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ABSTRACT

Austria's Hard-Currency Policy:
The Mechanics of Successful Exchange-Rate Peg*

One test of an exchange-rate peg is to ask whether the implicit inflation target of the pegging country is the same as that of the anchor country. If the inflation targets of the two countries are different, the peg's long-run credibility should be rejected. We examine the Austrian experience with a 'hard currency' policy aimed at targeting its exchange rate with the German mark. We find that when our feedback rule called for an increase in Austrian interest rates, the actual increases tended to exceed the implied increases, bolstering market confidence in the responsiveness of Austria's monetary policy.

JEL Classification: E52, E58
Keywords: monetary policy, inflation targeting, interest-rate policy instrument

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NON-TECHNICAL SUMMARY

The mechanics of carrying out the requisite interest-rate adjustments for a successful peg are far from obvious. In our evaluation of a country's inflation outlook and the future prospects of its exchange-rate peg, we consider whether the central bank employs two fundamental tactics that underpin exchange-rate stability in the short and long run. First, the central bank should indicate a willingness to adjust interest rates to dissipate deviations from the desired exchange rate. Second, in the absence of deviations from the desired exchange rate, the central bank must demonstrate a preference for the same inflation target as that of the anchor country.

The objective of this Paper is to explain the success of the Austrian hard-currency policy in terms of the above-mentioned tactics. Although Austria may be viewed as a 'pilot example' of exchange rate management, a central bank has to demonstrate some form of rule-like discipline to convince markets, so as not to rely on painfully high interest rates to maintain the peg. We argue that the Austrian National Bank bound itself to implicit 'rules of the game' for the exchange-rate peg in a similar manner to the Bank of England, which maintained unwritten rules of the game with respect to its interest-rate policies during the gold standard. In this vein, we estimate interest-rate rules for Austria in the post-Bretton Woods period to gain an understanding of the implicit 'rules of the game' needed to maintain the credibility of an exchange-rate peg.

The study attempts to unfold the Austrian strategy by comparing Austria's implicit inflation target with Germany's corresponding rate. The Austrian National Bank pursued a 'hard currency' policy by pegging the schilling to the German mark since the breakdown of the Bretton Woods System. The schilling's stability, together with Austria's inflation performance during the 1980s and early 1990s, suggests that the hard-currency policy was credible within financial markets. Its experience was unique for only a handful of countries were able to carry out a successful unilateral peg between 1975 and 1995. This Paper seeks to highlight a basis of that credibility: similar long-run target rates of inflation across the two countries and strong response of domestic interest rates to gaps between the target and actual exchange rate.

Our testing strategy develops first an inflation-targeting rule in terms of the policy instrument, then the importance of the fundamental tactics are tested within the empirical model. The rule-based model allows for feedback from multiple nominal-target variables (with only one truly independent long-run target) and shifts in the weights attached to each objective. Markov-switching is used to capture the time-varying response to deviations from the exchange rate or price target. Therefore, if Austria's implicit inflation target has been consistent with Germany's target, our methodology can determine whether monetary settings (short-term interest rates) are geared towards maintaining a similar inflation rate. The rule-based model is estimated both for Germany, where the Bundesbank is primarily concerned with the domestic price level, and Austria, where the National Bank's primary objective is to maintain an exchange-rate peg in relation to Germany.

The empirical estimates for the Austrian reaction function find significant feedback coefficients on the exchange rate and the inflation gaps in relation to Germany. Previous studies have concluded that convergence in the inflation rates is the most important fundamental determining the sustainability of an exchange-rate peg. Our results show that Austria's inflation target was essentially indistinguishable from Germany's. More importantly, our empirical framework provides some clues in the form of an implicit interest-rate rule as to how Austria has maintained the same inflation fundamentals as Germany. When the feedback rule called for an increase in Austria's short-term interest rates, analysis of the residuals finds that actual increases tended to exceed the model-implied increases. In other words, policy erred on the side of overreaction, underpinning market confidence in Austrian monetary policy.

As with the gold standard earlier this century, our empirical evidence for Austria is consistent with the view that unwritten 'rules of the game' evolved in the post-Bretton Woods era for central banks that pegged an exchange rate. Such implicit rules are important, because the central bank still carries out an interest-rate policy and the public must be able to draw conclusions about the central bank's intentions from interest-rate changes. Successful central banks demonstrate their willingness to adjust interest rates readily and in the expected direction in the face of inflation and exchange-rate gaps to maintain the peg's viability in the eyes of the public.

The mechanics of carrying out the requisite interest-rate adjustments for a successful peg are far from obvious. In our evaluation of a country's inflation outlook and the future prospects of its exchange-rate peg, we consider whether the central bank employs two *fundamental tactics* that underpins exchange-rate stability in the short and long run. First, the central bank should indicate a willingness to adjust interest rates to dissipate deviations from the desired exchange rate. Second, in the absence of deviations from the desired exchange rate, the central bank must demonstrate a preference for the same inflation target as in the anchor country.

The objective of this paper is to explain the success of the Austrian hard-currency policy in terms of the above mentioned tactics. Although Austria may be viewed as a 'pilot example' of exchange rate management, a central bank has to demonstrate some form of rule-like discipline to convince markets, so as not to rely on painfully high interest rates to maintain the peg. We argue that the Austrian National Bank bounded itself to implicit 'rules of the game' for the exchange-rate peg in a similar manner as the Bank of England maintained unwritten rules of the game with respect to its interest-rate policies during the gold standard, see Eichengreen, Watson and Grossman (1985). In this vein, we estimate interest-rate rules for Austria in the post-Bretton Woods period to gain an understanding of the implicit 'rules of the game' needed to maintain the credibility of an exchange-rate peg.

The study attempts to unfold the Austrian strategy by comparing Austria's implicit inflation target with Germany's corresponding rate. The Austrian National Bank pursued a 'hard currency' policy by pegging the schilling to the German mark since the breakdown of the Bretton Woods System. The schilling's stability, together with Austria's inflation performance during the 1980s and early 1990s, suggests that the hard-currency policy was credible within financial markets. Its experience was unique for only a handful of countries were able to carry out a successful unilateral peg between 1975 and 1995.[1] This paper seeks to highlight a basis of that credibility – similar long-run target rates of inflation across the two countries and strong response of domestic interest rates to gaps between the target and actual exchange rate.[2]

[1]Many European countries such as the Netherlands were part of the ERM for most the same period and could rely on some form of co-operation.

[2]An alternative route, which we do not explore in this paper, that merits further consideration is the role of the risk premium.

Our testing strategy develops first an inflation targeting rule in terms of the policy instrument, then the importance of the fundamental tactics are tested within the empirical model. The rule-based model allows for feedback from multiple nominal target variables (with only one truly independent long-run target) and shifts in the weights attached to each objective. Markov switching is used to capture the time-varying response to deviations from the exchange rate or price target. Therefore, if Austria's implicit inflation target has been consistent with Germany's target, our methodology can determine whether monetary settings (short-term interest rates) are geared towards maintaining a similar inflation rate. The rule-based model is estimated both for Germany, where the Bundesbank is primarily concerned with the domestic price level, and Austria, where the National Bank's primary objective is to maintain an exchange-rate peg in relation to Germany.

The paper is organised as follows. The next section outlines Austria's 'hard currency' policy and reviews its inflation record relative to Germany's. The second section presents the empirical model used to recover the implicit inflation and exchange-rate targets. The third section contains the main findings for Germany and Austria and includes goodness-of-fit tests. The final section concludes.

I. Austria's 'Hard-Currency' Policy

The Austrian National Bank adopted in 1974 the hard-currency policy, which entailed purposefully appreciating the Austrian schilling beyond its initial purchasing-power parity (PPP) level to generate disinflationary momentum. Fig. 1a shows that the schilling was re-valued twice and that since 1981 it has fluctuated within a narrow band with respect to the German mark.[3] At the time of the first oil shock, the schilling was re-valued upwards against the German mark in May 1974 despite weak macroeconomic fundamentals. The intention was to signal a stable monetary policy and constrain

[3]Our sample period stops at the end of 1994 before Austria entered the European Monetary System, and thereby adopted a formal exchange-rate target relative to the European Currency Unit (ECU), on January 1, 1995. We omit this latter regime from our data set.

wage growth over the medium term. By 1977, however, serious credibility problems emerged when the current account deficit soared to 4.5 percent of GDP, inflation remained stubbornly above that of Germany and the policy of the hard-currency strategy came under attack. A devaluation of the schilling was called for by Austrian and international economists.

Faced with the difficult choice of continuing with the hard-currency strategy, the schilling was re-valued for a second time in response to the second oil shock.[4] Hochreiter and Winckler (1995) contend that the September 1979 revaluation of the exchange rate to the German mark of 1.5 percent triggered an adjustment process that was instrumental for the credibility of the hard-currency strategy. Policymakers sought to induce an increase in the degree of real wage flexibility in the Austrian economy, so that real-wage adjustment, rather than exchange-rate changes, would maintain Austrian competitiveness in the face of shocks. The credibility of the hard currency policy was further tested during Germany's reunification process, which forced Austria's policy to take on higher than desired interest rates. Austria coped with these strains without abandoning its exchange-rate peg against the German mark. The schilling came away unharmed from the EMS currency crises of September 1992 and August 1993.

The Austrian National Bank's exchange rate policy consisted of adjusting its interest-rate differential with Germany. Fig. 1b plots the German and the Austrian 3-month Euro rate. The two market rates are characterised by three evolutionary phases, suggesting that Austrian credibility did not come immediately. From 1973 to 1977, the Austrian rates were on average 150 basis points higher than the German rates. Thereafter, until German reunification, the interest rate differential was reduced; however, the volatility of Austrian interest rates continued to exceed German rates. The post-reunification period shows that the Austrian rates converged with the German rates. Hence, it is evident from Fig. 1a and 1b that the near constant exchange rate cannot fully explain movements in the Austrian interest rates. Other factors such as inflation differentials should be considered.

Before the introduction of the hard-currency policy, the inflation differential between Austria and Germany was not large on average. As can be seen from Fig. 1c, however, through the mid-1970s Austrian inflation was higher

[4] During the course of the realignment of October 17, 1978, the shilling was devalued by one percent against the German mark. This was regarded as a technical correction, however.

than Germany's and more volatile. The same graph also shows that for the greater part of the hard-currency period, Austrian inflation tracked German inflation except on two occasions. The first stemmed from the 1973 oil shock, which hit Austria particularly hard. The second episode occurred in 1983-85 when Austria, as described by Hochreiter and Winckler (1995), was subject to an idiosyncratic supply shock arising from a crisis within nationalised industries. Austria also experienced a one-time increase in the value-added tax in 1984. We are able to analyse whether these two episodes had any effect on Austria's implicit inflation targets in relation to German inflation.

Although the Bundesbank does not announce formal inflation targets, its informal targets indicate what the profile of the implicit inflation targets should be for the two countries. The Bundesbank's informal inflation targets are documented in von Hagen (1995) and reproduced in Table 1. From 1975 to 1985, the Bundesbank referred to the informal inflation target as 'unavoidable inflation,' and this varied from year to year. Since 1986 the Bundesbank has defined a fixed, long-run inflation target of 0-2 percent. This target range for inflation was not maintained, however, in the aftermath of German reunification when inflation briefly rose above four percent.

II. Description of the Empirical Model

Our model of central bank management of short-term interest rates assumes that some rule-like discipline, as in the models of McCallum (1993) and Taylor (1993), is needed to maintain a focus on long-run goals and to convince markets that the policy is credible. Our model, which we hereafter refer to as the instrument model, is assumed to be robust to different underlying economic settings. Three main features make the instrument model useful for policy analysis: First, it defines a long-run target path for the nominal target variable. Second, the model's information set is based on past information and it incorporates forecasts of the relationship between the policy instrument and the nominal target variable. And, third, the model specifies the speed with which policy will adjust in response to a gap between actual and desired levels of the nominal target variables.

Our instrument model allows for feedback from inflation and exchange-rate objectives and for shifts in the weights attached to each. Several parameters in the instrument model are subject to change through Markov switching. This is intended to introduce flexibility, given that inflation objectives in the anchor country (Germany) were not absolutely constant across the sample period, and to underscore the view that interest-rate policies in the pegging central bank are not rigidly determined by any particular policy rule.

An inflation-targeting model of interest-rate changes for Germany is first estimated in order to arrive at estimates of Germany's implicit inflation target, which Austria presumably had to track when setting its own policies. Germany's monetary policy is modelled as one of inflation targeting, where the target rate of inflation cannot reasonably be assumed to have remained constant for the entire sample period that includes the post-Bretton Woods part of the 1970s and the early 1980s.

$$\begin{aligned} \Delta ln(1+i^G)_t &= -\pi_0(S1_t) + \Delta ln\left((1+i^G)\cdot P\right)_{t|t-1} + \epsilon_t \qquad (1) \\ &\epsilon_t \sim \text{Normal}(0, \sigma^2(S3_t)), \end{aligned}$$

where i^G stands for the three-month Euro mark interest rate, which is assumed to be controllable. P is the German price level measured by the consumer price index and $\pi_0(S1_t)$ is a parameter subject to Markov switching that corresponds to high and low inflation targets. The binary state variable that governs Markov switching in the inflation target is denoted $S1$. By allowing for shifts in the inflation target, we will be able to see how Austrian monetary policy responds to the German shifts. The error term, ϵ_t, is conditionally heteroscedastic in that its variance is subject to Markov switching governed by a state variable denoted $S3$.[5] (A new state variable $S2$ will appear in the Austrian interest-rate equation.) The possibility of conditional herscedasticity is allowed, because interest rates do experience periods of increased and reduced volatility and we also want to make more cautious inferences about potential shifts in the inflation target during periods of high volatility.[6]

The term that forecasts the interaction of this period's interest-rate change and inflation, $\Delta ln\left((1+i^G)\cdot P\right)_{t|t-1}$, serves analogously as a velocity forecast: it provides a best guess of how much to change the policy instrument to obtain a desired inflation rate. If the forecasted value turns out to be correct,

[5]The basic filtering and smoothing algorithms for a Markov switching model are discussed in Hamilton (1988, 1989).

[6]Kim (1993) notes that Markov switching in the variance is an adept alternative to GARCH models for modelling conditional heteroscedasticity or "ARCH" effects.

then inflation will equal π_0. Assuming that the forecasts we insert mirror the consensus forecasts of the time, the inflation target, π_0, should reflect the inflation intentions of the central bank.

In equation (1), the partial derivative between today's interest-rate change and π_0 is negative. A program of action designed to reduce the rate of inflation logically begins with increases in short-term interest rates. Similarly, if the forecast of inflationary pressure associated with a given interest-rate setting were to increase ($\Delta ln \left((1+i^G)\cdot P\right)_{t|t-1}$), then an increase in interest rates is projected to be necessary to achieve an inflation rate of π_0. This type of interaction between forecasts and instrument setting is the crux of many inflation targeting strategies, see Budd (1998). The Appendix discusses the derivation of time-series forecasts for $\Delta ln \left((1+i^G)\cdot P\right)_{t|t-1}$.

Once we have estimates of Germany's inflation target from equation (1), we can plug them into a model of Austria's interest-rate policy. For Austria, we assume that the central bank's interest-rate policy centers on choosing an interest-rate differential in relation to Germany to emphasise that Austria does not choose a short-run interest rate without referring to the level of short rates in Germany. In the model, we denote the interest-rate differential as $ln((1+i^A)/(1+i^G))$, where superscripts A and G refer to Austria and Germany. The interest rate for Austria is the three-month Euro schilling rate. Austria's monetary policy is assumed to close the gap between its implicit target of inflation, $\pi_0^A(S1)$, and Germany's probability-weighted target, $\widetilde{\pi_0^G}$.

$$\begin{aligned}
\Delta ln((1+i^A)/(1+i^G))_t \quad = \quad & -\pi_0^A(S1_t) + \Delta ln\left((1+i^A)/(1+i^G))\cdot P^A\right)_{t|t-1} \\
& +\lambda_1(S1_t)[\pi_0^A(S1_{t-1}) - \widetilde{\pi_{0,t-1}^G}] \\
& -\lambda_2(S2_t)[ln\,\tilde{e} - ln\,e]_{t-1} + \epsilon_t \qquad\qquad (1') \\
& \epsilon_t \sim \text{student-t}(0, \sigma^2(S3_t)\frac{n}{n-2})
\end{aligned}$$

where e is the schilling/DM exchange rate, P^A is the Austrian price level and $\tilde{e}$ is the target exchange rate defined below. The right hand side of equation (1′) includes two feedback terms: one is the difference in the inflation targets between Austria and Germany, $[\pi_0^A(S1_{t-1}) - \widetilde{\pi_{0,t-1}^G}]$, and the other is the difference between the target and actual schilling/DM exchange rate. Assuming that both feedback coefficients, λ_1 and λ_2, are positive, equation (1′) implies that if Austria's implicit target rate of inflation, π_0^A, is higher than

Germany's, then Austrian policymakers will raise their interest rate relative to the German rate. Similarly, if the schilling's exchange-rate is weaker than the implicit target, then the empirical model predicts an increase in Austrian interest rates relative to Germany's.

With only one policy instrument, however, Austria can choose only one long-run policy target, either the exchange rate or the inflation rate. This restriction does not prevent, however, the Austrian National Bank from taking feedback from both variables, provided that the target value of one is eventually reconciled with its actual value by some means other than policy actions. In Austria's case, we allow for rebasing of Austria's exchange-rate target such that the exchange-rate target is a weighted average of last period's actual and last period's target. Gradual rebasing occurs for values of δ less than one. In this way, one-time shifts in the exchange rate are gradually accommodated into the target rate. As δ decreases from one, the rate of accommodation increases.

Exchange Rate Target given $S2_t$:

$$ln\widehat{e}(S2_t) \quad = \quad \delta(S2_t)ln\widetilde{e}_{t-1} + (1-\delta(S2_t))ln e_{t-1} \qquad (2)$$

Probability Weighted Target:

$$ln\widetilde{e}_t \quad = \quad \sum_{j=0}^{1} \text{Prob}(S2_t = j \mid Y_t) ln\widehat{e}_t(S2_t = j) \qquad (3)$$

where $\widehat{e}$ is the target exchange rate conditional on the particular value of the state variable and Y_t is the set of data observable through time t. Note that $\delta(S2_t)$ is allowed to shift over time through Markov switching and is tied to $S2$, the same state variable that determines the strength of the feedback from the exchange rate.[7]

Because of the autoregressive nature of equation (2), inferences of the states at time t would depend on the entire history of past realisations of the state variables if it were not for the collapsing procedure of equation (3). Kim (1994) provides the justification for such a collapsing procedure and

[7] McCallum (1993) has used a similar weighting scheme; however, in his model δ remains constant.

notes that this procedure has a small effect on the calculated value of the likelihood function for maximum-likelihood estimation.

Six transition probabilities are defined for the feedback model's three state variables.

$$\begin{aligned}\text{Prob}(S1_t = i, S2_t = j, S3_t = k \mid Y_{t-1}) \;=\; & \text{Prob}(S1_t = i \mid Y_{t-1})\cdot \\ & \text{Prob}(S2_t = j \mid Y_{t-1})\cdot \\ & \text{Prob}(S3_t = k \mid Y_{t-1})\end{aligned} \tag{4}$$

$$\begin{aligned}\text{P}(S1_t = 0 \mid S1_{t-1} = 0) = p_1 \\ \text{P}(S1_t = 1 \mid S1_{t-1} = 1) = q_1 \\ \text{P}(S2_t = 0 \mid S2_{t-1} = 0) = p_2 \\ \text{P}(S2_t = 1 \mid S2_{t-1} = 1) = q_2 \\ \text{P}(S3_t = 0 \mid S3_{t-1} = 0) = p_3 \\ \text{P}(S3_t = 1 \mid S3_{t-1} = 1) = q_3\end{aligned}$$

where Y_{t-1} is all information available through time $t-1$. Maximum-likelihood estimates of the parameters are obtained by maximizing the log of the expected likelihood or

$$\sum_{t=1}^{T} ln \left(\sum_{i=0}^{1} \sum_{j=0}^{1} \sum_{k=0}^{1} \text{Prob.}(S1_t = i, S2_t = j, S3_t = k \mid Y_{t-1}) L_t^{(i,j,k)} \right) \tag{5}$$

where the student-t densities are

$$\begin{aligned} lnL_t^{(i,j,k)} \;=\; & ln\Gamma(.5(n+1)) - ln\Gamma(.5n) - .5ln(\pi n \sigma^2(S3_t = k)) \\ & -.5(n+1)ln\left(1 + \frac{\epsilon^2(S1_t = i, S2_t = j)}{n\sigma^2(S3_t = k)}\right) \end{aligned} \tag{6}$$

and Γ is the gamma function.

III. Estimation Results for Germany and Austria

The empirical results for the quarterly sample 1973:1-1994:4 are presented in the form of parameter estimates, graphs and a goodness of fit test. Equation (1) was estimated for German data and equation (1′) was estimated for Austria. The empirical estimates are given in Table 2.[8]

Empirical tests on equation (1) suggest that German monetary policy is best described as one of pure inflation targeting, with virtually no feedback taken from the exchange rate with the U.S. dollar or from a price-level target. Our empirical results for Germany are consistent with those of Bernanke and Mihov (1997) and Clarida and Gertler (1997), which identify the Bundesbank to be an inflation targeter. For Austria, on the other hand, the National Bank's manipulation of domestic interest rates responds significantly to the gaps in the exchange-rate target and gaps between the Austrian and the German inflation target. The estimated unconditional value of the target rate of inflation, π_0, equals 2.33 for Austria and lies close to the estimate of 2.86 for Germany.[9] These unconditional estimates are derived by taking the point estimates of $\pi_0(S1_t)$ and weighting by the unconditional probabilities of each state, where the Prob$(S1 = 0) = (1 - q_1)/(2 - p_1 - q_1)$.

Fig. 2a plots the probability-weighted values of the estimated inflation targets for Austria and Germany, where the probabilities are the filtered probabilities for $S1$ from the data. When interpreting Fig. 2a, recall from equation (1′) that the model-implied inflation target for the Austrian National Bank is not only π_0, but

$$\pi_0^A - \lambda_1(S1_t)[\pi_{0,t-1}^A - \widetilde{\pi_{0,t-1}^G}] + \lambda_2(S2_t)[ln\tilde{e} - lne]_{t-1}.$$

That is, Austria might have to import inflation or disinflation from Germany as called for by exchange-rate and inflation gaps relative to Germany. For this reason, Fig. 2b shows Austria's model-implied rate of inflation relative to Germany's estimated target rate of domestic inflation. Feedback from the gaps clearly illustrates how Austrian inflation is influenced by subtle shifts in Germany's inflation target.

Because exchange-rate feedback for Austria has its own state variable, $S2$, we separately discuss its shifts across the sample period. The degree of exchange-rate feedback for Austria is best illustrated by weighting the two values of λ_2 by the probabilities of being in the two states. Austrian monetary policy appears to have taken extensive feedback from the exchange

[8] The initial value of the exchange-rate gap for Austria was set to zero.

[9] The VAT shock allows to perform a consistency check for estimates concerning the implicit inflation target. The shock raises temporarily the inflation target from 2% to 5% for 1984.

rate. Fig. 3 illustrates that the feedback parameter on the exchange rate in Austria has varied between 0.4 and 0.6 throughout most of the sample period, and appears to have settled at about 0.55. A feedback parameter of 0.5, for example, means that the rule implies that the interest-rate differential increases 50 basis points following a quarter where a one percent gap develops between the actual and the target exchange rate.

In the late 1970s and early 1980s, the degree of exchange feedback diminished for brief periods. This period coincides with Austria's revaluation of the schilling at the time of the second oil shock. The rebasing parameter δ was low enough in an unrestricted model and was therefore set to zero in the low-feedback state; δ equals 0.93 in the high-feedback state, which implies that when Austrian monetary policy is targeting the exchange-rate closely, it does not rebase the target much to accommodate past exchange rate shocks. Fig. 4 shows the implicit target level of the exchange rate (100*log), relative to the actual exchange rate. In general, sharp exchange-rate movements in either direction lead to a gap between the implicit target and the actual rate, because the implicit target rate moves more slowly.

The feedback coefficients from exchange-rate and inflation gaps in the Austrian model are significant in at least one state. In the restricted model without feedback, the log-likelihood decreases from -112.7 to -120.7, and the estimates of the inflation target, π_0, for the two states show persistent swings in the inflation target from less than 3 percent to greater than 6 percent, which is much more than we would infer from the model with feedback from exchange-rate and inflation gaps.[10] Thus, failure to include feedback from exchange-rate and inflation gaps in the model would spuriously lead one to conclude that Austrian monetary authorities have had relatively large swings in their inflation targets. If the fluctuations in Austrian inflation were not largely imported from Germany, the Austrian schilling would not have much credibility with financial markets. In addition, the estimated value of $1/n$, the reciprocal of the degrees-of-freedom parameter for the student-t error terms increases and becomes significant in the model without feedback. A further result is that the residuals for Austrian changes in the interest-rate differential have much fatter tails when the feedback terms are absent. This means that without the feedback terms some large changes in Austrian interest rates would be hard to explain.

[10] These results are not reported for the sake of brevity and are available from the authors.

The Austrian model was also tested for sample dependency with a break at the end of 1983. This break point is useful, because it separates the periods before and after the crisis in Austria's nationalised industries and the increase in the value-added tax. It also occurs roughly at the midpoint of our sample period. The likelihood-ratio test statistic is 22.2 and its probability value with 16 degrees of freedom is 0.137. Thus, we are unable reject the hypothesis that the coefficients are stable across the first and second halves of the sample.

Diagnostic Tests and 'Rules of the Game'

To examine the goodness of fit more deeply, the test developed by Vlaar and Palm (1993) is used. The test is constructed by dividing the 90 observations into 20 groups based on the probability of observing a value smaller than the actual residual. If the model's time-varying density function fits the data well, these probabilities should be uniformly distributed between zero and one. Following Vlaar and Palm (1993), we define

$$N_i = \sum_{t=1}^{T} I_{it} \qquad \text{where} \qquad \begin{aligned} I_{it} &= 1, \quad \text{if} \quad \frac{(i-1)}{20} < EF(\epsilon_t/\sigma_t, \hat{\theta}) \leq \frac{i}{20} \\ &= 0, \quad \text{otherwise} \end{aligned}$$

where the expected value of the cumulative density function is taken across the eight combinations of the three state variables at each time in t. The estimated parameter vector is $\hat{\theta}$ and F is the cumulative density, which is student-t for Austria and standard normal for Germany. The goodness-of-fit test statistic equals $20/T \sum_{i=1}^{20} (N_i - T/20)^2$ and is distributed χ^2_{19} under the null. The specifications (1) and (1′) are not rejected for either Germany or Austria, because their test statistics are 19.1 and 28.9, with respective probability values of 0.451 and 0.066. In general, the changes in the Austrian interest-rate differential are more difficult to fit than the changes in German short-term interest rates. The latter shows more positive serial correlation and has a lower coefficient of sample kurtosis. These features of the data help explain why the German model can pass the goodness-of-fit test more easily, although neither model is rejected.

As reported above, if the feedback coefficients in the Austrian model are restricted to zero, the log-likelihood function decreases considerably from -

112 to -120. We would like to use the goodness-of-fit test described above to shed light on the source of the significance of the feedback coefficients. One possibility is that Markov switching in the feedback coefficients picks up outliers and "explains" them as regime changes. That is, the improvement in the likelihood function could be a result of improving the fit of a small number of outliers. A second possibility is that allowance for non-zero feedback coefficients and Markov switching in them improves the fit of the model in more than the tails. Vlaar and Palm's (1993) goodness-of-fit test can help us distinguish between these two explanations for the improvement in the likelihood function. First, the specification without feedback coefficients fails the goodness-of-fit test badly with a probability value below 0.01. Second, the problem with the distribution of the residuals across the 20 groups is not due to a simple pile-up of residuals in the tails, i.e., a high N_i count in the tails. Even the middle groups have much more uniform residual counts in the model with feedback coefficients. The feedback coefficients and Markov switching appear to do more than account for outliers in explaining changes in Austria's interest-rate differential.

We also looked at the Austrian residuals to uncover an implicit 'rules of the game' behind Austria's exchange-rate peg. The observations were divided into two groups, depending on whether the rule-implied change called for an increase in the interest-rate differential. For periods when the Austrian feedback rule called for increases, the residuals from the Austrian model are not distributed symmetrically around zero. Fig. 5 shows that for these observations a greater portion of the empirical density lies above zero. A Komolgorov-Smirnov test confirms that the distributions of the actual minus the implied interest-rate changes are not identical when the observations are divided into implied increases and decreases. The test statistic is 0.560 and the p-value is less than 0.001. From this, we conclude that one of the implicit 'rules of the game' in Austria's exchange rate peg was to overshoot implied interest-rate hikes. Such behaviour probably lent the hard currency policy credibility by demonstrating the willingness of the Austrian National Bank to raise interest rates aggressively when they were called to do so.

IV. Conclusions

As with the gold standard earlier this century, unwritten 'rules of the game' evolved in the post-Bretton Woods era for central banks that pegged an exchange rate. Such implicit rules are important, because the central bank still carries out an interest-rate policy and the public must be able to draw conclusions about the central bank's intentions from interest-rate changes. Successful central banks demonstrate their willingness to adjust interest rates readily and in the expected direction in the face of inflation and exchange-rate gaps to maintain the peg's viability in the eyes of the public.

In this article, we estimate an interest-rate rule for one successful pegging country, Austria, that finds significant feedback coefficients on exchange-rate and inflation gaps in relation to Germany. Previous studies have concluded that convergence in the inflation rates is the most important fundamental determining the sustainability of an exchange-rate peg. Our results show that Austria's inflation target was essentially indistinguishable from Germany's. More importantly, our empirical framework provides some clues in the form of an implicit interest-rate rule as to how Austria has maintained the same inflation fundamentals as Germany. When the feedback rule called for an increase in Austria's short-term interest rates, analysis of the residuals finds that actual increases tended to exceed the model-implied increases. In other words, policy erred on the side of overreaction, underpinning market confidence in Austrian monetary policy.

Appendix

The interest rate forecasts for the instrument model are based on a model by Kim (1994), which allows for two types of uncertainty. The first arises from heteroskedasticity in the error terms. This is modelled by a Markov switching process, which tries to match the persistence of periods of high and low volatility in the data. The second source of uncertainty arises as economic agents are obliged to infer unknown or changing regression coefficients.

The model generating the forecasts is

$$\begin{aligned}
\Delta ln\left((1+i)\cdot P\right)_t &= \beta_{0t} + \beta_{1t}\Delta ln(1+i)_{t-1} + \beta_{2t}\Delta ln P_{t-1} + \beta_{3t}\Delta ln e_{t-1} \quad (A1) \\
&\quad + u_t, \quad u_t \sim \text{Normal}(0, h_t) \\
h_t &= \sigma_0^2 + (\sigma_1^2 - \sigma_0^2)S_t \\
&\quad S_t \in \{0, 1\} \\
&\quad \sigma_1^2 > \sigma_0^2
\end{aligned}$$

$$\begin{aligned}
\text{Probability}(S_t = 0 \mid S_{t-1} = 0) &= r_1 \\
\text{Probability}(S_t = 1 \mid S_{t-1} = 1) &= r_2
\end{aligned}$$

Variable i is the 3-month Euro rate, P is the consumer price index, and e is the exchange rate. In the forecast for Germany (Austria), the German mark/US dollar (Austrian Schilling/German mark) exchange rate was used. Similarly, the Austrian forecast for $ln\left((1+i)\cdot P\right)_t$ replaces the interest rate, i_t, with the interest rate differential. The variances of the error terms are assumed to switch between a low and a high state according to a first-order Markov process. Persistence of low and high volatility states is increasing in r_1 and r_2, respectively. Note that the Markov switching in the forecast equation (A1) is distinct from the Markov switching in the interest-rate equation (1).

The time-varying coefficients assume that the state variables, β_t follow a random walk process:

$$\begin{aligned}
\beta_t &= \beta_{t-1} + v_t \\
&\quad v_t \sim \text{Normal}(0, Q)
\end{aligned}$$

The random walk assumption suggests that agents need new information before changing their views about the relationships among the variables.

Moreover, the time-varying structure of the forecasts allows it to adapt to structural breaks in the relationships between the dependent and explanatory variables.

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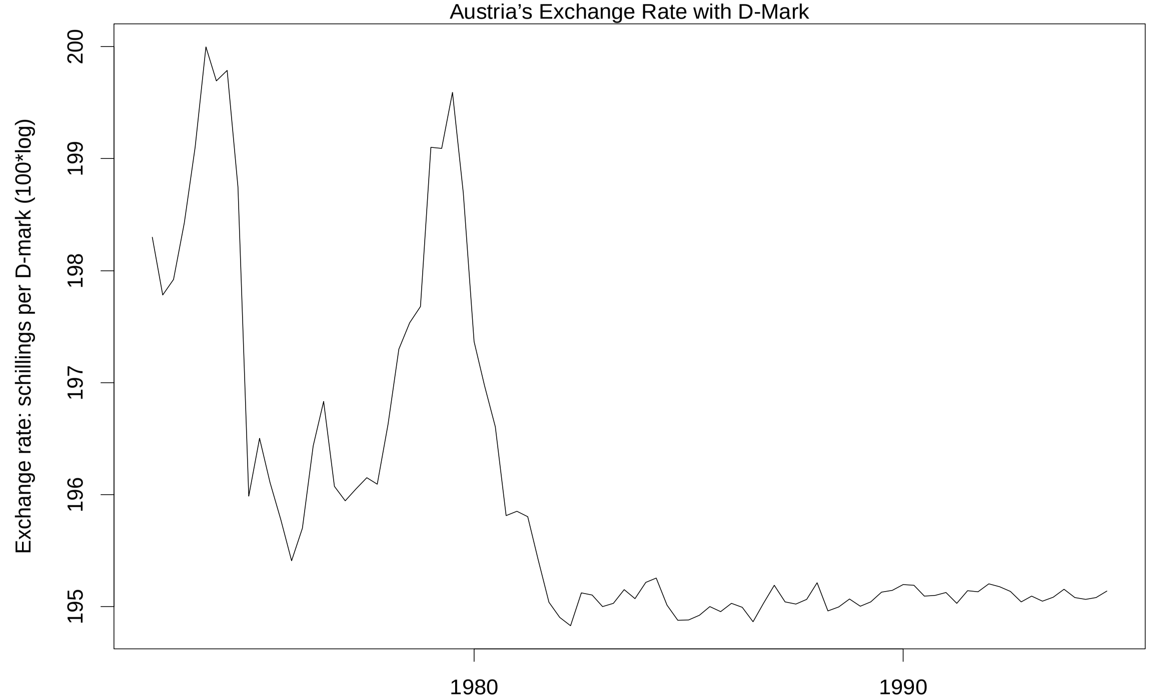
Table 1: Informal Inflation Targets for Germany	
year	**Unavoidable Inflation**
1975	4.5
1976	4.5
1977	3.5 “less than four”
1978	3
1979	3 “no new inflation”
1980	4
1981	3.8
1982	3.5
1983	3.5
1984	3
1985	2.5
1986-1994	2.0
Source: von Hagen (1995).	

Table 2: Indicator Models for Germany and Austria		
parameter	**Germany (1)**	**Austria** $(1')$
$\pi_0(S1=0)$	3.50 (.371)	4.64 (1.78)
$\pi_0(S1=1)$	0.710 (.553)	2.02 (.648)
$\lambda_1(S1=0)$	0	0.349 (.198)
$\lambda_1(S1=1)$	0	0.136 (.058)
$\lambda_2(S2=0)$	0	0.048 (.258)
$\lambda_2(S2=1)$	0	0.631 (.258)
$\delta(S2=0)$	n.a.	0
$\delta(S2=1)$	n.a.	0.926 (.174)
$\sigma^2(S3=0)$	0.189 (.043)	0.064 (0.023)
$\sigma^2(S3=1)$	2.93 (.836)	1.87 (.851)
p_1	0.969 (.034)	0.342 (.339)
q_1	0.895 (.080)	0.912 (.065)
p_2	n.a.	0.889 (.138)
q_2	n.a.	0.969 (.057)
p_3	0.968 (.024)	0.963 (.029)
q_3	0.947 (.043)	0.962 (.030)
$\frac{1}{n}$	0	0.127 (.265)
Log-Likelihood	-111.33	-112.71
No. of parameters	8	16
Note: Standard errors are in parentheses.		

Figure 1a

Austria's Exchange Rate with D-Mark



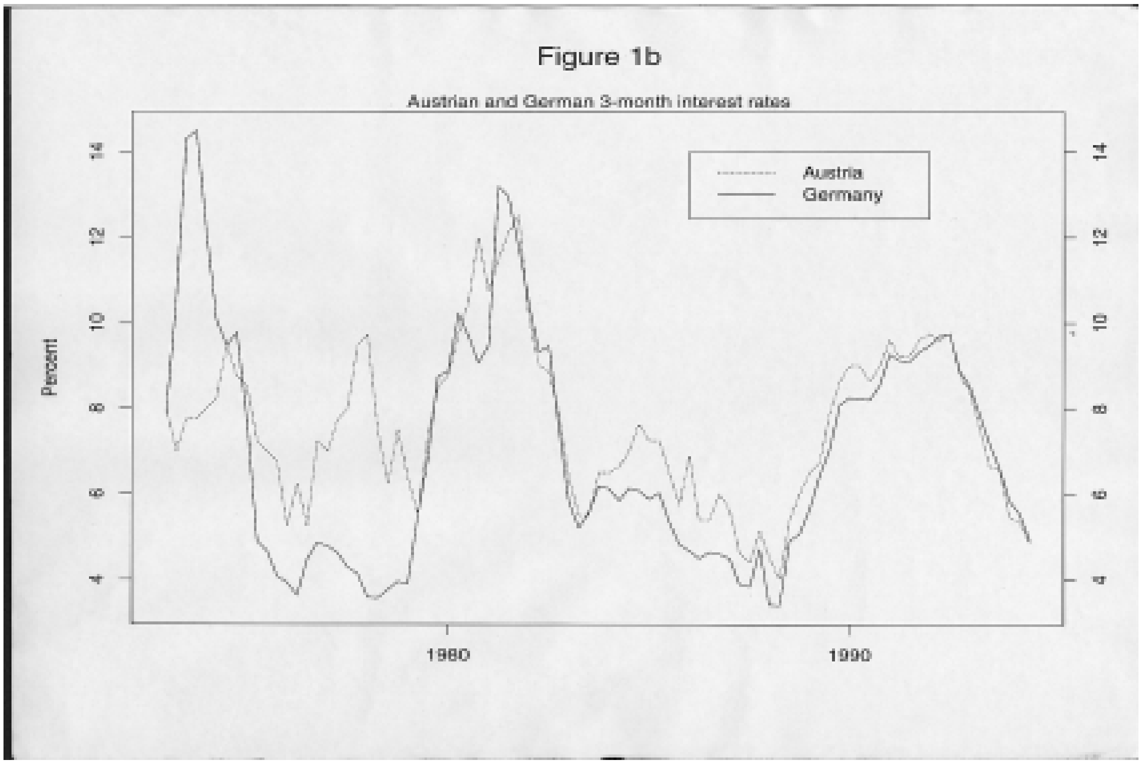


Figure 1b
Austrian and German 3-month interest rates
Austria
Germany
Percent
14
12
10
8
6
4
1980
1990

Figure 1c

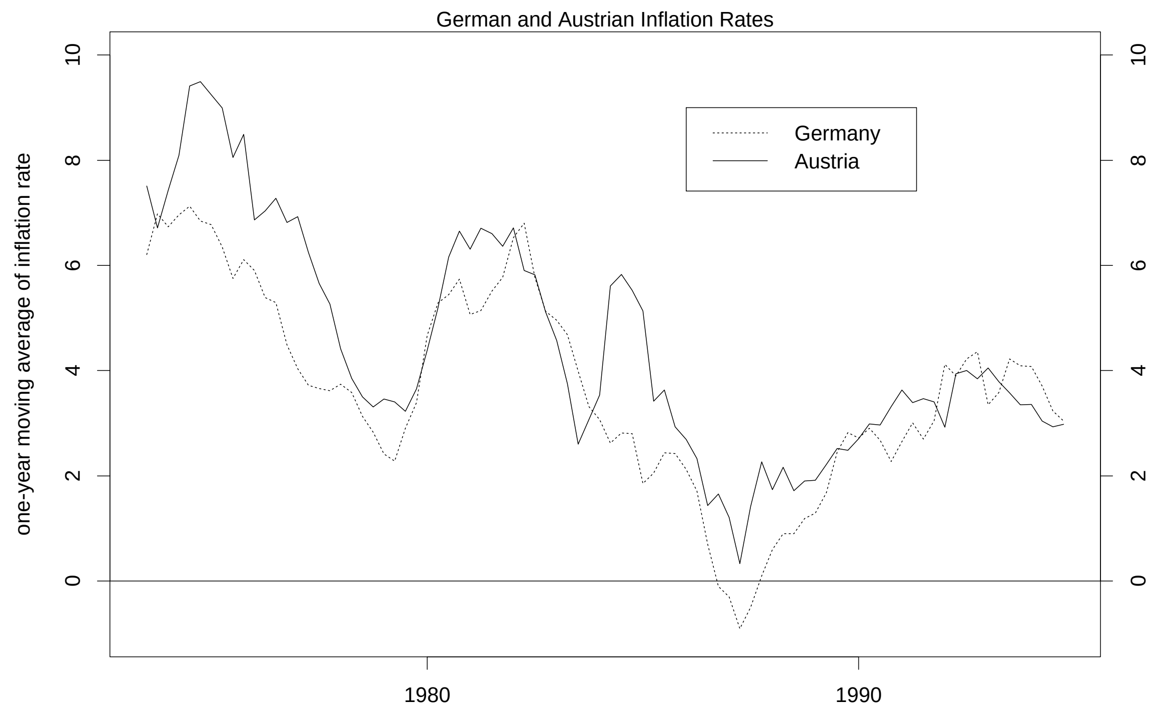

German and Austrian Inflation Rates
Germany
Austria
one-year moving average of inflation rate
0
2
4
6
8
10
1980
1990

Figure 2a

German and Austrian Implicit Inflation Targets

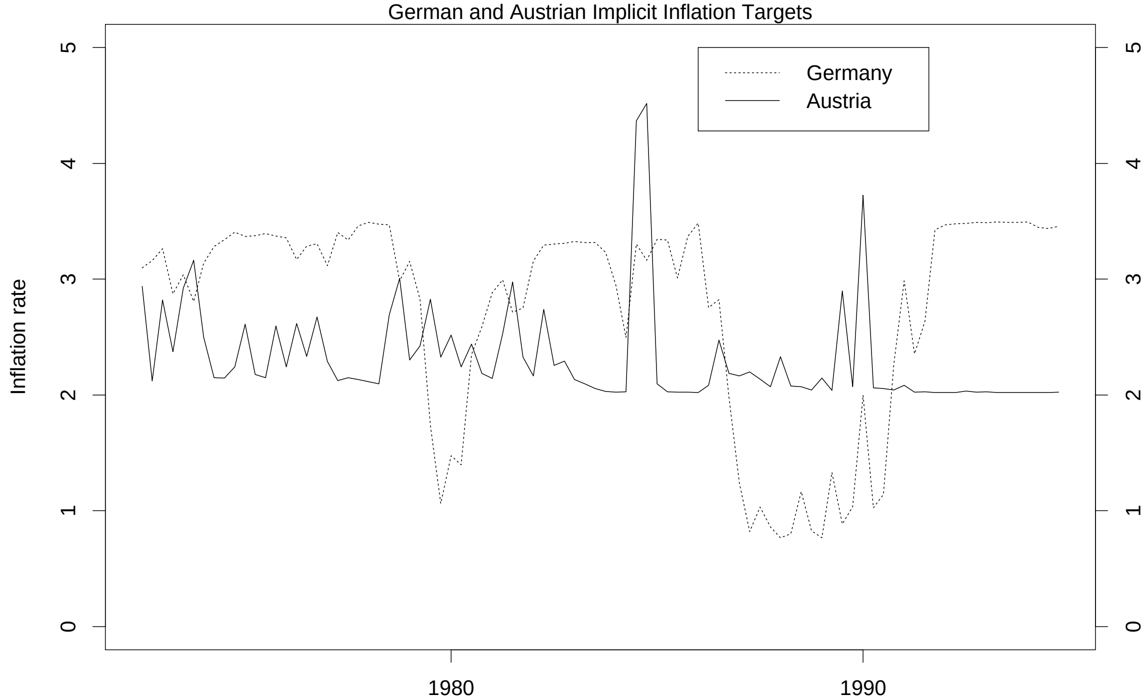


Figure 2b

German Inflation Trend and Austria's 'Effective' Target Given Feedback

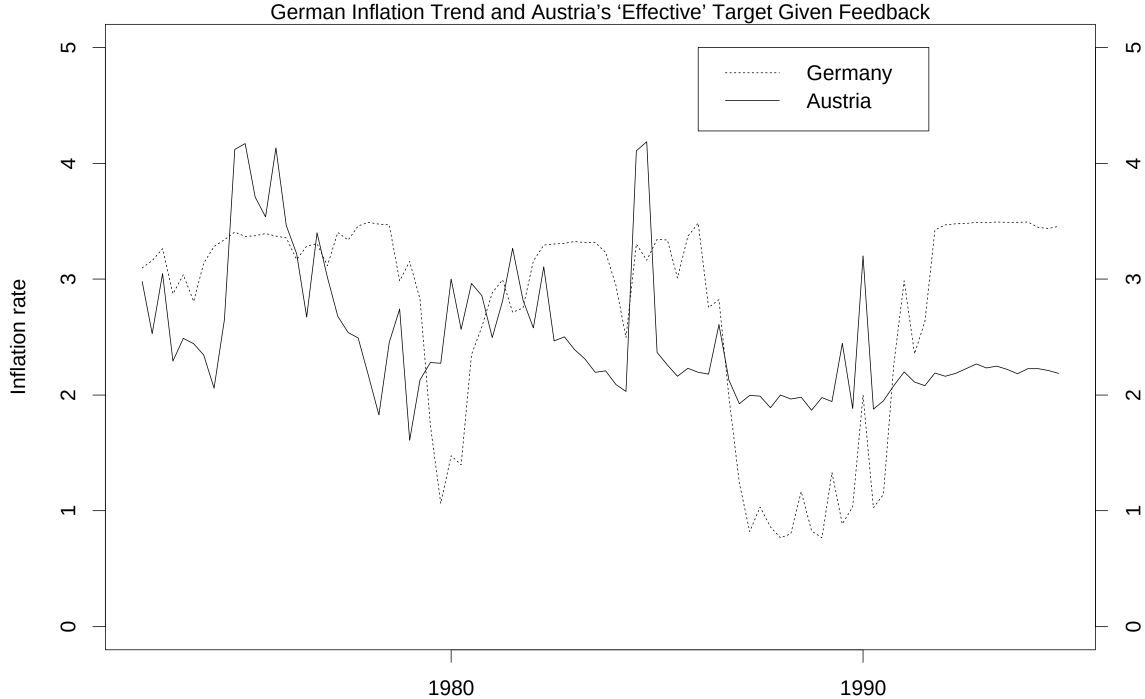


Figure 3

Strength of Exchange Rate Feedback for Austria

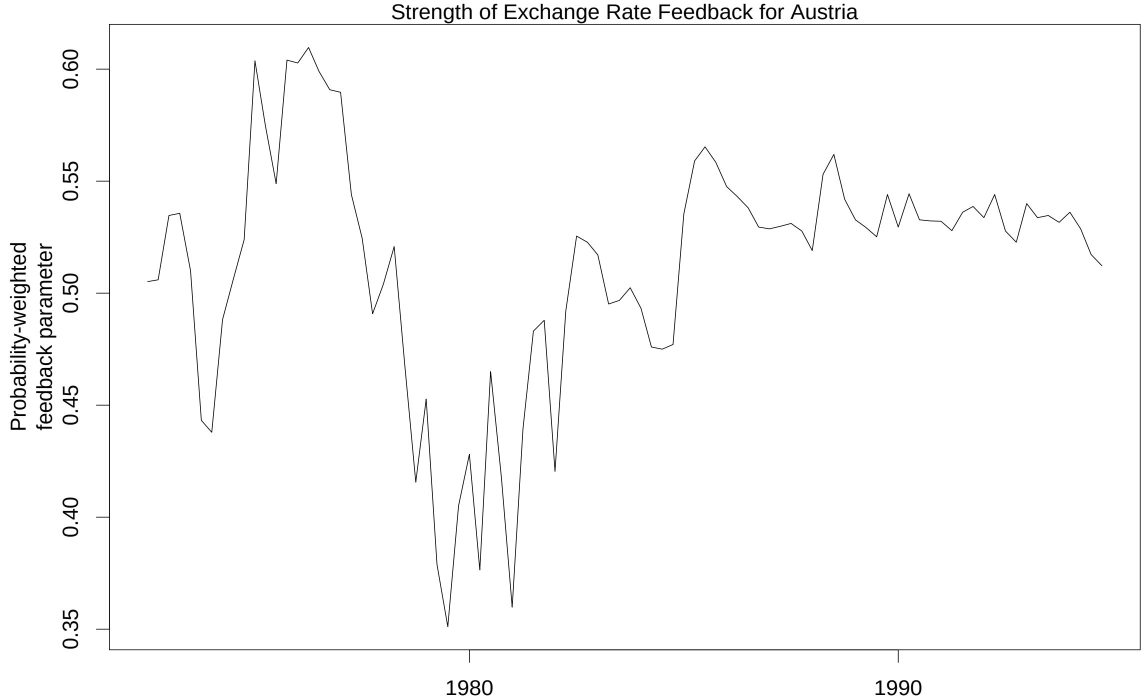


Figure 4

Austria's Exchange Rate with D-Mark and Implicit Target

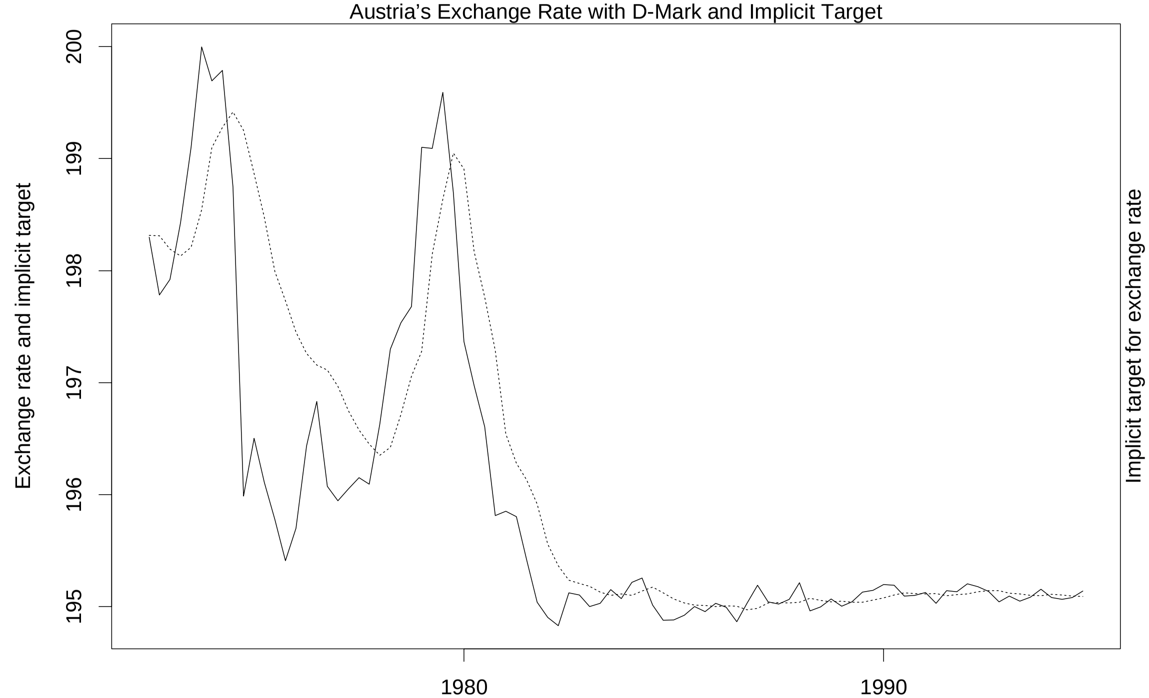


Figure 5: Empirical density of Austrian residuals when rule-implied change in interest-rate differential is positive