)$$

If real integration and exchange rate stability lead to a convergence of the non-anchor countries' monetary policy with the German monetary expansion, Germany as the anchor country can determine the price development in Europe and the German equilibrium price level determines the European price gap.

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8 This implies no assumption with respect to the equilibrium in an economic sense but defines the equilibrium exchange rate as a political constraint prices have to comply with if a devaluation is to be avoided. Parities are normalized to 1 in 1990 for all currencies.

9 The foreign-based price gaps are constructed with the central parities in the ERM. As realignments are influenced by deviations from PPP, the foreign-based price gaps cannot be assumed to be exogenous. However, this does not lead to a problem in the estimation, as only lagged values appear in the equation.

10 Studies investigating money demand for a group of European countries generally conclude that a stable money demand function on the European level exists. See Kremers and Lane (1990), Artis, Bladen-Howell, and Zhang (1993), Monticelli and Papi (1996), Wesche (1997).

The inflation rate in the EMS is modeled analogously, with the European price gap and the lagged dependent variable as explanatory variables.

$$\pi_t^E = \alpha + \beta(p_{t-1}^{*E} - p_{t-1}^E) + \sum_{j=1}^{n-1} \delta_j \pi_{t-j}^E + \varepsilon_t \qquad (4)$$

Alternatively, – with equation (3) and using the fact that the European price level is the weighted average of the national price levels – the model for the European inflation rate can be written in terms of the price gap relative to the German equilibrium price level.

$$\pi_t^E = \alpha + \beta(p_{t-1}^{*D} - p_{t-1}^E) + \gamma \sum_i w_i \bar{e}_t^{i,D} + \sum_{j=1}^{n-1} \delta_j \pi_{t-j}^E + \varepsilon_t \,. \qquad (5)$$

The assumption of Germany being the anchor country in the EMS can be tested with the coefficient on the German-based price gap. Assuming fixed exchange rates, the term $\sum w_i \bar{e}^{i,D}$ is constant. Then, the German price gap is transmitted directly into the non-anchor countries and demands a change in their monetary policy, as a deviation of the exchange rate from its parity can be only transitory. This would be reflected in a significant coefficient on the German-based price gap. Exchange rates, however, have not been constant since the beginning of the EMS but several realignments took place. A devaluation of a non-anchor country, reflecting a monetary policy that is incompatible with the German policy, leads to a rise in the European inflation rate. Therefore, it is also tested if the German based price gap exerts a significant influence on inflation in Europe when changes in the central parity are taken into account.

3 Empirical results

The countries investigated are Germany, France, the Netherlands, Belgium, and Austria. Germany and France are included because they are the driving forces behind European integration. The other three countries are small open economies, which are likely to be strongly affected by German monetary policy. Moreover, the Netherlands is the only country for which the fluctuation bands of ± 2.25 % still apply. Austria has been a formal member of the EMS only since 1995, but it has pegged its exchange rate to the German Mark for almost 20 years.

Quarterly data are used for the empirical test of the model. The sample period begins with the foundation of the EMS in the first quarter of 1979 and ends in the last quarter of 1996. It therefore includes the EMS crises of 1992 and 1993, which led to a widening of the exchange rate bands from ± 2.25 % to ± 15 % and thus may be seen as a *de facto* break down of the

ERM. However, for the countries considered here the exchange rate remained inside the narrow bounds even after the widening of the band so that it seems reasonable to consider the exchange-rate system as unchanged.[11] The GDP deflator is taken as the price variable, and real GDP as the output variable. Inflation is computed as the first difference of logarithmic prices.[12] The monetary aggregate used to compute velocity is broad money in the definition of the *International Financial Statistics* (*money* plus *quasi money*). Data that were not seasonally adjusted at the source were adjusted using the X-11 procedure. As in Hoeller and Poret (1991), the European variables are aggregated with the exchange rate of the base year 1987. This year was chosen because it lies approximately the middle of the sample period, and from 1987 on a period of relatively stable exchange rates followed until 1992.[13] The European inflation rate is defined as the change in the weighted average of national price levels with GDP shares as weights.

Fig. 1 shows the inflation rate in each country and for Europe over the sample period. After the early years of the EMS, inflation converged to German levels, giving at the first glance support to the notion that Germany substantially influences prices in Europe. Only in the aftermath of German Unification the German inflation rate exceeded inflation in the other countries. Table 1 shows, however, that the correlation between the national (annual) inflation rates and the German inflation rate is relatively low. Over the whole sample period this correlation lies between 27 % for Belgium and 66 % for Austria, thus confirming that there was considerable monetary autonomy. German Unification in general weakened the correlation between the inflation rates in the EMS, especially for France and the Netherlands which did not experience an increase in inflation like Germany. After the EMS crises the correlation increases again, indicating that increased market integration may lead to higher arbitrage and thus to less monetary independence.

Special care is necessary when determining the order of integration of the variables as standard statistical methods apply only for stationary variables. Thus, if inflation has a unit root,

[11] Only for France the exchange rate left the narrow band in 1995 but returned into the band in 1996.

[12] For Germany, the price index is from the *Monthly Statistics* of the Deutsche Bundesbank, for the other countries it is from the *International Financial Statistics* of the International Monetary Fund. For Belgium, quarterly data for the GDP deflator were obtained by interpolating the annual deflator with the consumer price index.

[13] Alternatively, one could use purchasing power parities for the aggregation of the European variables. However, results do not differ qualitatively from those with base year exchange rates. This is in line with Groeneveld, Koedijk, and Kool (1996) whose results are also robust with respect to the choice of purchasing power parities or base year exchange rates.

eqs. (2), (4) and (5) should be estimated in first differences. Table 2 shows unit root test for the inflation rates. As the evidence for the time series properties of the inflation rate in the literature is mixed, different tests are applied. With the ADF test, Dutch and European inflation seem to be non-stationary, whereas the PP test regards only European inflation as non-stationary. The SB test (Sargan and Bhargava, 1983; Bhargava, 1986) rejects non-stationarity for all time series, and the KPSS test (Kwiatkowski et al., 1992) – in contrast to the other tests considering the null of stationarity – regards all time series except for the Dutch inflation rate as non-stationary.[14] Especially in France and the Netherlands inflation declined substantially after 1983 when the commitment to fixed exchange rates became more credible so that non-stationarity could arise through a break in the level of the series. Therefore, inflation in France and the Netherlands was tested for the existence of a break after the realignment in March 1983 (Perron, 1989). The test statistics are –7.60 for France and –10.24 for the Netherlands compared to a critical value of –3.77 so that in both cases non-stationarity is clearly rejected against the alternative of a break in the level of the series.

Next, a P-star model is estimated to assess the influence of the German monetary conditions on the other European countries. The price gap is computed by using the deviations of velocity and output from their equilibrium values. Testing for a unit root, the existence of a stochastic trend in velocity and output cannot be rejected.[15] Therefore, the Hodrick-Prescott filter is used to compute the equilibrium values, y^* and v^*.[16] Concerning the effects of German Unification it is assumed – as in Issing and Tödter (1995) – that German Unification led to a 10 % jump in German potential output but had no impact on the long-run velocity of M3 (see Scheide, 1993). For the computation of the foreign-based price gaps the EMS official parities were used as equilibrium exchange rates. For Austria it is assumed that the official parity for 1995 applied during the whole sample period. This assumption seems reasonable as the actual exchange rate fluctuated around this level during the whole sample period.

[14] If inflation turns out to be I(0), cointegration of inflation rates cannot be used to find evidence for the German role in the convergence of the inflation rates, as e. g. in Artis and Nachane (1990). If inflation is already stationary, stationarity of the inflation differential to Germany is meaningless.

[15] Results not shown. The single exception is velocity for Austria, which seems to be trend stationary. To keep methods comparable, also here the Hodrick-Prescott filter was applied.

[16] See Hodrick and Prescott (1997). For the Hodrick-Prescott filter the standard smoothing factor of 1600 is used here. Hoeller and Poret (1991), Kool and Tatom (1994) and García-Herrero and Pradhan (1998) employ the Hodrick-Prescott filter to construct the equilibrium values for output and velocity. Groeneveld (1995) and Groeneveld, Koedijk, and Kool (1996) compute the equilibrium values with a Kalman filter. A comparison of different methods for the estimation of potential output by the Deutsche Bundesbank (1995)

Next, the domestic and the foreign-based price gaps are tested for a unit root. Non-stationarity of the domestic price gap would imply that the actual price level does not converge towards the equilibrium price level so that a P-star model would make no sense. Analogously, non-stationarity of the foreign-based price gap would reject the hypothesis that the foreign price level converges towards the German equilibrium price level, even if exchange rate realignments are accounted for. Table 3 shows that all price gaps are stationary, therefore validating the hypothesis that the actual price level returns to some equilibrium – either defined by the national or by the German monetary conditions.[17]

Table 4 shows the results for the P-star model on the national level. The dependent variable is the quarterly inflation rate. As regressors up to four lags of the domestic and the foreign-based price gaps, four lags of the dependent variable, and a constant are included. Insignificant terms were eliminated successively. As other determinants of inflation import prices and the relative price of oil (see e. g. Tödter and Reimers, 1994; Tatom, 1992) were considered but were mostly insignificant and therefore omitted.[18] Since the correlation between the domestic and foreign-based price gaps is low, both are incorporated simultaneously. For those countries where a break in the inflation rate was found a dummy is included, taking the value of one from the first quarter of 1983 on. Except for Germany, where the ARCH statistic indicates some problems with heteroscedasticity, the models are satisfactory. The adjusted R^2 for Germany, Belgium and Austria is below 30 %, indicating that some factors influencing inflation may not have been captured.[19] Most price gaps enter with a lag of one quarter. For Germany and France, however, the domestic price gap enters with a lag of two quarters while for the Netherlands the foreign and for Austria the domestic price gap are lagged by three quarters.[20] For all countries the own price gap has the right sign and is significant at least on the 10 % level. The coefficient estimate implies a reduction of the price gap of 7 – 12 % each quarter,

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suggests that the difference between values derived by the Hodrick-Prescott filter and explicit estimates for potential output is small.

[17] The foreign-based price gap for the Netherlands is only stationary when including a trend. In the Dutch equation, therefore, a trend is included, too. As this means that the equilibrium real exchange rate follows a trend, results should be interpreted with caution.

[18] Wages were not included because a simultaneity bias may result if wage negotiations take the inflation rate into account. Increase in wages are assumed to be captured in the output gap.

[19] Using the annual change in the price level as dependent variable would result in a higher R^2, but has no influence on the estimate for the price gap.

[20] Groeneveld, Koedijk and Kool (1996) lag price gaps by three quarters, Tödter and Reimers (1994) and Scharnagl (1996) use an average of the last four price gaps. Kool and Tatom (1994) lag price gaps by one period but use annual data, Hoeller and Poret (1991) annual viz. semi-annual data.

except for Austria where the disequilibrium declines by almost 20 % in a quarter. The foreign-based price gap is significant for France, the Netherlands and Austria. The coefficient estimates, however, are only about half as large than those of the domestic price gaps. Only for Belgium the foreign-based price gap is insignificant and has the wrong sign. Thus, for the other countries the hypothesis is confirmed that Germany determines equilibrium price level and the actual price level moves towards this equilibrium. This result coincides with the conclusion by Kool and Tatom (1994) who also find that a German-based price gap determines inflation the Netherlands and Austria.[21] Tatom (1992) corroborates the influence of the German price gap on prices in Austria, though he cannot confirm the validity of the P-star model in its simple form.

Next, a model for the European inflation rate is estimated (Table 5). As the unit root tests favored the hypothesis that the European inflation rate is I(1), the model is estimated in first differences. Only one of the price gaps is included at the time, because the correlation between the European price gap and the price gap relative to Germany is higher than on the national level. The significant European price gap shows that the P-star model also applies on the European level, i. e., that the average price level in the five European countries is determined by the monetary conditions in the whole area. The coefficient implies a reduction of the disequilibrium of about 10 % in one quarter and thus corresponds to the findings of other studies.[22]

The second column of Table 5 shows the regressions with the German-based price gap. The coefficient for the price gap relative to Germany is insignificant, thus rejecting the hypothesis that the German equilibrium price level determines the European prices. Even if dummies are included to account for higher inflation due to realignments, the European price gap relative to Germany remains insignificant. Moreover, while the coefficient for the European price gap is of the same magnitude as the coefficients in the national models, the coefficient of the German-based price gap is much smaller. This means that though Germany influences inflation in the smaller European countries, its own price level is also influenced by monetary conditions in the other countries. German therefore does not solely determine monetary policy in the whole system.

[21] Kool and Tatom (1994) also find an influence of a German-based price gap on inflation in Belgium but their results are sensitive to the specific definition of the price gap.

[22] Hoeller and Poret (1991) find an adjustment of 36 % per year. Fels and Mayer (1995) obtain a coefficient of 0.07 with quarterly data for the three European countries Germany, France, and the Netherlands.

4 Conclusion

In this paper, the P-star model is used to explain inflation on the national level and for a hypothetical European Monetary Union. On the national level, there is some support for the P-star model as indicated by the significant coefficients for the domestic price gaps. Also for Europe as a whole the P-star model applies, indicating that the price level development in European Union is influenced by the monetary conditions in the whole area. Though the speed of adjustment of the actual towards the equilibrium price level seems relatively low, the results are in line with the results generally found in the literature. A German influence could be detected for France, the Netherlands and for Austria. The influence of the German-based price gap, however, is smaller than the effect of the domestic price gap. On the European level, it cannot be confirmed that Germany plays a unique role in the determination of the price level in Europe. Nevertheless, it can be expected that in the future the linkages between the price levels of the European countries will further increase, since the progress in economic integration with the Common Market program will lead to increased competition and a tighter connection of goods markets' prices.

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Tables and Figures

Table 1. Correlation with the German inflation rate

Sample	*79:1-96:4*	*79:1-86:4*	*87:1-90:2*	*90:3-93:3*	*93:4-96:4*
π^{FRAU}	0.42	0.68	0.30	-0.29	0.91
π^{NL}	0.56	0.78	0.40	-0.32	0.14
π^{BEL}	0.27	-0.11	0.13	0.64	0.19
π^{AUS}	0.66	0.55	0.63	0.29	0.74

Notes: Correlation between the year to year change in the GDP-deflator of the respective country and Germany. FRA means France, NL the Netherlands, BEL Belgium, and AUS Austria.

Table 2. Unit root tests for the inflation rates

	ADF	*PP*	*SB*	*KPSS*	*Regression*
π^{GER}	-3.022	-5.314	1.229	0.484	C,1
π^{FRA}	-3.936	-3.274	0.467	1.302	C,12
π^{NL}	-2.468	-8.917	1.773	0.415	C,3
π^{BEL}	-3.428	-7.830	1.867	0.983	C,1
π^{AUS}	-3.384	-10.323	2.434	0.854	C,2
π^{E5}	-1.463	-2.664	0.548	1.540	C,2

Notes: π is the rate of inflation, defined as the first differences of the log GDP deflator; GER signifies Germany, FRA France, NL the Netherlands, BEL Belgium, AUS Austria, and E5 the aggregate of the 5 countries. Lags were added until a Lagrange multiplier test failed to reject no serial correlation at the 5 % level. The specification is indicated in the last column with C meaning the inclusion of a constant, and the number of lags indicated thereafter. The sample period is 1979:1 to 1996:4. ADF level is the Augmented Dickey-Fuller, PP the Phillips-Perron, SB the Sargan-Bhargava and KPSS the Kwiatkowski-Phillips-Schmidt-Shin test statistic. The critical value for the 5 % significance level is –2.904 for the ADF and PP test, 0.26 for the SB and 0.463 for the KPSS test. First differences of the inflation rates are stationary in all cases.

Table 3. Unit Root Tests for the Price Gaps

Domestic Price Gap	*ADF*	*Regression*	*German-Based Price Gap*	*ADF*	*Regression*
Germany	-4.539	N,1			
France	-2.076	N,0	France	-3.077	C,2
Netherlands	-3.407	N,0	Netherlands	-3.479	T,3
Belgium	-4.392	N,2	Belgium	-2.493	N,0
Austria	-4.275	N,0	Austria	-3.011	C,1
Europe 5	-3.391	N,1	Europe 5	-3.830	N,0

Notes: ADF is the Augmented Dickey-Fuller test statistic. Tests were first performed including a constant, which was dropped if insignificant. The final specification of the test is indicated in the column “Regression” with T meaning the inclusion of a constant and a trend, C a constant and N without constant and trend. Lags were added until a Lagrange multiplier test failed to reject no serial correlation at the 5 % level. The critical values for the 5 % level of significance are– 3.473 for the specification T, –2.904 for C and –1.946 for N.

Table 4. P-star model on the national level

Variable	p^{DEU}	p^{FRA}	p^{NL}	p^{BEL}	p^{AUS}
domestic price gap	0.076 (1.923)	0.066 (1.730)	0.122 (2.118)	0.091 (2.329)	0.193 (2.476)
lags	2	2	1	1	3
foreign-based price gap	–	0.033 (1.906)	0.103 (3.183)	-0.008 (-0.702)	0.089 (3.448)
lags	–	3	1	1	1
adjusted R^2	0.22	0.70	0.36	0.28	0.28
LM(4)	0.91	5.19	5.73	2.68	8.04
ARCH(4)	10.75	4.83	5.38	6.51	4.59

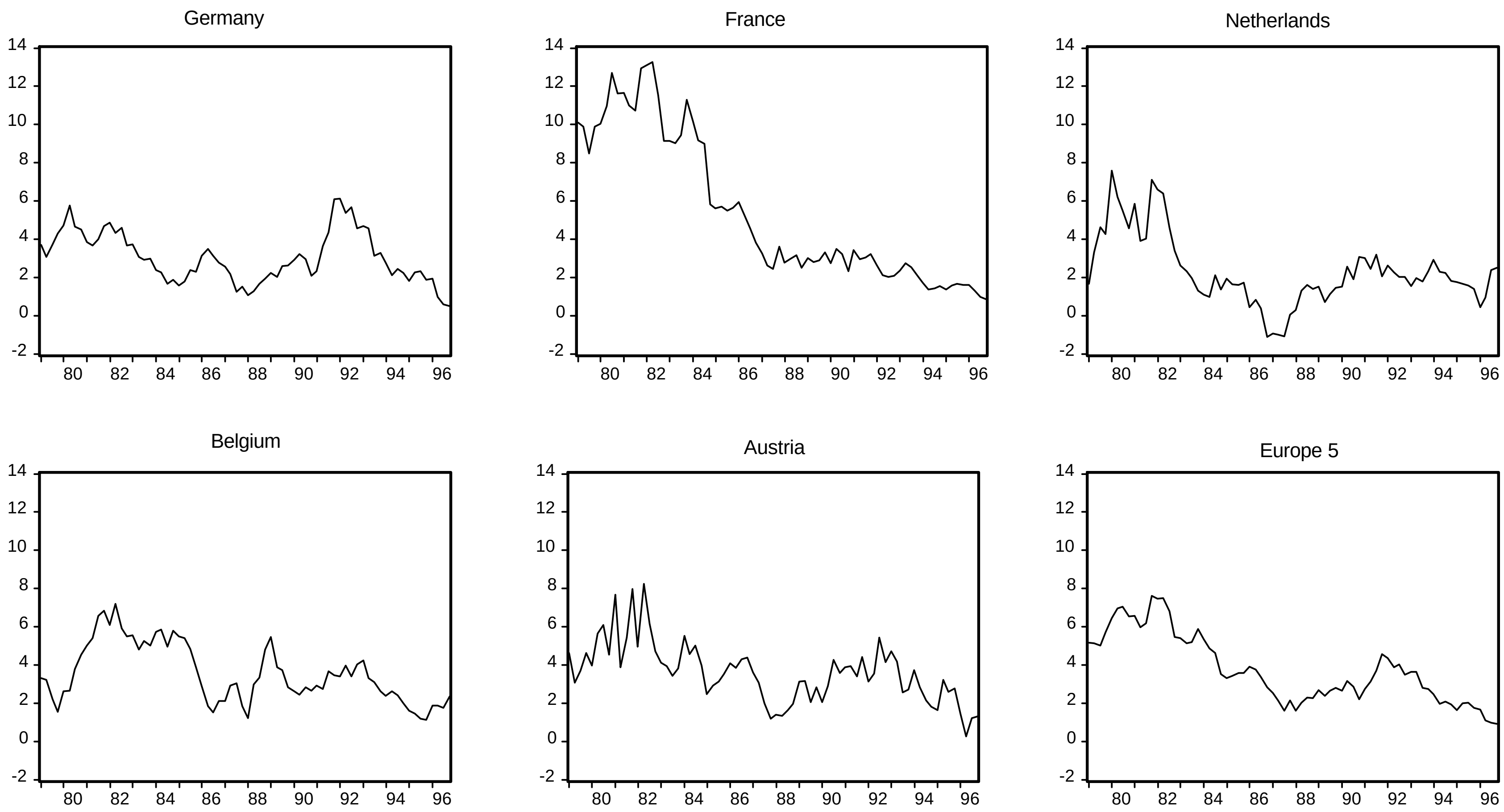
Notes: The full models include up to four significant lags of the lagged dependent variable and a constant. T-values in parenthesis. In the Dutch equation a trend and a dummy is included taking the value of 1 from 1983:1 on. LM(4) is a Lagrange multiplier test for fourth order autocorrelation. ARCH(4) is a test for conditional heteroscedasticity. Both tests are $\chi^2(4)$ distributed, the critical value is 9.49.

Table 5. P-star model on the European level

Variable	Dp^{E5}	Dp^{E5}	Dp^{E5} *(Dummies)*
European price gap	0.085 (2.260)		
lags	1		
German-based price gap		0.012 (1.450)	0.008 (1.089)
lags		1	1
adjusted R^2	0.33	0.27	0.37
LM-test	1.45	5.65	3.72
ARCH	7.90	6.68	0.17

Notes: The full models include up to four significant lags of the lagged dependent variable. T-values in parenthesis. LM(4) is a Lagrange multiplier test for fourth order autocorrelation. ARCH(4) is a test for conditional hetero-scedasticity. Both tests are $\chi^2(4)$ distributed, the critical value is 9.49.

Fig. 1. Annual inflation rates (in %)



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