Discussion Paper No. 04-01

The Impact of EMU on Inflation Expectations

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Non-technical summary

This paper's basic idea is the following: A central bank's reputation has an impact on inflation expectations. This allows to draw conclusions about ECB's monetary credibility by studying the formation of inflation expectations in the years before and after the start of EMU. This approach is unique compared to the existing first attempts to evaluate the ECB regime. In this literature, approaches dominate that focus on ECB institutions and actions e.g. through the estimation of Taylor type reaction functions. These methods have merits but also natural limitations since they do not reveal how the ECB is perceived by economic agents. In this sense they can only shed light on one side of the credibility issue – how the central bank is designed and how it behaves. Our approach looks at the other and equally important side of monetary credibility – how the new central bank's design and behaviour affects inflation and inflation expectations.

In the first, theoretical step of our analysis, we summarise the insights about a central bank regime's characteristics and inflation expectations in a Barro-Gordon framework. Although real world processes driving inflation expectations are much more complex than described in this theoretical setting, the following messages emerge for the empirical analysis:

- Any important change in the level of inflation expectations that may have occurred with the regime change in 1999 which cannot be explained by other standard factors is an indicator for a change in monetary credibility.
- Increasing inflation forecast errors during the early EMU years (which cannot be explained by other standard factors) may be a hint for uncertainty about the new central bank's type.
- Changing patterns of inflation expectation formation in the post-1999 era may be resulting from learning processes about the new central bank's type.

Expectation data for our empirical investigation originate from the ZEW Financial market survey. These qualitative data are quantified by the Carlson-Parkin approach. Expectation formation is modelled within a flexible framework allowing both for rational and adaptive elements. We interpret varying degrees of rational expectation formation across time as indicator for the degree of uncertainty about the central bank regime. Furthermore, a separate estimation of expectation formation for the Bundesbank era allows to simulate inflation expectations of the EMU period assuming the continuing relevance of Bundesbank era parameters. The comparison of the simulated series with the actual inflation expectations serves as an indicator for changes in monetary credibility.

The results indicate that the monetary regime change from the Bundesbank to ECB did not have a strong and lasting impact on the formation of inflation expectations and that the anti-inflationary credibility of both central banks is not perceived to differ significantly. However, the analysis also reveals that the years immediately before the start of EMU were characterised by a relatively large degree of uncertainty: in this time, market participants resorted to backward-looking expectations even more than usually. This is a plausible result because of the uncertainty about the new central bank's characteristics. Once in charge of monetary policy the ECB was quickly successful to restore certainty about its true Bundesbank-like type and expectation formation returned to its old patterns.

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Abstract

This paper analyses the impact of the monetary regime change from the Bundesbank to the ECB in 1999 on inflation expectations. In the theoretical part, the Barro-Gordon model is used to derive the potential effect of a new central bank on inflation, inflation expectations and forecast errors. The econometric investigation is based on a flexible specification of expectation formation which allows both for rational and adaptive elements. Data on inflation expectations originate from the ZEW Financial Market Survey. The results indicate that the monetary regime change did not have a strong and lasting impact on the formation of inflation expectations and that the anti-inflationary credibility of both central banks is not perceived to differ significantly. However, the analysis also reveals that the years immediately before the start of EMU were characterised by a relatively large degree of uncertainty: in this time, market participants resorted to backward-looking expectations even more than usually. This is a plausible result because of the intitial uncertainty about the new central bank's characteristics. Once in charge of monetary policy the ECB was quickly successful to restore certainty about its true Bundesbank-like type.

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inflation expectations, credibility, ZEW Financial market survey,

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1 Introduction

With the ECB's take-over of monetary responsibility from the national central banks in January 1999, Europe experienced a fundamental change of its monetary regime. Already years before that date a fierce debate had started between supporters and opponents of European Monetary Union (EMU) whether this regime shift would bring about more or less monetary credibility and price stability. The pros and cons of this debate are by now well known and the differing views are related to factors ranging from the institutional setting of the Maastricht Treaty up to the inflation preferences of the public.[1]

Now the time is coming to leave the field of theoretical speculation about the character of the regime change and to evaluate this question by empirical means. Hence, it is the objective of this paper to contribute to this ex post assessment using the expanding post-1999 data set. With the increasing time span the conditions are improving to explore what economic developments in the first years of EMU reveal about the regime change's characteristics. More specifically we try to answer the following question: What can we learn about the new central bank's monetary credibility given observable inflation and inflation expectations?

This approach is unique compared to the existing literature evaluating the ECB regime. In this literature, approaches dominate that focus on ECB institutions and actions e.g. through the estimation of Taylor type reaction functions.[2] These methods have merits but also natural limitations since they do not reveal how the ECB is perceived by economic agents. In this sense they can only shed light on one side of the credibility issue – how the central bank is designed and how it behaves. Our approach looks at the other and equally important side of monetary credibility – how the new central bank's design and behaviour affects inflation and inflation expectations.

Conceptually, our approach appears to be straightforward. If - compared to the Bundesbank - the ECB is perceived to be less anti-inflationary we should observe an increase in inflation expectations paralleling the regime change. However, the empirical implementation of this basic idea faces difficulties. While monetary credibility is an important long-run determinant for inflation and inflation expectations short-run developments are heavily influenced by other factors like the business cycle, exchange rate developments or oil prices. This precludes jumping to conclusions from simple comparisons of average levels. Furthermore, each em

[1] For an overview of the issues see for example Bini Smaghi/Gros (2000). A particularly sceptical view at the characteristics of the new regime is provided by Vaubel (2003).

[2] For example Ullrich (2003) or Heinemann/Hüfner (2004).

pirical approach has to account for the possibility that a regime change might be associated with increasing uncertainty about the central bank's true type. While decades of experience were a solid basis to build a judgement about the Bundesbank's preferences this record is missing for the newly established ECB. This consideration adds a second dimension to the analytical problem: Inflation expectations in the early EMU years might not solely be influenced by a change in the perceived monetary credibility but also by increasing uncertainty about the new regime's properties.

In order to deal with these interrelated issues we employ the following research strategy. First we look at the monetary regime change within the theoretical framework of the standard Barro-Gordon model (section 2). This framework is not only helpful to specify more precisely what is meant by the term "monetary credibility". It also allows to distinguish between different possible outcomes of a change in the central bank regime. It thus gives valuable hints to any empirical approach as to what we can learn from observable inflation (and inflation expectations) patterns in regard to the perceived monetary credibility of a new central bank.

Our subsequent empirical analysis exploits these theoretical insights. After a short descriptive look at inflation performance before and after the 1999 regime change (section 3) we estimate a flexible specification of inflation expectations both for the Bundesbank and EMU era (section 4). On the basis of these estimations we detect shifts in perceived monetary credibility and/or increasing uncertainty about the new central bank's type. Our approach does not indicate that the ECB's credibility is significantly different from that of the Bundesbank. However, it reveals a substantial amount of uncertainty about the new central bank's type among financial market experts in the years prior to EMU. With the start of EMU, however, this uncertainty has quickly vanished and lost its impact on the formation of inflation expectations.

For the construction of inflation expectations, this analysis benefits from the *ZEW Finanzmarkttest* data set which originates from a monthly survey among 350 financial market experts and which starts in December 1991. Transformation of the categorical survey data into a continuous expectations series is executed through a standard variant of the Carlson-Parkin method.

2 A new central bank in the Barro-Gordon model

Monetary credibility

We use the term "monetary credibility" for the public perception that a central bank's policy actions are devoted to fighting inflation. Credibility in this sense can be undermined by very different and interacting phenomena:

- The weight of inflation in a central bank's loss function is low. This may be a consequence of the constitutional decision which defines the central bank's official objectives or due to the individual preferences of the central bank's decision makers.
- The official objective of the central bank is tough on inflation but independence from government is not convincingly protected so that the government's interests in growth and employment harm the central bank's anti-inflationary reputation.
- The time-inconsistency problem (Kydland and Prescott 1977; Barro and Gorden 1983a,b) resulting from the short-run expansionary effects of an inflation surprise is relevant.

The regime change from Bundesbank to ECB may have affected all three dimensions. Even if one argues in the context of the central bank loss function that the ECB constitution is a copy of the Bundesbank framework there might be differences between the preferences of both institution's governing council members. Neither it is obvious that the Bundesbank and ECB regime are identical in regard to independence: While some argue that independence of ECB is better protected through its legal fundament in the Maastricht Treaty others point to the potential political influence through exchange rate politics. Finally it is hard to decide from a theoretical point of view whether the ECB is able to commit itself to a certain inflation objective.

In the following we depict on the basis of the standard Barro-Gordon model the pattern how differences in credibility between Bundesbank and ECB should impact on inflation, inflation expectations and employment for different information and commitment assumptions.

The framework

In a short recapitulation the Barro-Gordon model[3] is summarised by the following equations. The loss function of a central bank is:

[3] Barro and Gordon (1983a,b). For a summarising exposition of the Barro-Gordon approach see Persson and Tabellini (1990).

(1) $L(\pi, x) = (\pi^2 + \lambda (x - \chi)^2)/2$

where π is inflation, x denotes the employment deviation from the natural rate and χ stands for the employment target defined as deviation from the natural rate. The coefficient λ indicates the weight which the central bank assigns to employment relative to price stability.

The central bank faces a Phillips curve economy described by

(2) $x = \mu(\pi - \pi^e) - \varepsilon$

where employment is a linear function of unexpected inflation and shocks represented by ε with zero mean and standard deviation σ. The parameter μ characterises the slope of the short-run Phillips curve. The shock ε is observed by the central bank before it decides inflation but not by economic agents before they build inflation expectations.
The equilibrium solution for inflation, inflation expectations and employment under discretion and full information about the central bank's preferences are as follows. Inflation and inflation variance are given by:

(3) $\pi = \lambda\mu\chi + \frac{\lambda\mu}{(1 + \lambda\mu^2)}\varepsilon$

with

(4) $\text{var}(\pi) = \frac{\lambda^2\mu^2}{(1 + \lambda\mu^2)^2}\sigma^2$.

The rational expectation assumption of Barro-Gordon explains the fact that inflation expectations π^e include the systematic inflation bias resulting from the time-inconsistency but not the stochastic surprise which has an expected value of zero:

(5) $\pi^e = \lambda\mu\chi$.

Inflation expectation is higher the flatter the Phillips curve (i.e. the larger μ), the larger the weight of employment in the loss function (λ) and the higher the employment target χ.
Equilibrium employment diverges from natural rate only if $\varepsilon \neq 0$. The shock's impact is cushioned by the central bank's inflation reaction to the shock. The systematic inflationary bias of this discretionary solution does not have an impact on equilibrium employment since it does not come as surprise. Employment and its variance are given by:

(6) $$x = -\frac{1}{1+\lambda\mu^2}\varepsilon,\ E(x) = 0$$

with

(7) $$\mathrm{var}(x) = \frac{1}{(1+\lambda\mu^2)^2}\sigma^2.$$

A new central bank under certainty

Given this modelling framework we can now describe what is essential for our analysis: how differences in the Bundesbank and ECB setting would impact on inflation, inflation expectations and employment. First, we assume that there is complete information so that economic agents immediately know the new central bank's parameters.

Table 1 summarises the impact of model parameters on the equilibrium under this assumption

The regime change will lead to falling, constant or increasing inflation expectations (and mean inflation) depending on (subscripts *ECB* and *BB* denote the ECB and Bundesbank regime):

(8) $$(\lambda_{ECB}\mu_{ECB}\chi_{\mathrm{ECB}}) \ < / = / > \ (\lambda_{\mathrm{BB}}\mu_{BB}\chi_{BB}).$$

The same is true on average for the actual inflation. According to equation (4) inflation volatility is driven by both the monetary preference parameters and the variance of the occurring shocks. Thus, not only differences in the monetary regimes' characteristics but also a change in the variance of shocks hitting the economy have an impact on inflation volatility.

In this model there can only be temporary deviations of employment from natural rate caused by inflation surprises. Hence, average employment will not be affected by the regime change but its volatility may change since according to equation (7) employment volatility is positively related to the variance of shocks and negatively to the parameters μ and λ.

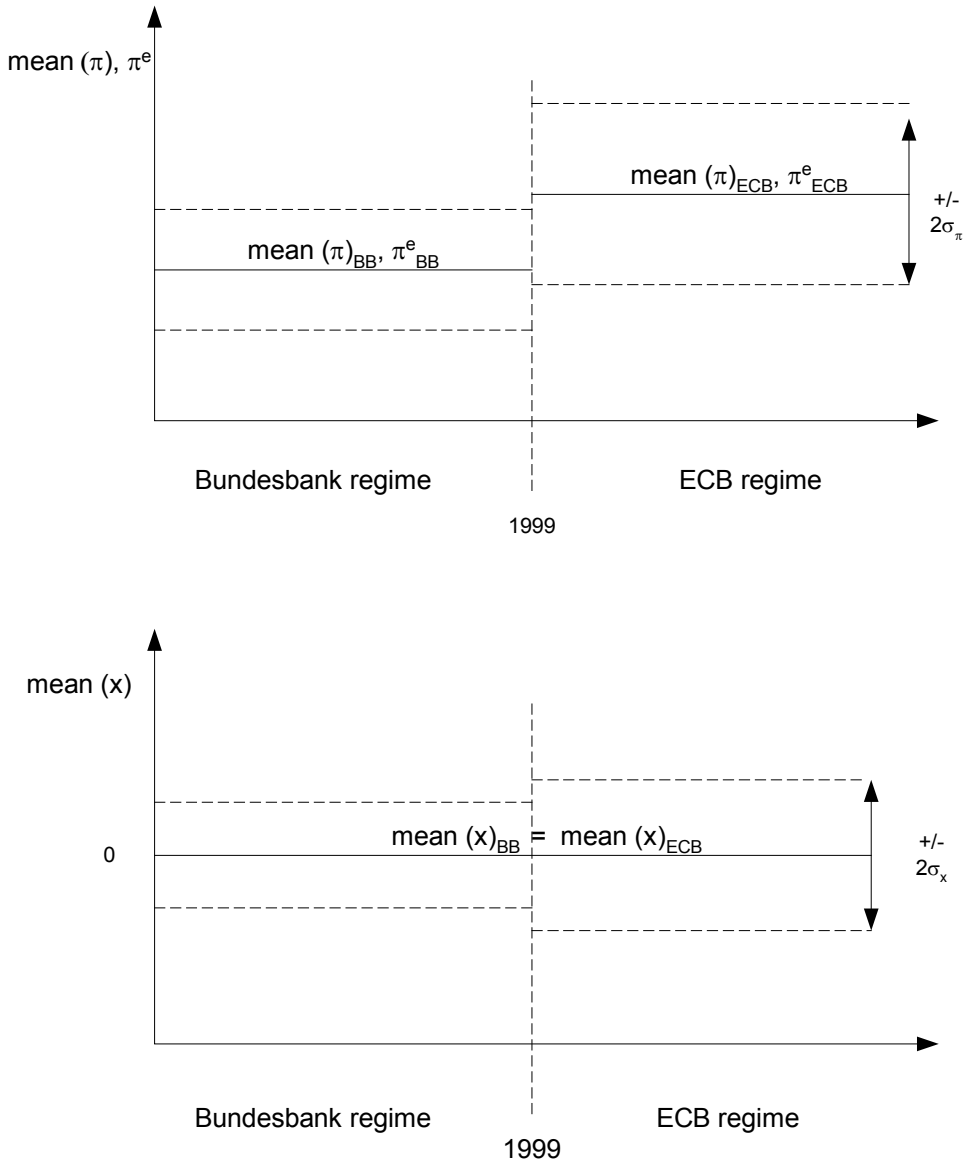
If reality would be completely described by the model, we could draw the following conclusions with regard to the regime change's characteristics from the observation of economic variables pre- and post-1999: Increasing average inflation and inflation expectations accompanied by increasing inflation volatility and decreasing employment volatility would indicate a larger employment weight in the central bank's calculus (either resulting from a larger weight λ or a larger short-run trade-off between inflation and employment, μ).

Table 1: Reaction of equilibrium to parameters under certainty

		increase in parameter			
		λ	μ	χ	σ
sign of equilibrium impact in regard to	mean (π) ($=\pi^e$)	+	+	+	no impact
	var (π)	+	ambiguous: -/+ depending on $\lambda\mu^2$ >/< 1	no impact	+
	mean (x)	no impact	no impact	no impact	no impact
	var (x)	-	-	no impact	+

Figure 1 depicts as an example the pattern that would result from an increase of λ as a consequence of the 1999 regime change from Bundesbank to ECB. There would not only be an increase in average and expected inflation rate (both do not differ due to rational expectations and complete information) but also an increasing inflation volatility.

Figure 1: Impact of $\lambda_{ECB} > \lambda_{BB}$, complete information



Uncertainty about the new central bank's type

An essential feature of the complete information setting is that inflation expectations equal mean inflation. However, the assumption that economic agents know the central bank's preferences is particularly questionable in the case of a newly established central bank like the ECB in its infancy. While agents from long experience with the Bundesbank can be assumed to know this institution's loss function the same cannot be expected for the ECB. Therefore, the analysis has to account for the possibility that the regime change has not only affected the game's parameters but also its information structure. The consequences of uncertainty about the central bank's "type" in the Barro-Gordon model are that economic agents can have rational but biased inflation expectations. Expectations are rational since all available information including the knowledge of the model is used.

Expectations do not equal mean inflation and are in this sense biased since agents are uncertain whether they face a tough or a soft central bank. Hence they will base their inflation expectations on a probability weighted average of both types (Barro, 1986).

To analyse the impact of a regime change that also implies a change from certainty towards uncertainty the outcome becomes much more complicated since theory identifies different possible equilibria which are separating, pooling or of a hybrid nature. For the sake of expository clearness we focus on the separating equilibrium. With a separating equilibrium the initial monetary actions of the new central bank are signals that allow agents to identify the central bank's type. If the new central bank is tough it will, in the initial period, act tougher than under certainty in order to signal its true type. If the new central bank is soft it will, in the initial period, not send out this signal of toughness since - given its preferences – the employment costs would be too high. Therefore, economic agents get to know the central bank's true type in the initial period. As a consequence, after the initial period the bias in inflation expectations will vanish and the complete information outcome as described above will prevail.

The pattern resulting from the incomplete information ECB setting has the following characteristics: With the change from the complete information Bundesbank to the incomplete information ECB regime inflation expectations should start to become biased. A tough (soft) central bank should be accompanied with an upward (downward) bias in inflation expectations. This bias results in an initial employment below (above) the natural rate. Together with its employment consequences this bias will vanish after the initial stage as agents begin to know the true parameters of the new central bank.

Figure 2: Regime change assuming uncertainty about ECB's "type"

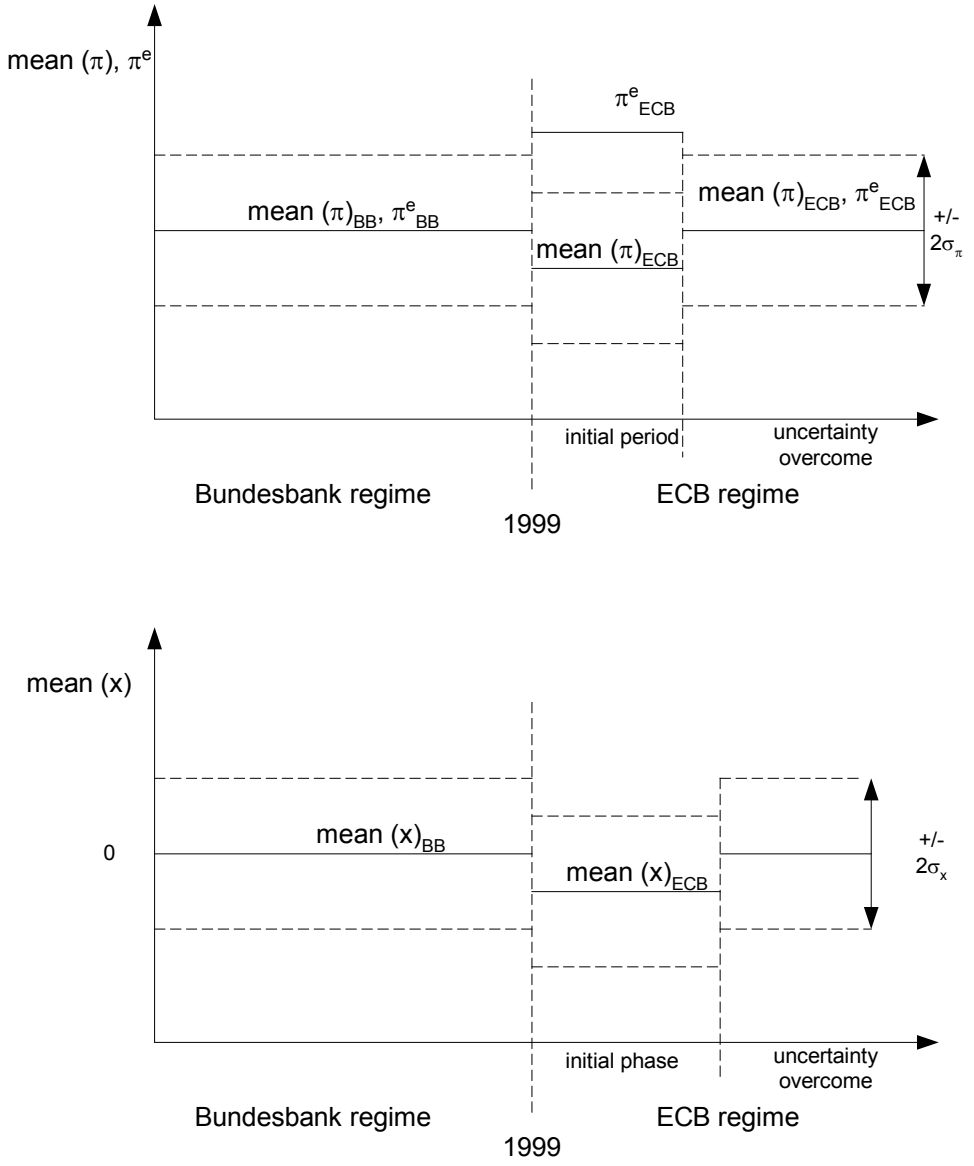


Figure 2 depicts one specific variant of the uncertainty assumption: Immediately after the regime change, economic agents assign a positive probability to the case that the ECB is softer on inflation than the Bundesbank. Actually, the ECB's parameters are assumed to be identical to the Bundesbank. In the initial period the ECB has to signal its true type through a particularly tough monetary policy, i.e. a particularly low inflation rate. This signal overcomes uncertainty so that afterwards the system returns to its Bundesbank equilibrium.

The message for empirical testing

It would be a naive undertaking to base any empirical testing directly on the Barro-Gordon model. The real world processes driving inflation and inflation expectations are much more complex than described in the theoretical setting. Nevertheless, the model analysis has at least three clear messages what we could learn from observing inflation and inflation expectations around the Bundesbank-ECB regime change:

- Any important change in the level of inflation expectations that may have occurred with the regime change in 1999 which cannot be explained by other standard factors is an indicator for a change in monetary credibility.
- Increasing inflation forecast errors during the early EMU years (which cannot be explained by other standard factors) may be a hint for uncertainty about the new central bank's type.
- Changing patterns of inflation expectation formation in the post-1999 era may be resulting from learning processes about the new central bank's type.

Before we develop our estimation strategy on the basis of these insights we continue by explaining sources and handling of our data and presenting some descriptive results.

3 Data and descriptive analysis

Calculation of inflation expectations

We generate our inflation expectations data on the basis of the ZEW Financial Market Survey.[4] This survey among German financial market experts has been carried out on a monthly basis since December 1991. The covered experts (regularly 300-350 participants) come from banks, insurance, investment and industrial companies. Within their companies the respondents mostly hold positions in the financial, research and economic departments or the investment and securities departments.

The experts are asked for a qualitative assessment of their inflation expectations. The forecast horizon is six months. With regard to inflation expectations respondents have the choice between "The annual inflation rate in the general economy in the medium term (6 months) will increase/not change/decrease/don't know". This assessment is given for Germany, USA, Japan, UK, France, Italy and since January 1999 also for the euro area as whole.

[4] For further details see www.zew.de.

For quantifying these qualitative assessments we follow a standard variant of the probability approach pioneered by Carlson and Parkin (1975).[5] The starting point of the approach is the assumption that every individual bases her answers on a subjective probability distribution for inflation rates given her information set. The expected inflation rate is then identical with the conditional expected value of the distribution. If the expected inflation rate exceeds a certain threshold the answer is „increase“ and if the expected inflation falls below a threshold „decrease“ and in between is the indifference interval resulting in a „no change“-answer. For the treatment of the “don’t know category” there are different possibilities (see Marnet, 1996) but since the category is minimally occupied in the ZEW survey we simply ignore these answers. The next assumption of Carlson-Parkin is that the thresholds are identical across individuals even if they do not have to be symmetric and constant over time. Hints to the relevant thresholds come from the ZEW panel itself which twice was polled to quantify these thresholds: The first poll was taken in December 1993 and the second in August 1997. While the first asked for symmetric thresholds the second incorporated the possibility of asymmetry. For the calculation of the inflation expectations series the mean value of the answers of the first survey is used until July 1997 and afterwards the mean value of the asymmetric thresholds (see Table 2).

Table 2: Thresholds for the indifference interval “no change” ZEW survey

	Basic value of inflation	Mean value of answers	
December 1993 symmetry restriction	3.7	+/-0.23	
August 1997 no symmetry restriction	1.7	-0.18 (lower threshold)	+0.21 (upper threshold)

Source: Poll of ZEW survey participants

The final assumption of the Carlson-Parkin approach is that the subjective probability distributions are independent of one another and have the same known form across individuals. If the assumptions are satisfied we can conclude that the proportion of “rise” answers is identical to the probability that inflation in 6 months exceeds the upper threshold and the proportion

[5] For details see Pesaran (1987, ch. 8). A frequently applied alternative, the so called “regression approach” by Pesaran (1984) is not applicable in our case since the ZEW survey does not include any question in regard to the current perception of inflation.

of the "decrease" answers is the same as the probability that the future inflation rate will be lower than the lower threshold given the information at the time expectations are formed. The expected inflation rate corresponds to the expected value of the distribution given the information set. The quantification will crucially depend on the chosen form of the aggregate distribution function. For the calculation we use a standard normal distribution following most of the literature on transforming qualitative survey data.[6]

From the survey results we get the expected change of inflation regarding the next 6 months, $\Delta_t \pi^e_{t+6}$. Therefore, to derive inflation expectations ${}_t\pi^e_{t+6}$ we use the following equation:

$$\Delta_t \pi^e_{t+6} = {}_t\pi^e_{t+6} - \pi_t \ .$$

In order to take account of the one month publication lag for inflation we have to use lagged inflation (annual inflation rate based on the consumer price index for Germany, source: Federal Statistical Office) for the calculation of the expected inflation rate:

$${}_t\pi^e_{t+6} = \pi_{t-1} + \Delta_t \pi^e_{t+6} \ .$$

We continue to use German (and not euro area) inflation rates and the expected change in the German (and not euro area) inflation rate after 1999. We thus avoid the conceptual complications that would result from jumping from national to euro area variables. There is also a data argument for this proceeding: Expected changes in German and euro area inflation rates do not differ substantially. Nevertheless, we have to keep in mind that the euro area and not the German inflation rate is the relevant inflation variable from the point of view of ECB. Hence, if we observed a structural break in German inflation expectations we would have to check whether divergence between euro area and German inflation rates could be behind this (indeed, we do not observe this structural break).

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[6] The normal distribution of inflation expectations is criticized by different authors, e.g. Batchelor and Orr (1988). But Balcombe (1996) does not find a hint for skewness or curtosis in QSBO survey data and Mitchell (2002) analyses the class of stable distributions and finds no advantaged with regard to the normal distribution using data of the Industrial Trends Survey in the UK manufacturing industry. Using the Dutch consumer survey Berk (1999) compares the transformation of qualitative data into inflation expectations using the normal, central and non-central t-distribution. He finds that the accuracy of the inflation expectations is not improved although the effect of the non-normal asymmetry is substantial.

Descriptive results

The expectation series resulting from the described calculation are depicted in Figures 3a and 3b together with actual inflation. Figure 3a for monthly series and 3b for the 4-month moving average seem to indicate that expectations lag actual inflation. Thus expectations tend to underpredict inflation during periods of rising inflation and overpredict it during periods of decreasing inflation. This finding is a frequent result of studies on inflation expectations (e.g. Andolfatto et al., 2002). This result has a clear impact on pre- and post-1999 prediction errors. While pre-EMU the downward trend in inflation is associated with an overprediction, the (moderate) post-1999 rise in inflation rate is associated with an underprediction. Obviously, average inflation between 1992 and 1998 exceeds average inflation post-1999.

Figure 3a: Inflation and inflation expectations for Germany

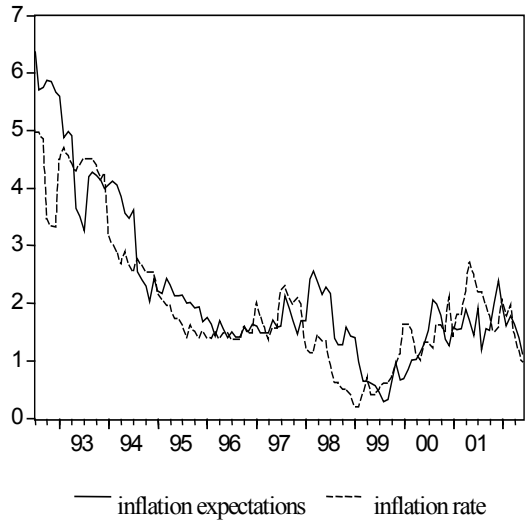
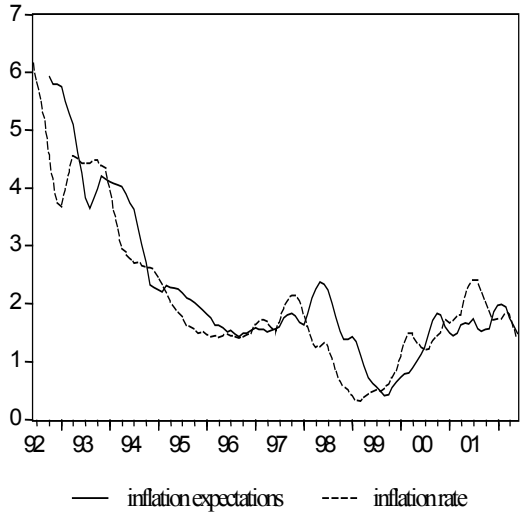


Figure 3b: Inflation and inflation expectations for Germany, 4 month moving average



Descriptive statistics are summarised in Tables 3 and 4 which underline the visual findings of a decline in average inflation (and inflation expectations) post-1999 and a changing sign in the prediction error. The mean declines from 2.35 to 1.30 per cent for the inflation rate and from 2.71 to 1.30 per cent for the expected inflation. For the standard deviation of inflation rate and inflation expectations we see that there is considerable lower variance after 1999. Furthermore, the drop in the standard deviation seems to be stronger for inflation expectations than for the inflation rate. The mean error as the gap between the inflation rate and the infla

tion expectations narrows after 1999 and changes sign (from –0.36 to 0.002). The mean absolute error is higher than the mean error for both time periods indicating that the forecast errors counterbalance each other to a certain degree.

Obviously, it would be highly misleading to interpret these descriptive findings directly in the credibility framework set up above. Actual inflation is heavily influenced by short-run determinants so that the lower post-1999 inflation average is no clear indicator for a more credible and anti-inflationary central bank. The changing sign in the expectations error after 1999 corresponds to the well established empirical fact that expectations are sticky to a certain extent and that inflation was downwards/upwards trending before/after 1999. Therefore, it does not necessarily indicate the existence of a credibility premium for a more credible central bank. Hence, we need more subtle means to draw conclusions in regard to the credibility impact of the regime change.

Table 3: Summary statistics for inflation and inflation expectations (CPI price index)

	Inflation rate		Expected inflation rate	
	Based on the consumer price index (base 2000=100)		Based on categorial data of the ZEW Financial Market Test	
Sample	1992:07-1998:12	1999:01-2003:07	1992:07-1998:12	1999:01-2003:07
Mean	2.35	1.30	2.71	1.30
Median	1.97	1.21	2.15	1.29
Std.Dev.	1.26	0.58	1.40	0.49
4-Month moving average				
Mean	2.45	1.29	2.67	1.31
Median	1.92	1.21	2.18	1.43
Std.Dev.	1.31	0.56	1.31	0.44

Table 4: Forecast errors

	1992:07-1998:12	1999:01-2003:07
Forecast error $mean(\pi_t - \pi_t^e)$	-0.36	0.002
Absolute forecast error $mean(\mid \pi_t - \pi_t^e \mid)$	0.58	0.36

4 Testing inflation expectations formation

We base our analysis on the estimation of an expectations formation model suggested e.g. by Carlson and Valev (2002) and Gerberding (2001). It takes account of the empirical fact that expectations formation can only partly be characterised to be fully rational and that backward looking and adaptive expectations play a role – at least for a part of economic agents. The specification is flexible in the sense that it allows both for rational expectations and simple rules of thumb and leaves the relative weight of both assumptions to the data:

$$(9) \qquad {}_t\pi^{e}_{t+6} = c_1\,{}_t\pi^{re}_{t+6} + (1-c_1)({}_{t-6}\pi^{e}_{t} + c_2(\pi_t - {}_{t-6}\pi^{e}_{t}))$$

The coefficient c_1 denotes the relative importance of fully rational expectations (π^{re}). With c_1=1 we have the case of purely rational expectations formation. The second terms stands for the "pragmatic" adaptive formation of expectations based on past inflation performance where coefficient c_2 measures the speed at which economic agents adapt their expectations to past forecast errors.

In our context, the model's flexibility offers an approach to control for credibility effects of the regime change. Changes in the rationality of expectations formation that occur with the regime change from Bundesbank to ECB can reveal changing certainty about the new central bank's type. Here, our focus is on the coefficient c_1. If this coefficient declines after 1999 this would support the view that agents are more uncertain about ECB's monetary preferences than was the case with the Bundesbank. Increasing uncertainty would disable agents to build unbiased expectations so that they would have to return to backward-looking rules of thumb. In addition, changes of the same coefficient in the years after 1999 can indicate whether this uncertainty is being diminished through learning effects based on meaningful signals by the ECB.

Furthermore, we also employ the model in order to reveal the relative credibility of both central banks as perceived by the participants of the ZEW survey. Based on an estimation of the Bundesbank era we can simulate inflation expectations for the Euro era. Any systematic difference between simulated and actual expectations reveals a credibility premium or discount for the new central bank. This credibility test is more meaningful than simply comparing mean inflation expectations. Implicitly, through the inclusion of rational inflation expectations this approach takes account of exogenous factors driving the inflation rate.

Estimation

In order to estimate equation (9) some qualifications are necessary. Because the actual inflation rate is not known at the time expectations are formed we lag the part of adaptive expectation formation for one period and get the following estimation equation (an error correction approach taking the time series properties of inflation and inflation expectations into account produced similar results and is obtainable from the authors):

$$(10) \qquad {}_t\pi^e_{t+6} = c_1\pi_{t+6} + (1-c_1)({}_{t-7}\pi^e_{t-1} + c_2(\pi_{t-1} - {}_{t-7}\pi^e_{t-1})) + \varepsilon_t .$$

Here, we follow the usual way to quantify rational expectations and use realised inflation rates in *t+6* for expectations formed in period *t*. However, one has to be aware of the fact that, in this case, the error term of the estimation equation includes the expectations error of rational expectations (see e.g. Fair 1993, p. 172). We cope with the resulting correlation between the regressor π_{t+6} and ε_t by applying two-stage least squares. The instrument list contains a constant, the inflation rate based on the consumer price index up to lag 18, and the annual growth rate of industrial production (source: OECD) up to lag 12.

Our estimation period starts in August 1993 motivated by the fact that to this date the turbulences in the European exchange rate system had been overcome and the widening of EMS fluctuations bands had established a *de facto* free floating exchange rate regime. The sample period ends in 2003:1. Estimating equation (10) on the basis of the full sample period gives the following results (Newey-West HAC standard errors and covariance, t-values in brackets):

$$(11) \qquad {}_t\pi^e_{t+6} = \underset{(6.43)}{0.41}\,{}_t\pi_{t+6} + (1-0.41)({}_{t-7}\pi^e_{t-1} + \underset{(6.19)}{1.06}(\pi_{t-1} - {}_{t-7}\pi^e_{t-1})) + \varepsilon_t ,$$

$\overline{R}^2$	0.86
Autocorrelations of the residuals[1]	
AC(1)	0.797
AC(2)	0.613
AC(3)	0.498
AC(4)	0.410
AC(5)	0.374
AC(6)	0.276
AC(7)	0.173
$\chi^2(28)$ [2]	34.44

1 Two standard error bounds: $\pm 2/\sqrt{T} = 0.19$ for 114 observations.

2 Test statistic for overidentifying restriction, degrees of freedom in parenthesis. Large values reject the null hypothesis of validity of the instruments and proper specification of the estimation equation (Baltagi 1998, p. 288-289).

As the estimated equation (11) shows, rational expectations get a weight of more than one third. The adaptive part hints to an immediate full adaptation of inflation expectations to the most recently published inflation rate. Obviously, the equation is plagued by a high degree of autocorrelation. Not until lag seven the autocorrelation is not significantly different from zero at the 5 per cent significance level for the first time as the two standard error bound indicate. Because of the autocorrelation we correct the standard errors and covariances by the Newey-West method. A test for over-identifying restrictions (Baltagi 1998, p. 289) does not indicate endogeneity of the instruments.

In order to check for the robustness of our results given the autocorrelation problem, we also estimate a more general specification of equation (10) with different time horizons for inflation expectations formation up to six months (see appendix). The results reveal a less severe autocorrelation of the equation residuals and at the same time support our findings: They indicate that the adaptive part of expectations still implies the full adjustment of expectations for the forecast error and that there is a significant part of forward-looking expectations formation independently of the time horizon of expectations formation.

To investigate whether there is a structural break caused by the regime shift in monetary policy we cannot rely on break point tests because of the high autocorrelation of the error term in equation (11). Therefore we estimate two separated time periods from 1993:8 until 1998:12 and from 1999:1 until 2003:2. This does not give a hint for important differences in the parameters between the two periods and compared to the whole period as table 4 shows. In particular, the coefficient c_1 does not indicate that uncertainty about the inflationary process is increasing after 1999 - on the contrary, the weight of rational expectations increases. But again the equations exhibit a high degree of autocorrelation in the error terms. Moreover, it seems to be that for the first time period the validity of the instruments cannot be confirmed or the equation is misspecified.

To visualise possible differences between the Bundesbank and ECB regime with regard to expectations figure 3 presents the results of a the following simulation: Inflation expectations of the euro area are calculated on the basis of the expectation regression for the Bundesbank era. If credibility of Bundesbank and ECB is different the simulated expectation series should differ significantly from the actual inflation expectations. As the figure shows both series are for the most part similar indicating that there is no credibility discount or surcharge on inflation expectations in the Euro era compared to the Bundesbank past.

Table 4: Estimation equation (10) for separated time periods

	1993:8 – 1998:12[1a]	1999:1 - 2003:1[1b]
c_1	0.296 (3.19)	0.339 (3.59)
c_2	1.016 (5.69)	1.010 (6.24)
$\overline{R}^2$	0.88	0.77
Autocorrelations of the residuals[2]		
AC(1)	0.892	0.744
AC(2)	0.772	0.536
AC(3)	0.703	0.393
AC(4)	0.627	0.308
AC(5)	0.567	0.307
AC(6)	0.490	0.203
AC(7)	0.390	
AC(8)	0.328	
AC(9)	0.268	
AC(10)	0.212	
	$\chi^2(19)$ [3]= 50.91	$\chi^2(28)$ [3]= 39.93

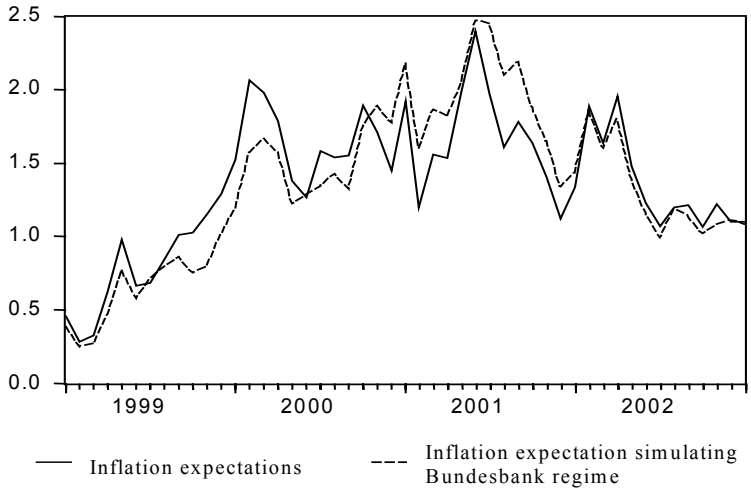
1a 2SLS, Newey-West HAC standard errors and covariances, t-statistics in parentheses, instruments: constant, inflation rate from lag 3 to lag 12, and growth rate up to lag 12.

1b 2SLS, Newey-West HAC standard errors and covariances, t-statistics in parentheses, instruments: constant, inflation rate up to lag 18, and growth rate up to lag 12.

2 Two standard error bounds: $\pm 2/\sqrt{T} = 0.25$ for 65 observations (first time period) and $\pm 2/\sqrt{T} = 0.29$ for 49 observations (second time period).

3 Test statistic for overidentifying restriction, degrees of freedom in paranthesis. Large values reject the null hypothesis of validity of the instruments and proper specification of the estimation equation (Baltagi 1998, p. 288-289).

Figure 3: Simulation of expectations resulting from Bundesbank regression and actual series



For a more detailed analysis we employ a rolling regression of equation (10). The estimation window contains 24 months and the analysis starts in 1993:8. The resulting estimation coefficients are ascribed to the last date each estimation period contained. As the picture shows, there seems to be no breakpoint in January 1999 with a considerable drop in rational expectations building. The drop occured earlier since the years 1996-1998 appear to be characterised by a particularly backward-looking expectation formation. With the start of EMU the weight of rationality quickly returns to its levels of the early nineties.

These findings allow the following interpretation: Uncertainty about the central bank's future type was at a maximum in the year immediately prior to and the first half year of the EMU. With the EMU start and first practical experience of market participants with the Euro and the ECB this uncertainty has quickly vanished. Obviously, the learning process was fast and smooth.

In regard to the speed of adjustment in the adaptive expectation term, c_2, there is no clearly explainable pattern. This coefficient fluctuates around one hinting to a formation of expectations relying on the last published inflation rate.

Figure 6a: Coefficient c_1 resulting from rolling regression of equation (10)

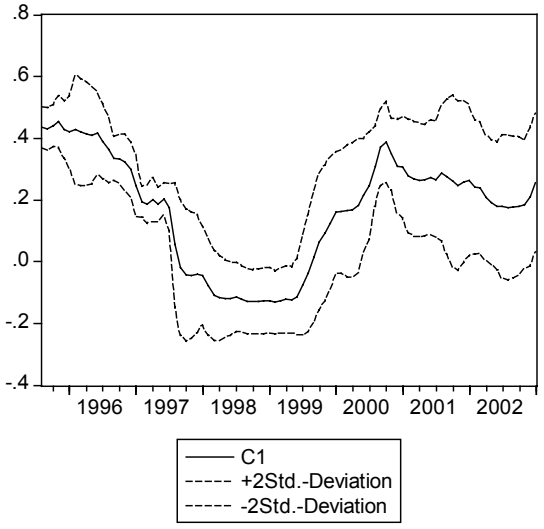
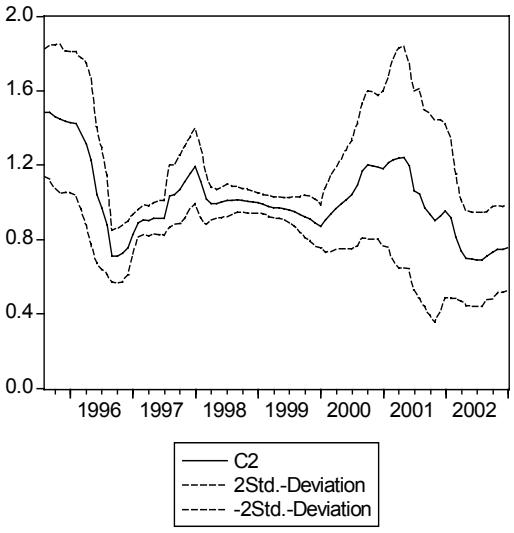


Figure 6b: Coefficient c_2 resulting from rolling regression of equation (10)



5 Conclusion

This study shows that the monetary regime change from the Bundesbank to ECB did not have a strong and lasting impact on the formation of inflation expectations. In particular, there is no indication that the new central bank's anti-inflationary credibility is perceived to differ significantly from that of the Bundesbank as the regime change is not associated with a noticeable structural break in the formation of inflation expectations. However, the analysis reveals that the years immediately before the start of EMU were characterised by a relatively large degree of uncertainty: in that time, market participants resorted to backward-looking expectations even more than usually. This is a plausible result because of the lack of practical experience with the new central bank to that time. Once in charge of monetary policy the ECB was quickly successful to restore certainty about its true Bundesbank-like type and expectation formation returned to its old patterns.

Appendix

To confirm the stability of the estimation result of equation (11), we estimate a more general specification of this equation with different time horizons for inflation expectations formation up to six months. Furthermore, we assume that the adaptive part of expectations formation is based on the most recently taken expectations. Because we do not know whether the experts really build inflation expectations for the time horizon of $t+6$ we allow for different time horizons up to six months in the forward looking part of equation (1A). The same problem appears for the adaptive part. Because we do not know which expectations is the basis for the determination of the expectations error of the previous month we allow for an correction of this error with expectations up to lag seven as shown in the second part of equation (1A):

$$(1A) \qquad {}_t\pi^e_{t+j} = \sum_{i=1}^{6} c_i \pi_{t+i} + \left(1 - \sum_{i=1}^{6} c_i\right)\left({}_{t-1}\pi^e_{t+j} + \sum_{i=0}^{5} c_{7+i}(\pi_{t-1} - {}_{t-7+i}\pi^e_{t+j})\right) + \varepsilon_t \,.$$

After successively removing the insignificant terms we get the following estimation result (Newey-West HAC standard errors and covariance, instruments: inflation rate based on the consumer price index up to lag 18 and the annual growth rate of industrial production up to lag 12, t-values in brackets):

$$(2A) \qquad {}_t\pi^e_{t+j} = \underset{(2.64)}{0.30}\,\pi_{t+5} + \underset{(2.39)}{0.27}\,\pi_{t+2} + (1-0.57)\left({}_{t-1}\pi^e_{t+j} + \underset{(2.63)}{0.80}(\pi_{t-1} - {}_{t-2}\pi^e_{t+j})\right) + \varepsilon_t \,.$$

$\bar{R}^2 = 0.85$	
Autocorrelations of the residuals[1]	
AC(1)	0.549
AC(2)	0.570
AC(3)	0.392
AC(4)	0.297
AC(5)	0.182
AC(6)	0.112
$\chi^2(26)$ [2]	36.42

1 Two standard error bounds: $\pm 2/\sqrt{T} = 0.19$ for 114 observations.

2 Test statistic for overidentifying restriction, degrees of freedom in paranthesis. Large values reject the null hypothesis of validity of the instruments and proper specification of the estimation equation (Baltagi 1998, p. 288-289).

The autocorrelation decays more rapidly than in the basic equation (11). A Wald test indicates, that the sum of the coefficients of the forward-looking part are not different from the

coefficient in equation (11) at the 5 per cent level (F-statistic=2.83, probability 0.09) and the coefficient determining the extent of the error correction is not different from one (F-statistic=0.45, probability 0.50).

The estimated equation implies that the experts do not form their expectations for a time horizon of six months but for a shorter horizon of five and two months. We interpret the results in the following way: the adaptive part of expectations contains the full adjustment of the expectations error and there is a significant part of forward-looking expectations formation independently of the time horizon of expectations formation.

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