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ABSTRACT

During the 1970s and early 1980s, Spain suffered high rates of inflation but inflation declined and by 1997 inflation had fallen to approximately 2 percent. To fight inflation, Spain implemented austere monetary programs, joined the EMS in 1989, enacted central bank autonomy in 1994, and introduced inflation targets in January 1995. Certainly, these and other policies are in part responsible for the decline in inflation. However, it is unclear the extent of the contribution of each policy. This paper takes the first steps in capturing the magnitude of the effects of the different policies on inflation. It estimates a switching-regime model of inflation that allows for the endogenous identification of the dates of the switching from one regime to another. This possibility of dating the start of the different inflation regimes will allow us to link the evolution of inflation regimes to the timing of implementation of the anti-inflationary strategies.

1. INTRODUCTION

In the early 1980s, after the explosion in inflation in the 1970s following the two oil shocks, all European economies engaged -to different extent- in extremely tight monetary policies to fight the escalating inflation. Many of those countries also joined the EMS in the hope that this arrangement, by accepting Germany monetary policy, would provide additional discipline, and thus, would help in further reducing inflation. The efforts to reduce inflation were further intensified in the late 1980s with a push for increased institutional independence for central banks. Finally, in the 1990s many countries introduced what can be called 'inflation target regimes', with explicit quantitative inflation targets. Again, this new regime was introduced to help in reducing inflation. While the economics profession views about the role of the EMS, central bank independence, and inflation targeting in effectively reducing inflation differs, inflation did fall in Europe with inflation rates now oscillating around 2 percent.

Spain, as the other European economies, also suffered high rates of inflation in the 1970s and in the early 1980s, but, as shown in Figure 1, inflation did decline and by 1997 inflation had collapsed to approximately 2 percent. To fight inflation, Spain implemented austere monetary programs, joined the EMS in 1989, enacted central bank autonomy in 1994, and introduced inflation targets in January 1995. Certainly, these and other policies are in part responsible for the drop in inflation. However, it is unclear the extent of the contribution of each policy. This paper takes the first steps in capturing the magnitude of the effects of the different policies on inflation. It estimates a model of inflation that allows for different regimes, with the mean rate of inflation, inflation persistence, and volatility possibly differing across regimes.

The method implemented is the Hamilton (1989) filter, which allows for the endogenous identification of the dates of the switching from one regime to another. This possibility of dating the start of the different inflation regimes will allow us to link the evolution of inflation regimes to the timing of implementation of the anti-inflationary strategies. For example, it will allow us to examine whether membership to the EMS affected inflation persistence or whether the ***Banco de España*** gained reputation as a tough anti-inflationary monetary authority as a result of this decision. The rest of the paper is organized as follows. Section 2 provides a chronology of the events leading to the reduction of inflation from 25 percent in

1977 to 2 percent in 1997. Section 3 presents the methodology and the models to be estimated. Section 4.1 reports the estimation of a two-state switching-regime model for inflation. Section 4.2 generalizes the model of inflation to a three-state switching-regime model. Section 5 concludes.

2. A CHRONOLOGY OF ANTI-INFLATION STRATEGIES

The return of Spain to democracy in 1975 was accompanied by expansionary fiscal policies. The structural fiscal deficit increased to 2 percent of GDP in 1976 and continuously increased thereafter reaching 7 percent of GDP by 1985. In the first few years monetary policy basically accommodated to the changes in the fiscal stance, with money supply (M1) growing around 20 percent between 1975 and 1977. By the end of 1977, inflation had reached almost 25 percent. With inflation rapidly accelerating, in December 1977 the Suárez government, announced the *Pactos de la Moncloa* plan. The social pact between the government, political parties, and the unions included among its key features a mechanism to break the inflation inertia: wages were going to be set according to expected inflation and not to compensate for past inflation. The *Pacto* was complemented with contractionary monetary policy. In contrast with the previous accommodating monetary policy, the *Banco de España* started to take an active role in monetary policy by publicly announcing monetary growth target rates, with the target bands for M3 declining from 14.5-19.5 percent in 1978 to 10.5-14.5 percent in 1984. The plan was very successful with inflation declining to less than 10 percent by 1984.

The instability of money demand brought about by the liberalization of the banking industry starting in 1978 and the flurries of financial innovations that followed the deregulation, led the *Banco de España* to de-emphasize the targeting of monetary aggregates. Notably, around this time monetary policy started to take into account the trade-weighted exchange rate, particularly after 1986, when Spain joined the European Economic Community. With the de-facto pegging of the peseta since 1986 and the more formal pegging after Spain joined the ERM in the first half of 1989, the monetary authority lost some control over monetary policy. During the 1986-1991 period, there were large, cumulative inflows of capital attracted by the higher yields of Spanish bonds and by the growing belief by international investors that Spain was on an irreversible convergence path toward the Economic and Monetary Union. As it is examined in greater detail in Ayuso and Escrivá (1998), the large capital inflows could not be completely sterilized, with money supply growing at a pace extremely high to guarantee price stability. In fact, during the 1986-1991 period the growth rate of the targeted broad monetary aggregate always surpassed the target band and inflation increased rapidly, climbing from about 5 percent in 1987 to about 7.5 percent in 1989. Inflation was further fuelled by an expansionary fiscal policy. Between 1988 and 1993 public deficit increased from 3.3 percent of GDP to 7.5 percent, with public expenditure reaching 50 percent of GDP and government debt also increasing to approximately 60 percent of GDP. Although inflation started to converge to the rate of inflation in Germany, the convergence was slow and the peseta appreciated massively. The ERM crisis in 1992, with the devaluations of the peseta in September and November 1992, interrupted briefly this process, with inflation increasing to about 5 percent in 1994.

In 1994 the government implemented a new set of anti-inflationary policies. First, the Program of Convergence for the Spanish economy was revised and more emphasis was given to reducing public deficit according to the guidelines included in the Maastricht Treaty. Second, the labour market was given more flexibility, and third the *Banco de España* gained independence in 1994 (*Ley de Autonomía del Banco de España de 1994*). Also, in 1995 the *Banco de España* started to implement a regime of inflation targets. By the end of 1997 inflation had declined to approximately 2 percent.

3. METHODOLOGY

With a changing fiscal and monetary stance, the stochastic process followed by inflation will also change over time. To examine whether in fact the stochastic process followed by inflation changed as a result of the stabilization programs implemented since the 1960s, we will estimate a switching-regime model for inflation. The model consists of the following equations:

$$\pi_t = \delta_0(R_t) + \sum_{j=1}^{q} \delta_j(R_t)\pi_{t-j} + \epsilon_t(R_t), \quad \epsilon_t(R_t) \sim N(0,\sigma^2(R_t)) \qquad [1]$$

$$Prob(R_t = j | R_{t-1} = i) \;=\; p_{ij}, \quad i,j \;=\; 1,2,...,n, \qquad [2]$$

where π_t is the annual rate of inflation, R_t is the variable representing the inflation regime, and n is the number of possible regimes. In (1) inflation is modeled as an autoregressive process of order q with regime-dependent constant, autoregressive parameters, and volatility. Since some of the anti-inflation programs included de-indexation schemes, one expects that inflation persistence will decrease after the stabilization program is implemented, that is the sum of the $\delta_j(R_t)$ parameters will become smaller after an anti-inflation program is implemented. Equation (2) shows the Markov chain transition probability matrix, where p_{ij} is the probability of switching from Regime i to Regime j in one period.

We allow for up to a maximum of three regimes. We first explore a two-regime switching model. We afterwards examine whether the inflation rate can be best described by a three-regime switching model and explore different formulations for the three-regime model.

To estimate the model in equations [1]-[2], we use a modified Hamilton's (1989) nonlinear filter. Since there is no presumption that in fact there were changes in regime, the estimation procedure does not impose the existence of two or more differentiated states. Moreover, the estimation is based on the assumption that the regime is not observed directly but must be inferred based on the observation of current and past values of inflation. For the two-regime model, with regimes 0 and 1, the optimal forecast of this process can be thought of as the following sequence of steps.

For any period t, we have a certain prior about the probability of being in state 1 or 0 based on past information:

$$Prior(R_t = 1) \;=\; (1 - p_{10}) Post(R_{t-1} = 1) \;+\; p_{01} [1 - Post(R_{t-1} = 1)] \qquad [3]$$

where

$$Prior(R_t = 1) = Prob(R_t = 1 | I_{t-1}), \; I_t = \{\pi_t, ..., \pi_1\}, \; \text{and} \; Post(R_t = 1) = Prob(R_t = 1 | I_t).$$

We then calculate the density function of π_t

$$f(\pi_t|I_{t-1}) = f(\pi_t|R_t=1)\ Prior(R_t = 1) + f(\pi_t|R_t=0)\ [1 - Prior(R_t=1)] \quad [4]$$

Finally, we update our predictions using the Bayes formula:

$$Post(R_t=1) = \frac{f\ (\pi_t|R_t = 1)\ Prior\ (R_t=1)}{f\ (\pi_t|I_{t-1})} \quad [5]$$

We update repeatedly over the entire sample using [3]-[5].

The estimation procedure is as follows. We start at $t=1$ with the unconditional probability, which we set equal to the limiting probability of being in Regime 1 of the Markov process in equation [2]. Using [3]-[5] we construct the sample log likelihood

$$\sum_{t=1}^{T} log\ f(\pi_t|I_{t-1}) \quad [6]$$

which can be maximized numerically with respect to the unknown parameters $\delta_0(R_t)$, $\delta_j(R_t)$ and $\sigma^2(R_t)$.

The test of the multi-regime models against single-regime models is not straightforward because the parameters in the transition probability matrix become nuisance parameters, i.e. they are not identified under the null hypothesis of a single regime. The likelihood surface under the null will be flat, instead of locally quadratic in the neighbourhood of the null, as required by standard distribution theory. As a result the global maximum may be quite far from the null. Hansen (1992) proposes a method for calculating an approximation to the distribution of a valid test statistics using the empirical distribution of an upper bound of the LR statistic. To compute the empirical distribution of the statistic for the multi-regime versus the single regime model we need a single state model which plays the role of the null and the values of the parameters under the alternative. We test the null hypothesis under two different assumptions about the inflation process: a random walk and an AR(4) -see the Appendix for more details. For the nuisance parameters, we follow Hansen (1992) and use three different grids for the relevant parameters. The use of different grids is aimed, first, at covering a reasonable range, and second, at analysing the robustness of the result of the test.

4. DATA AND RESULTS

As it is usual in the related literature, the price index we use is the Consumer Price Index (CPI). Our sample spans the period 1961:1 -1997:3. Due to the well documented seasonality in the Spanish CPI (Matea and Regil, 1996) we focus on annual inflation. However, we sample the data at quarterly frequencies. As it is well-known, this implies an overlapping in the data that induces a moving average component in the residual of the univariate model. This requires a correction for autocorelation in the estimated variance-covariance matrix. Whereas such a correction is available for linear models (see Newey and West, 1987) it is not clear how to correct in non-linear models like ours. In order to circumvent this problem, we approach the MA component by expanding the autoregressive one.(1)

4.1 The Two-Regime Model

Table 1 shows the maximum-likelihood estimates of several two-regime switching models chosen according to the standard strategy of going from the general to the particular. Three main characteristics can be inferred from the results in Table 1. First, the autoregressive structure of the two-state model is quite simple: only the first order autoregressive parameter is found to be significant and there are no differences in persistence between both regimes. In spite of the above-mentioned problem of overlapping, we cannot reject the null of zero higher order autoregressive parameters in any of the regimes.

Second, according to the estimated means and variances there seems to be two different regimes, one of them showing a much higher volatility (2.08 versus .71) and also a higher unconditional mean(2) (15.8 vs. 2.3). This result is in line with those presented among others by Evans and Watchtel (1992) and Ricketts and Rose (1995). That is, in a two-state model, high inflation seems to be associated with increased uncertainty about future inflation. Nevertheless, note that the intercepts in both regimes are only marginally different from each other.

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(1) Notice that using monthly data would have intensified the data overlapping problem.

(2) I.e. $\delta_0/(1-\delta_1)$

Before going beyond in the interpretation of our results we have to test formally whether our two-regime model provides a better fit than a single-regime model. Table 2 shows the main results of the Hansen test. As can be seen, we clearly reject in all cases the null hypothesis of single-state representation against our two-state representation for the Spanish inflation process.

According to our estimates of the transition matrix, the probabilities of staying in any regime are quite high. This is a rather standard result in the related literature (see, for example, Ricketts and Rose, 1995). Using this probabilities and equations (3)-(5), we can construct the prior probabilities of being in different inflation regimes and the expected inflation rate according to this model. Figure 2 shows the prior probabilities of being in each of the two regimes. These probabilities point towards a change initiated around 1978 and consolidated around 1984, which could be related to the anti-inflation program implemented in 1978, *Los Pactos de la Moncloa.*[3] As the transition probabilities, prior probabilities are also close to the limit 0-1 case. However, the average inflation in each regime is different enough as to yield forecasting errors comparable to those in Ayuso and López-Salido (1998). As Chart 3 shows, there are different periods where systematic differences arise between the annual observed and 1-year-ahead expected inflation. During the period of increase in the inflation rate, the two-state model tends to under-predict, but once inflation starts to decrease the model tends to over-predict. During the long disinflationary episode experienced by the Spanish economy, inflation expectations reflected the observed inflation movements with some delay. This process seems to end around 1989. After 1989, the observed inflation movements are identified mainly as transitory deviations around the values that characterise the low inflation regime. Thus, under- and over-prediction periods are much shorter and less important from a quantitative standpoint.

It should be noticed, however, that our previous analysis is mainly based on a difference in the average inflation in each regime which, from a statistical point of view, is only marginally different from zero. Remember from Table 1 that the main difference between the two regimes that we are able to identity is a difference in volatility. Can we really state that there are a low inflation regime and a high

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[3] Of course, our approach is not precise enough as to allow us to discriminate between this policy change and other possible changes that could have taken place by that time.

inflation regime in Spain? Looking at Chart 2, it is possible that we are identifying a change in volatility around 1978, not a change in mean. In order to examine this issue, we now extent our model to include an additional (third) regime.

4.2. A Three-Regime Model

Again, the model estimated is represented by equations (1)-(2) with several restrictions. First, the model estimated is an AR(1) with regime-independent first order autoregressive parameter. Second, the transition probability matrix is restricted so that the transition between the 'high' inflation regime to the 'low' inflation regime can only occur through an intermediate regime of 'medium' inflation.[4]

Table 3 shows the main results of our estimates. We have estimated two different models. Model 1 corresponds to the most general specification of the equation (2). Interestingly, the inflation mean is correlated with volatility, so that the higher the rate of inflation, the higher the volatility. Our estimates suggest the existence of three regimes.[5] They can be characterized as follows: a low and stable inflation regime, a medium and more volatile inflation regime and a high and volatile inflation regime. Nevertheless, the intercepts (and therefore, average inflation) in States 2 and 3 are rather similar and the same applies to the estimated variance in regimes 1 and 2. We cannot reject these two restrictions, that are therefore incorporated into Model 2.

Model 2, our preferred specification, allows us to identify three regimes slightly different from the three regimes in Model 1. Thus, as Table 4 shows, there seems to be a high and volatile inflation regime, a high but stable inflation regime and a low and stable inflation regime. According to the unconditional means in each

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(4) Three-state models with different and higher order autoregressive parameters and unrestricted transition probabilities have also been estimated. First, we cannot reject the null hypothesis of a single first order common parameter at 3 percent level of significance (see Table 3). Second, when they are not restricted, the transition probabilities from state 1 to state 3 and from state 3 to state 1 are estimated at around 5e-06.

(5) Given its heavy computational requirements, we have not performed yet the formal test of the three-regime model against the null of a two-regime model.

regime, average 'low' and 'high' inflation are estimated at 3.7 and 11.9 percent, respectively, whereas 'low' and 'high' standard deviations are estimated at 0.65 and 2.05. These estimates are quite similar to those of the two-regime model, particularly those regarding volatility.

The transition probabilities among those regimes are now less close to the limit 0-1 values but for Regime 1. Chart 4 shows the corresponding prior probabilities of being in each regime. As can be seen, we still identify the perceived change in volatility we referred to in the previous section: around 1978, inflation volatility is perceived to change from high to low. But we do not observe a similar perceived change in the average inflation by that time. Such a change does not occur until late eighties.[6] Interestingly, it is at this time that Spain joined the ERM and a fiscal consolidation plan was announced, suggesting that both events could have helped in achieving a lower inflation.

Finally, Chart 5 shows 1-year-ahead expected annual inflation and the actually observed one. This chart offer a picture rather similar to that of the two-regime model and therefore, expanding the model does not modify our previous conclusions. Doubts about the current inflation regime and -maybe to a lesser extent- non-zero probabilities of changing to a different regime can explain forecasting errors far from the usual white noise assumption. As examined before, it seems that agents' expectations adjust slowly over time. Note, however, that the relatively protracted periods of under- or over-prediction of inflation are not a sign of irrationality but a sign of imperfect information.

5. CONCLUSIONS

This paper examines whether the stochastic process followed by the rate of inflation in Spain from 1962 to 1997 can be better characterised as following a switching-regime. Our preferred model is the one with three regimes: the first regime is characterised by high and volatile inflation. The second regime is better

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[6] To further check this result we have also estimated a two-regime model for a shorter subsample starting in 1978. Our results confirm the change in the unconditional mean (point estimates are 12.2 percent and 4.4 percent) which agents perceive to occur around late eighties.

described by high inflation and low volatility. Finally, the third regime is one of both low inflation and volatility.

Average low and high inflation are estimated around 3 and 11 percent, respectively, whereas low and high standard deviations are estimated at 0.65 and 2.05. According to our estimates, agents perceived a change from high to low inflation volatility around 1978 and a change from high to low inflation around 1989. Both years are important in the evolution of the Spanish policy-mix: in 1978 the *Pactos de la Moncloa* marked an important change in the economic environment and in 1989, Spain joined the EMS.

Finally, we illustrate that the existence of different inflation regimes has major implications for inflation forecasting. With imperfect information, agents do not observe the current regime nor are they able to fully anticipate a switch to another one. Thus, there are protracted periods in which inflation expectations are over or under the ex-post observed inflation and, therefore, *ex-post* expectation errors are correlated over time. These expectation errors, however, are not a sign of agents irrationality but can be explained in terms of an imperfect information problem.

Table 1. Maximum likelihood estimates of two-regime models

Parameters	(1)	(2)	(3)	(4)	(5)
$\delta_0(R_t=0)$	-.02 (.16)	-.02 (.10)	-.02 (.11)	-.00 (.04)	.08 (.15)
$\delta_1(R_t=0)$	.87 (.11)	.87 (.10)	.87 (.12)	.98 (.01)	.97 (.01)
$\delta_2(R_t=0)$	.17 (.12)	.16 (.13)	.11 (.11)	--	--
$\delta_3(R_t=0)$	.01 (.10)	-.05 (.08)	--	--	--
$\delta_4(R_t=0)$	-.06 (.08)	--	--	--	--
$\sigma(R_t=0)$	.70 (.06)	.71 (.06)	.71 (.06)	.71 (.06)	.71 (.06)
$\Delta\delta_0$	1.07 (.49)	.92 (.50)	.84 (.49)	.95 (.47)	.44 (.26)
$\Delta\delta_1$	.08 (.17)	.09 (.16)	.09 (.16)	-.05 (.04)	--
$\Delta\delta_2$	-.09 (.22)	-.08 (.23)	-.14 (.16)	--	--
$\Delta\delta_3$	.16 (.18)	-.07 (.16)	--	--	--
$\Delta\delta_4$	-.23 (.14)	--	--	--	--
$\Delta\sigma$	1.26 (.17)	1.34 (.17)	1.34 (.16)	1.35 (.16)	1.37 (.16)
p_{11}	.991 (.009)	.992 (.008)	.992 (.009)	.992 (.009)	.992 (.009)
p_{00}	.992 (.007)	.992 (.007)	.992 (.008)	.992 (.008)	.992 (.009)
logL	-219.4	-224.4	-226.6	-229.9	-230.5
N	139	140	141	142	142

Notes:
- Standard errors -in brackets- are robust to heteroscedasticity.
- $\Delta\delta_j = \delta_j(R_t=1)-\delta_j(R_t=0)$
- $\Delta\sigma = \sigma(R_t=1)-\sigma(R_t=0)$

Table 2. Standarised LR Hansen test

Grid	H_0:$\Delta\pi = u_t$	H_0:$P_4(L)\Delta\pi = u_t$
1	6.785 (2.721)	4.741 (2.767)
2	6.712 (3.156)	5.650 (3.421)
3	6.662 (3.685)	5.450 (3.719)

Notes:

- LR statistics have been obtained using 1000 Monte Carlo replications en each grid point. 5 percent critical values are in brackets.
- Grid 1 (256 grid points):
  - δ_0 from .05 to .11 in steps of .02 (4 grid points);
  - σ from .60 to .75 in steps of .05 (4 grid points);
  - p_{00},p_{11} from .87 to .99 in steps of .04 (4 grid points);
- Grid 2 (256 grid points):
  - δ_0 from .01 to .31 in steps of .10 (4 grid points);
  - σ from .40 to 1.0 in steps of .02 (4 grid points);
  - p_{00},p_{11} from .54 to .99 in steps of .15 (4 grid points);
- Grid 3 (1296 grid points):
  - δ_0 from .05 to 1.3 in steps of .25 (6 grid points);
  - σ from .01 to 1.26 in steps of .25 (6 grid points);
  - p_{00},p_{11} from .49 to .99 in steps of .10 (6 grid points);

Table 3. Maximum likelihood estimates of alternative three-regime models

	MODEL 1			MODEL 2		
Parameters	$R_t=1$	$R_t=2$	$R_t=3$	$R_t=1$	$R_t=2$	$R_t=3$
$\delta_0(R_t)$	.26 (.22)	.74 (.74)	.92 (.39)	.28 (.16)	.90 (.36)	
$\delta_1(R_t)$	.93 (.03)			.92 (.02)		
$\sigma(R_t)$	.64 (.06)	.89 (.19)	2.07 (.14)	.65 (.15)		2.05 (.16)
p_{1R_t}	1.00	.00	--	1.00	.00	--
p_{2R_t}	.03	.94	.03	.05	.84	.11
p_{3R_t}	--	.02	.98	--	.03	.97

logL (Model 1) = -228.4 logL (Model 2) = -229.35
LR test Model 2 vs. Model 1 = 1.90

Notes:

- Standard errors -in brackets- are robust to heteroscedasticity.
- T-ratios for δ_j, $j=2,3,4$ are .07, -.92 and -1.5, respectively.
- The likelihood ratio statistics for $\delta_1(R_t=1)=\delta_1(R_t=2)=\delta_1(R_t=3)$ is 7.4, with a p-value of .03.

Table 4. Inflation regimes in our three-regime switching model.

		Average inflation	
		Low	High
Inflation variability	Stable	Regime 1	Regime 2
	Volatile	--	Regime 3

CHART 1. THE SPANISH INFLATION

QUARTERLY ANNUAL RATE

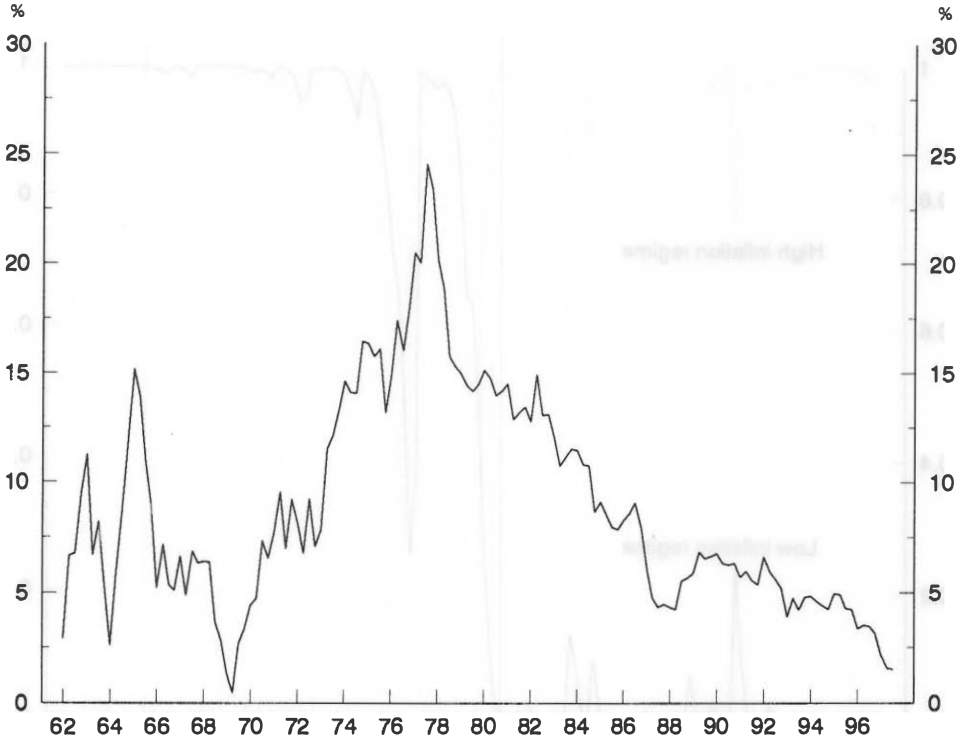


CHART 2. ESTIMATED PRIOR PROBABILITIES

2-REGIME MODEL

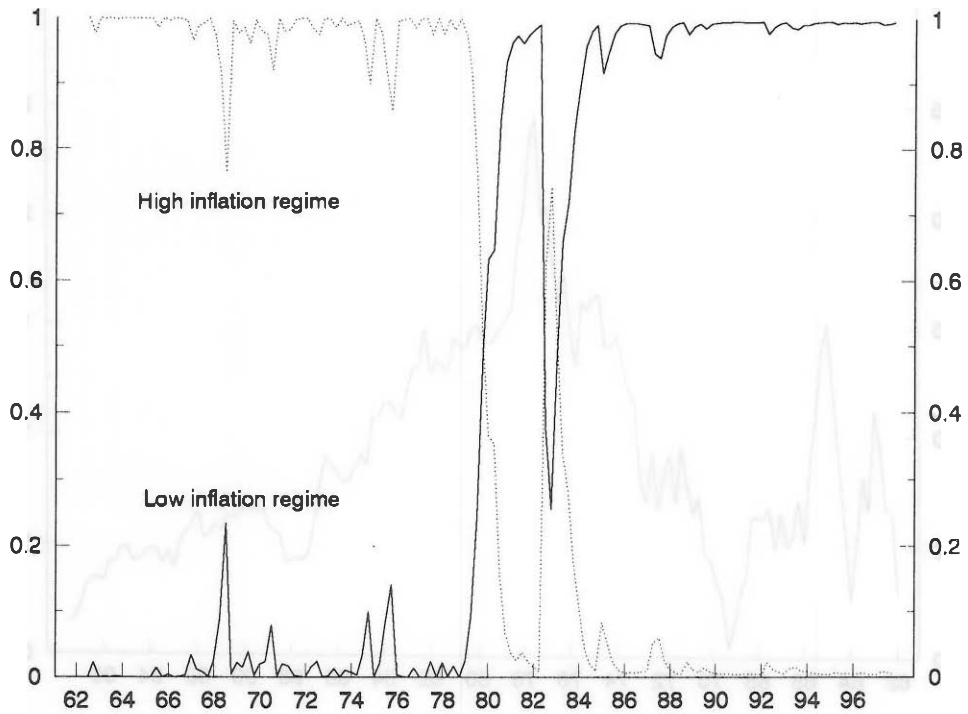


CHART 3. EXPECTED AND OBSERVED ANNUAL INFLATION

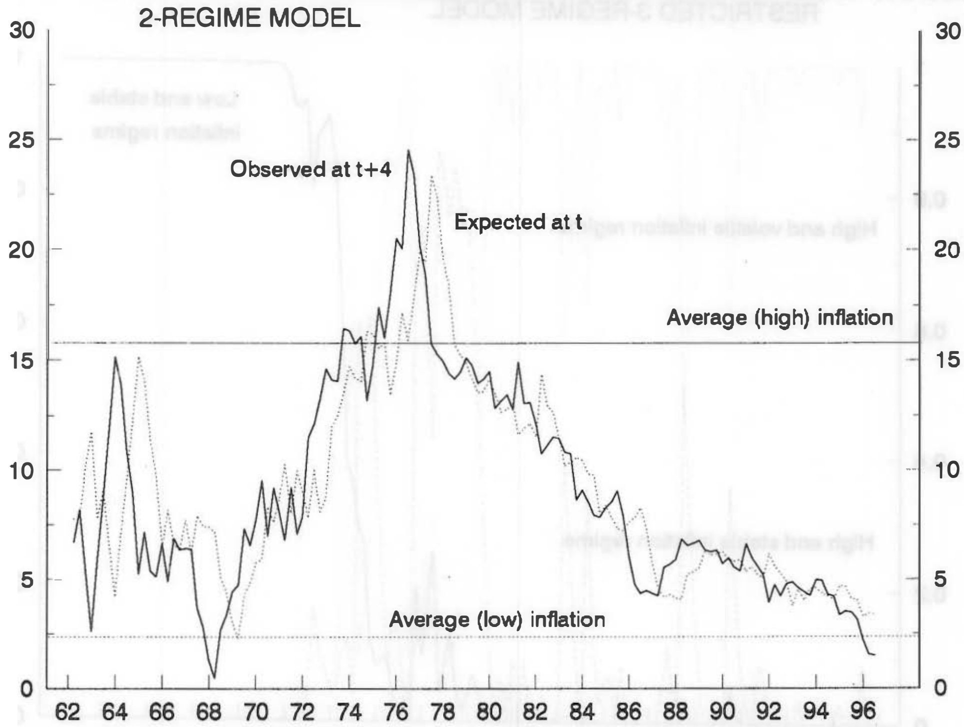


CHART 4. ESTIMATED PRIOR PROBABILITIES
RESTRICTED 3-REGIME MODEL

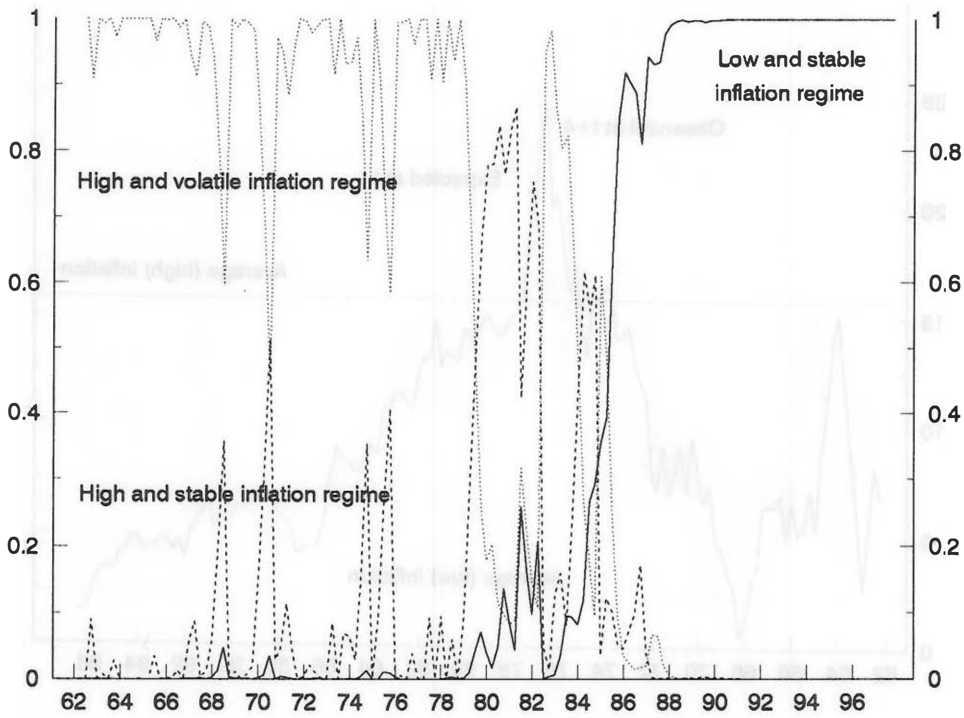
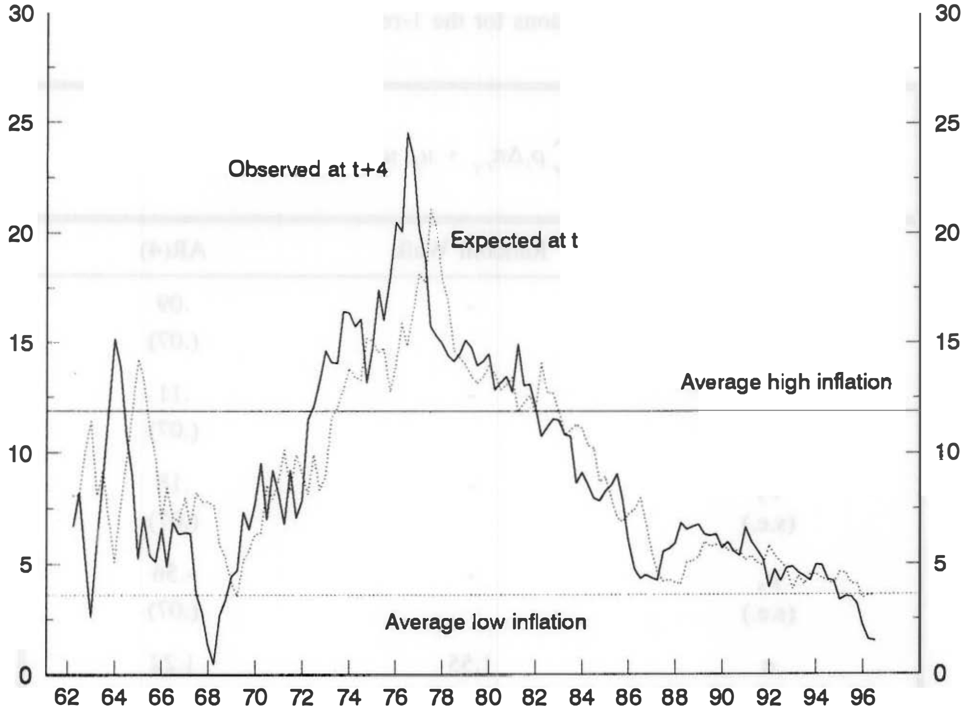


CHART 5. EXPECTED AND OBSERVED ANNUAL INFLATION
RESTRICTED 3-REGIME MODEL



APPENDIX

Table A1. Alternative representations for the 1-regime inflation model

$$\Delta\pi_t = \sum_{j=1}^{4} \rho_j \Delta\pi_{t-j} + u_t;\ u_t \sim D(0,\sigma_u^2)$$

	Random Walk	AR(4)
ρ_1	-	.09
(s.e.)		(.07)
ρ_2	-	.11
(s.e.)		(.07)
ρ_3	-	.18
(s.e.)		(.07)
ρ_4	-	-.56
(s.e.)		(.07)
σ	1.55	1.22
Q(1) (p-value)	0.00 (.96)	0.02 (.89)
Q(4) (p-value)	47.32 (.00)	1.30 (.86)
Q(20) (p-value)	75.27 (.00)	23.3 (.27)

Notes:
- Q(n) is the Ljung-Box statistic for residual autocorrelation up to order n.

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