Inflation and output in Germany: the role of inflation expectations

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Discussion Paper 5/97

Economic Research Group

of the Deutsche Bundesbank

October 1997

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ISBN 3–933747–07–4

Summary

The observation, analysis and forecasting of inflationary trends is of particular interest to all economic agents - not just to institutions with monetary policy tasks. Almost all central banks have specified a price target as the final goal of monetary policy, for example, and some central banks also use inflation forecasts as intermediate targets. For the financial markets, present and future inflationary trends are essential determinants, above all, for interest and exchange rate movements. Price trends and price expectations also play a major role in plans and decisions in the goods markets.

The aim of the present study is to examine in greater detail the relationship between inflation and output as a major aspect of explaining inflation. Particular attention is given to modelling inflation expectations which, for the first time in Germany for the CPI, have been obtained directly from survey data. To do this, qualitative survey data are converted into quantitative inflation expectations which are then compared with possible underlying expectation formation processes. It becomes apparent that the expectation formation of private economic agents can be described by a modified extrapolative expectations model.

The inflation expectations captured from the survey data are then included directly in the econometric specification of the input-output relationship. As an alternative, the inflation-output equation is estimated assuming various expectation formation hypotheses, i.e. without direct use of the directly captured inflation expectations. This means, firstly, that a longer estimation period can be used as a basis and, secondly, that the relevance of the assumed modified extrapolative expectation formation hypothesis can be verified as an alternative. Here, too, the modified extrapolative expectations hypothesis shows itself to be the most suitable.

Overall, a significant and, over time, stable relationship between inflation and output can be observed. Furthermore, it is possible to demonstrate a non-negligible influence on the price trend externally through import price movements. Of principal monetary policy importance is the indicated persistence in the inflationary trend, which is characterised by adjustment time lags of over one year.

Finally, the inflation-output equation is examined in terms of its suitability as an additional instrument for inflation forecasts. For this purpose, ex-post and ex-ante simulations are conducted which, overall, display good forecasting properties.

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Inflation and output in Germany: the role of inflation expectations[1]

"To prophesy is extremely difficult - especially with respect to the future."
Chinese proverb

I. Introduction

It is not only for monetary policy that analysing and forecasting price movements is of key importance. Because of the complexity of the processes behind price movements, it is advisable to draw on different perspectives and approaches in studying them. One possible point of approach is provided by the relationship between inflation and output.[2] This relationship has been the subject of numerous studies, especially outside Germany, as is illustrated by the overview article by Roberts (1995). Other studies have been undertaken by Clark *et al.* (1996) for the United States, by Fisher *et al.* (1997) for the United Kingdom, by Duguay (1992) for Canada, and by Chadha *et al.* (1992) and Turner (1995) for various industrial countries.

So much attention is paid to the relationship between price and output movements because that relationship can be regarded as an essential element of the monetary transmission path. Thus, many central banks, such as the Bank of England and the central banks of Canada and New Zealand, take explicit account of that relationship in their analyses. Above and beyond that, the relationship between inflation and output is used as a basis for determining prices in many macroeconomic models.[3] Finally, the inflation-output relationship can be used for inflation forecasting.

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[1] I should like to express my thanks to my colleagues M. Bohnert, G. Coenen, R. Fecht, D. Gerdesmeier, H. Herrmann, J. Hoffmann, T. Jost, M. Kremer, M. Scharnagl, and K.-H. Tödter, to A. Cunningham and L. Mahadeva of the Bank of England, the participants of a seminar at the Oesterreichische Nationalbank as well as the participants of a workshop at the Deutsche Bundesbank for their valuable ideas and suggestions.

[2] The term "output" refers below in all cases to the "output gap" (capacity utilisation).

[3] Additionally, in larger models, the labour market is often modelled explicitly by using a wage equation, for example. Generally, however, it is possible to derive the relationship between inflation and output as an essential element of the reduced form. Duguay, P. (1992), for instance, includes a more detailed discussion of the aspects involved in concentrating the analysis on the aggregated inflation-output relationship.

The aim of the present study is to analyse the relationship between inflation and output on an empirical basis for Germany. This is an attempt to gain new insights into an economic transmission mechanism which is of major importance for economic policy. In this context, the analysis of expectation formation will be of particular importance, and will thus be a main point of emphasis in our study. The study will test various expectation formation models and also include households' price expectations gained from surveys.[4] In that way, forward-looking expectations can be included directly without specifying a model. Furthermore, the survey data will be used to try to gain a more accurate insight into the expectation formation of the economic agents. That is of interest not only for the relationship considered here but also for monetary and economic policies as a whole. Finally, the specification of the inflation-output relationship gained from the studies is to be examined in terms of its suitability as an additional instrument for inflation forecasting.

In the second chapter, consideration will initially be given to theoretical aspects of the inflation-output relationship and of the various possibilities of modelling inflation expectations. Following this, a method of converting qualitative survey results on inflation into quantitative values will be presented. Subsequently, that method will be applied to the available data. After this the question of whether these price expectations can be interpreted as rational expectations will be considered. On that basis, an attempt will be made to use the survey data to model the determinants of the expectation formation of households.

In the third chapter, after the relevant variables have been determined and defined, the inflation-output relationship will be tested empirically for Germany using the quantified inflation expectations. Following this, the inflation-output relationship will be investigated assuming various extrapolative expectations hypotheses. Taking the results obtained in the previous chapter as a basis, a model which contains the adjustment of expectations to a basic inflation rate, or an inflation rate regarded as "inevitable" by the economic agents, will be analysed as a variant. Finally, ex-post and ex-ante simulations will be used to investigate the suitability of the estimated inflation-output functions for inflation forecasts. In addition, their forecasting quality will be compared with the expectations gained directly from the surveys.

4 Including price expectations derived from surveys of households has, to our knowledge, not been tackled yet for Germany.

The fourth chapter summarises the results of the present paper and points out its economic policy implications.

II. The inflation-output relationship and determination of inflation expectations

II.1 Theoretical considerations

The study conducted by Phillips in 1958 may be regarded as the starting point for all the more recent analyses of the relationship between inflation and output.[5] For that reason, the relationship between inflation and the output gap is often referred to as a Phillips curve, although Phillips' original study was based on the relationship between nominal wages and the unemployment rate.[6] Because of statistical problems and their conviction that a trade-off between inflation and unemployment does not exist in the long term, that original Phillips curve was extended by Friedman and Phelps into an expectations-augmented Phillips curve.[7] They assumed that, for employees, real wages and not nominal wages were relevant to decision-making, as a result of which price expectations were incorporated into the Phillips equation. As argued by Phillips, the rate of change in wages is then dependent, firstly, on the level of underemployment or the deviation of the actual unemployment rate from the natural or equilibrium unemployment rate. Furthermore, since employees regard real wages as relevant, the rate of change in nominal wages is determined by the expected price rises. Moreover, changes in labour productivity can play a role as an additional determinant, especially if the trade unions are in a position to push through wage increases in line with developments in productivity independently of the employment situation. If the Phillips curve is shown with the inflation rate, however, and not with the rate of change in wages as the dependent variable, that variable is cancelled out, assuming mark-up pricing behaviour by the enterprises.[8]

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[5] See Phillips, A.W. (1958)

[6] See Lipsey, R.G. (1960) for how this is derived theoretically.

[7] See Friedman, M. (1968) and Phelps, E. (1967).

[8] After insertion of the Phillips curve into the mark-up equation, the variable for developments in productivity can be cancelled out since the inflation rate, given a mark-up pricing behaviour by enterprises, is inter alia dependent on developments in productivity. See Samuelson, P.A. and Solow, R.M. (1960) and Burda, M. and Wyplosz, C. (1993), pp. 245.

In studies, the rate of underemployment is often replaced by the output gap (y-y*) as a determinant of the inflation rate. This can be substantiated by Okun's Law, for example, which postulates a fixed relationship between the output gap and the deviation of the unemployment rate from its natural level. But even if Okun's Law is granted only restricted validity for Germany for the period under review, it can be argued that pay settlements in Germany have, in many cases, been determined more by the economic situation (captured here by the output gap) than by the size of the unemployment rate. Furthermore, the output gap may gain additional importance for determining prices if the mark-up set by the enterprises is not constant, but susceptible to cyclical changes. It hence seems plausible to postulate the following relationship.[9]

$$\pi = \pi^e + g(y-y^*) \tag{1}$$

Over and above the considerations advanced so far, external price shocks (s), too, have to be taken into account in an open economy, which is subject to government intervention. Instances of such price shocks might be changes in raw material prices, in other import prices or tax changes. On the assumptions mentioned, the inflation-output equation then assumes the following form which will be the basis of the empirical investigation:

$$\pi = \pi^e + g(y-y^*) + h(s) \tag{2}$$

From an economic policy point of view, the consumer price index is most interesting as a price variable for the present investigation since the public's inflation expectations are likely to be geared to that price index. The consumer price index has a special role in public discussions of economic policy activity. It is very important in pay negotiations, for example, since wage and salary earners have an interest in linking wages and salaries to the cost of living. Using the consumer price index in the calculations in the following section is also advisable for reasons of consistency: That is because the expectations ascertained from the survey data of the *Gesellschaft für Konsumforschung* (GfK) are compatible only with the consumer price index.

[9] With π = inflation rate, (y-y*) = output gap, π^e = expected inflation rate and g (.) = functional form.

The inflation expectations π^e still have to be modelled in order to test equation (2) empirically. One option for this purpose is the use of adaptive or extrapolative expectations in the empirical investigation. The adaptive expectations hypothesis assumes that the economic agents adapt their expectations in the light of expectation errors made in the past, whereas the extrapolative expectations hypothesis assumes that the economic agents extrapolate from the past trend.[10]

On the other hand, a modified extrapolative model of expectation formation is also conceivable. This assumes the existence of a "normal level" of the inflation rate, or of an institutionally and/or structurally determined "inevitable" basic inflation rate π^*. In empirical studies using this approach, the "normal level" of the inflation rate or the basic inflation rate is often approximated by the moving average of the inflation rate over a given time horizon. The basic inflation rate π^* may also be seen as the central bank's price or inflation target or, more precisely, as the central bank's price target presumed by the economic agents.[11] The economic agents form expectations of the basic inflation rate and assume that the actual rate of inflation adjusts directly to the basic inflation rate. This hypothesis can be extended by assuming a gradual adjustment of expectations. The economic agents then assume a time lag in the adjustment of actual inflation to basic inflation. The adjustment parameter α is all the greater, the slower the speed of adjustment to basic inflation or the price target estimated by the economic subjects.[12] This modified extrapolative expectation formation model may be interpreted as a return-to-normality model, in which the "normal level" corresponds to the basic inflation rate or the central bank's price target.

(3) $$\pi^e = \alpha \cdot \pi_{-1} + (1 - \alpha) \cdot \pi^*, \qquad \text{with } 0 \leq \alpha \leq 1$$

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10 The adaptive expectation formation model can be reduced to a general extrapolative model in the form $\pi^e = \Sigma\lambda_i \cdot \pi_{t-i}$ with $\Sigma\lambda_i = 1$ and $i = 1, 2, 3, \ldots n$. See Pindyck, R. S. and Rubinfeld, D. L. (1991), pp. 206.

11 The price target can only be used as an approximation variable for the economic agents' long-term expectations or the basic inflation rate, however, if the central bank has a high degree of credibility and if the price target does not deviate from actual price movements on a significant scale in the long term. These conditions do obtain for Germany, however, for the period under review. See also footnote 37. For the Bundesbank's normative price assumption, see Table 7 in section III.1.

12 If π^* stands for the inflation target, then α is also a measure of the central bank's credibility. It should be noted, however, that α is also crucially influenced by other factors, such as institutional circumstances, for which the central bank cannot take responsibility.

The concept of extrapolative or adaptive expectations may be regarded as a pragmatic approach to dealing with expectations, and one that is undoubtedly correct for a large number of situations in reality. Nevertheless, the criticism is made of these expectation theories that only the past and present values of the variables that are to be explained are used for expectation formation and that other influences and relationships are ignored, giving rise to the possibility of systematic errors. Given adaptive expectations and accelerating inflation, for instance, inflation is systematically underestimated. Furthermore, with extrapolative expectation formation, one-off price shocks, for example, which are also identified as transitory by the economic agents, lead to changes in expectations, regardless of whether these price changes are only short-term in nature. The economic agents do not use all the information about the future that is available to them. These points of criticism apply only partially to the modified extrapolative expectations, since a forward-looking element is present in the expectation formation when the basic rate of inflation is taken into consideration. On the other hand, the objection can be made to this hypothesis of expectation formation that the determination of the basic inflation rate is relatively unspecified and, moreover, that verification is needed as to whether the Bundesbank's price assumption has the influence on economic agents' expectations in Germany that has been assumed in advance.

These objections to the extrapolative and adaptive expectation hypothesis have led to Muth's development of the theory of rational expectations. In contrast to the theories listed above, this approach processes all the information that is relevant to the future, including theoretical notions of the key factors influencing the expectation variables. In econometric practice, this implies that all the expectation variables appearing in a model are generated by the model itself, with the expectation values of the exogenous variables being specified. The expectations are then designated as model-consistent expectations. An essential feature of the theory of rational expectations is that the subjective expectations are, on average, correct, i.e. that, over time, they match the value of a variable X which actually occurs; the economic agents thus do not make any systematic errors ($E(\varepsilon_{t+1}| \Omega_t) = 0$):

(4) $x^e_{t+1} = E(x_{t+1}| \Omega_t) = x_{t+1} + \varepsilon_{t+1}$, with $E(\varepsilon_{t+1}| \Omega_t) = 0$

Ω_t = information available at time t and

ε_{t+1} = expectation error

The theory of rational expectations is likewise criticised, one point of criticism being the assumption that, ignoring all the information costs, the economic agents possess complete information and hence full knowledge of all the transmission mechanisms.

There are various approaches to the econometric implementation of rational expectations, a distinction being made between full-information and limited-information methods. In the full-information estimation method, the whole model is estimated using, for example, the three-stage ordinary least squares method (3SLS), taking due account of potential restrictions. The full-information estimation methods are more efficient than the limited-information approaches, but have the drawback that incorrect specification of one part of the model gives inconsistent results in all parts of the model. In practice, preference is given to the limited-information approaches on account of their greater robustness and because they are simpler to implement.[13] The limited-information methods include, for example, the widely-used McCallum approach and the use of survey data on expectations.

In the McCallum method, the unobservable rational expectations are replaced by the expectation variables' values that have actually occurred.[14]As these variables are correlated with the residual, an "errors in variables" problem arises, which is avoided by using instrumental variable estimation. In the second limited-information method, the unobservable rational expectations are replaced by survey data. The advantage of this method is that the expectations are not constructed using set model assumptions, but measured directly from surveys. Therefore, and because - as far as we are aware - this method has not been applied to Germany so far, the inflation expectations below are obtained from survey data.

Under those conditions, there are basically two possibilities for the concrete design of the expectation variables' parameter in the inflation-output equation. In neo-classical approaches with perfectly flexible factor and goods prices, the expectation variable is entered with a coefficient of one. This would have significant monetary policy implications. Thus, a reduction in inflation would be possible with immediate effect and even without losses of output as a consequence of a disinflationary policy which is regarded as totally

[13] See, for example, Begg, D. (1985), pp. 89.
[14] See McCallum, B.T. (1976), pp. 484.

credible. In reality, however, it is always possible to observe a greater or lesser sluggishness of price movements. Neo-Keynesian approaches take account of this effect by including the lagged endogenous variables.

$$(5) \qquad \pi_t = \alpha \cdot \pi_{t-1} + (1 - \alpha) \cdot \pi^e_{t+1} + g(y_t - y^*_t) + h(s_t)$$

This method can be justified, firstly, by the fact that some of the economic agents are following a forward-looking expectation formation and the others a backward-looking one.

A more theoretically grounded explanation is offered by the staggered-contract approach of Taylor, which has been developed further by Buiter and Jewett, and by Fuhrer and Moore. In the real staggered-contract approach, it is assumed that the economic agents conclude nominal wage contracts with a duration of a certain number of periods, e.g. of four quarters. In contrast to Taylor, however, it is not the development of the nominal wage contracts that is taken into consideration but that of the real wage contracts; the real value of all the contracts that are valid over the period of the contract which is just about to be concluded is taken into consideration. Thus, it is not only the past real values that are of relevance but also the expected future real contract prices. The price level, assuming a mark-up behaviour, is produced as the weighted average of the contract prices which are valid at that point in time. An inflation-output curve, which takes the following form, may then be derived using the Fuhrer and Moore method:[15]

$$(6) \qquad \pi_t = f(L) \cdot f(L^{-1}) \cdot [\pi_t + \gamma \cdot g^{-1}(L) \cdot (y_t - y^*_t)]$$

The rate of price changes is hence symmetrically dependent on both past and future values of the inflation rate and the output gap. If the model is based on somewhat more general assumptions, it is no longer possible, however, to make any accurate statement about the precise form of the lag structure and the coefficients. It should be noted, however, that both lags and leads are entered into the equation. The empirical investigation must then identify the actual structure.

[15] With L as a lag operator. See Taylor, J.B. (1980), pp. 1, Fuhrer, J. and Moore, G. (1995), pp. 127 and Buiter, W. and Jewett, I. (1981), pp. 211.

II.2 Determining the inflation expectations from survey data

Forecasts made by institutions are one of the means by which the economic agents' inflation expectations can be quantified. Some of these forecasts receive a great deal of public attention, and it may be assumed that the economic agents' expectation formation is influenced by those forecasts. From an empirical point of view, the use of inflation forecasts has the advantage that the data on expected price movements are already available in a quantitative form.

The best known forecasts of this kind for the inflation rate in Germany are those by the national economic research institutes and the Council of Experts for the Assessment of Overall Economic Trends (*Sachverständigenrat*).[16] They are, however, published only once a year (or, at most, semi-annually), and are therefore suitable only for studies with yearly data, which puts the empirical analysis on a much narrower base than a study using quarterly data. There are also forecasts by international bodies, such as the OECD. However, these, too, are available only on an annual or semi-annual basis. In addition, the general public has only limited access to them and they presumably therefore have only a minor impact on expectation formation in Germany.

Regularly available on a monthly basis are the quantitative forecasts of 29 institutions (including the major banks, securities firms, economic research institutes and other services) published by Consensus Forecast.[17] This survey has only been conducted since October 1989, however, and hence does not have enough observations for an investigation on a quarterly basis. With Consensus Forecast there is the additional problem that the forecasts produced apply for each of the two subsequent years and not over a fixed forecasting horizon of, say, three or twelve months.

A similar temporal restriction applies to the inflation expectations that are published by the *Zentrum für Europäische Wirtschaftsforschung* (Centre for European Economic Research) (ZEW) in Mannheim.[18] These are, in fact, available only from December 1991. The ZEW

[16] For a study on the efficiency of forecasts by nine institutions, see Neumann, M.J.M. and Buscher, H.S. (1985).
[17] See, for example, Consensus Forecast (1996), pp. 8.
[18] See ZEW (1997).

inflation expectations, which have a forecasting horizon of six months, are based on a qualitative three-category survey of 350 financial experts from banks, insurance firms and selected industrial enterprises. The qualitative data are quantified by the ZEW using the Carlson-Parkin method, which will be described in greater detail below.

Alternatively, the expectations of the economic agents themselves can be obtained from surveys. This has the advantage of directly capturing the economic agents' expectations. One drawback of this method is that the data obtained by direct survey may be biased, depending on the way in which the question is worded, the sample size and motives of those questioned. That is particularly true, however, in the case of quantitative surveys, and less so if qualitative surveys are available.[19] Qualitative surveys are available in the form of the ifo business survey and the GfK consumer surveys. As far as we are aware, there are no quantitatively based surveys for Germany.

The ifo survey is a three-category survey of manufacturing enterprises. These enterprises state whether, taking account of the changes in conditions, their domestic sales prices (net prices) are likely to rise, stay roughly the same, or fall during the next three months. In addition, the enterprises are questioned about movements in their domestic sales prices compared with the preceding month, the answers likewise being assigned to those three categories. Information on the enterprises' assessments of price movements in the past are helpful for some methods of converting qualitative data into quantitative data. Price expectations ascertained by the ifo institute are less well suited to the present investigation of consumer prices since they are based on surveys of manufacturing enterprises. They are more appropriate for analysing and explaining producer prices.

The GfK data are based on a survey of 2000 consumers for western Germany and 500 consumers for eastern Germany; for reasons of consistency, only the west German data were used in the study that follows. The consumer survey has been carried out on behalf of the EU Commission with a reduced set of questions every quarter since 1972, and with a full set of questions every month since 1980.[20] Owing to database problems at the EU, however, the data recorded on a monthly basis and split into the individual categories are

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19 See Lahiri, K. and Dasgupta, S. (1992), p. 391.
20 See GfK (1996).

available only from 1986 onwards.[21] The relative opposing position balance calculated by the GfK, which gives the response categories as a net total, going back to 1980, is still available, however.

The advantages of the GfK survey are the comparatively large sample size, the more detailed subdivision of the answers into six categories and the availability of data on the assessment of past developments. On account of the large sample and the GfK's selection criteria, it can be assumed that the average household on which the samples are based more or less corresponds to the average household used as a basis for calculating the consumer price index.

Table 1: GfK questions and response categories on price movements

How, in your view, have prices moved during the past 12 months?	How, in your view, will prices move in the coming 12 months?
slight fall (A')[a]	fall slightly (A)
scarcely any change (B')	stay roughly the same (B)
slight rise (C')	rise less sharply than before (C)
moderate rise (D')	rise by roughly the same amount as before (D)
sharp rise (E')	rise more sharply than before (E)
don't know (F')	don't know (F)

a With A, B, etc. as relative shares of those respondents who decided on the respective category.

Since the GfK data are available only in qualitative form, they must be quantified in an appropriate manner. There are various ways of doing this. Generally, these can be subdivided into probability methods and regression methods. The regression method is not used here, as it tends to be more suited to surveys of enterprises.[22]

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[21] The responsible bodies of the EU are endeavouring to recover the data for the period before 1986.

[22] See Batchelor, R.A. and Orr, A.B. (1988), p. 322. On the regression approach in general, see Pesaran, M.H. (1984), pp. 34 and Pesaran, M. H., pp. 221.

The probability method is based on work by Carlson and Parkin.[23] They assume that each individual i forms its survey response on its own subjective probability distribution with the density function $f_i(\rho_{i,t+1}|\Omega_{i,t})$ for the expected change in the relevant price index ($\rho_{i,t+1}$) at time t+1, and answers the survey questions in the light of this distribution. The expected price change at time t (${}_t\pi^e_{i,t+1}$) is then given as:

(7) $${}_t\pi^e_{i,t+1} = E(\rho_{i,t+1} \mid \Omega_{i,t})$$

It is also assumed that there is a range of price changes about zero $(-\delta, \delta]$ in which the respondents cannot distinguish price changes from zero. If price changes are smaller than δ in absolute terms, the respondents do not perceive that inflation. The values δ and $-\delta$ are designated as a just noticeable difference in inflation around zero. For the three-category case, the following response behaviour becomes apparent when taking these threshold values into account:

"prices are rising"	if ${}_t\pi^e_{i,t+1} > \delta$,
"prices are falling"	if ${}_t\pi^e_{i,t+1} \leq -\delta$,
"prices remain the same"	if $-\delta < {}_t\pi^e_{i,t+1} \leq \delta$.

On the assumption that an aggregate probability distribution of all the respondents $f_i(\rho_{i,t+1}|\Omega_{i,t})$ can be derived from the subjective distributions $f(\rho_{t+1}|\Omega_t)$, a relationship can be established between the qualitative responses and the quantitative price expectations on which those answers are based. That is because the probability (W) that the respondents' expected price change is lower than the lower threshold corresponds to the value produced by the aggregate cumulative density function (F_t) for $-\delta$. The value of the cumulative density function for $-\delta$ is equal to the share of respondents who assume falling prices (${}_tA_{t+1}$):

(8) $$W(\rho_{t+1} \leq -\delta \mid \Omega_t) = F_t(-\delta) = {}_tA_{t+1}$$

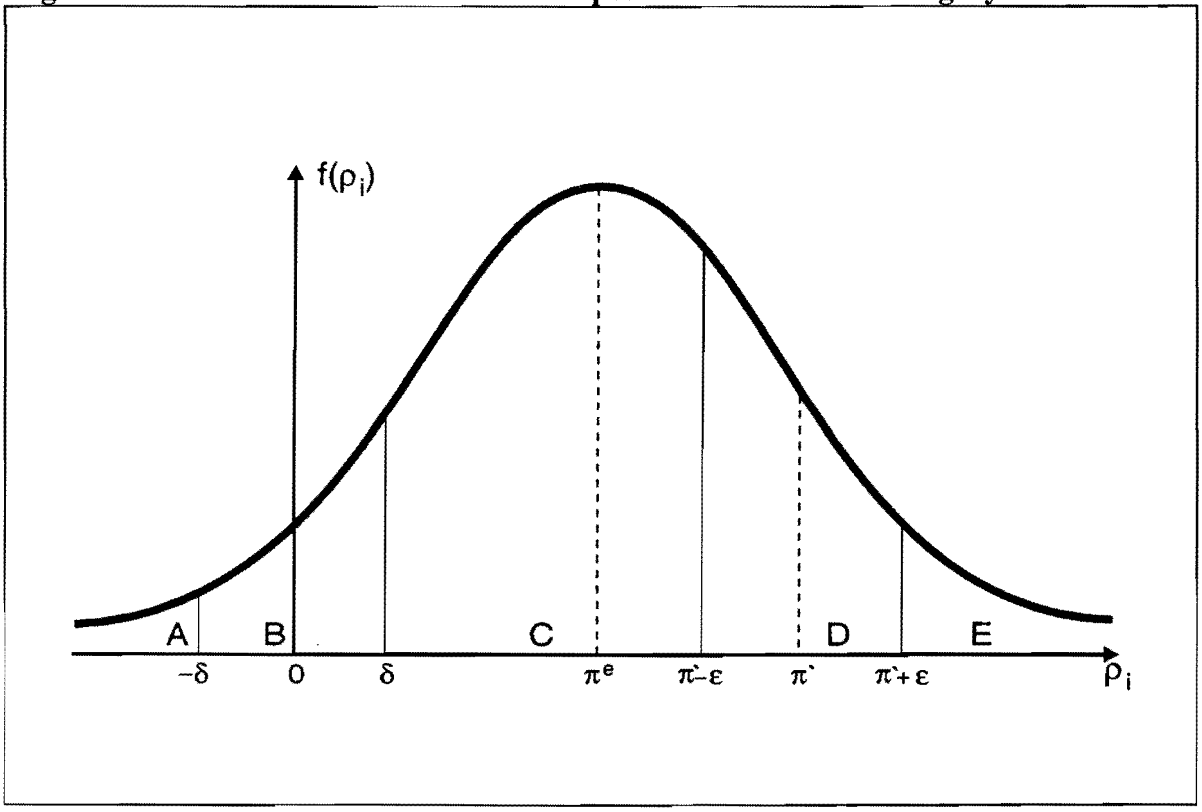
[23] See Carlson, J.A. and Parkin, M. (1975).

Accordingly, the probability that the price change expected by the respondents is greater than the upper threshold arises from one minus the aggregate cumulative density function (F_t) for δ, and this value is equal to the share of respondents who assume rising prices (${}_tB_{t+1}$):

$$W(\rho_{t+1} > \delta \mid \Omega_t) = 1 - F_t(\delta) = {}_tB_{t+1} \tag{9}$$

Now, it is only the cumulative density function (F_t) that has to be specified for converting the shares ${}_tA_{t+1}$ and ${}_tB_{t+1}$ into the expected inflation rate (${}_t\pi^e{}_{t+1}$). Carlson and Parkin assume a normal distribution and justify it with the central limit theorem.

Figure 1: Distribution of mean inflation expectations in the five-category case



The Carlson and Parkin method has been extended by Batchelor and Orr to the four and five-category case. They assume a logistic distribution rather than a normal distribution, however, since empirical examinations have shown that, although the distribution of expectations is symmetrical and unimodal, it cannot necessarily be regarded as normal.[24]

[24] On this point and on the following remarks, see Batchelor, R.A. and Orr, A.B. (1988).

In the five-category case, the respondents' assessments of the past movements of prices are explicitly drawn on in the calculation. For an interval around the mean perceived inflation of the last 12 months (π'), threshold values ($-\varepsilon$ and ε) are assumed for just noticeable differences in inflation around mean perceived inflation. On the above assumptions, the shares of each of the five response categories can be assigned areas below the probability distribution and these give the respective probabilities. Thus, the area for the range $(-\infty, -\delta]$, can be assigned to share A, the area with $(-\delta, \delta]$ to B, the area with $(\delta, \pi'-\varepsilon]$ to C, the area $(\pi'-\varepsilon, \pi'+\varepsilon]$ to D, and area with $(\pi'+\varepsilon, +\infty)$ to E.[25] Batchelor and Orr then record the following formulae for the respondents' mean expected inflation.[26]

(10) $$\pi^{e}_{t+1} = \pi'_t \cdot (a_t + b_t) / (a_t + b_t - c_t - d_t)$$

and

(11) $$\pi'_t = \pi^{m}_t \cdot (a'_t + b'_t) / (a'_t + b'_t - c'_t - d'_t)$$

The variables a_t, b_t, c_t und d_t are the abscissae of the standard logistic distribution corresponding to cumulative probabilities A_t, A_t+B_t, $A_t+B_t+C_t$ und $A_t+B_t+C_t+D_t$. respectively.

The advantages of the procedure used here over the Carlson-Parkin method may be seen in the increased information content and accuracy in modelling the expectations resulting from a more detailed breakdown, the avoidance of implausible results based on borderline cases, the noticeability thresholds no longer having to be assumed as constant, and the possibility of replacing the assumption of the unbiasedness of the expectations by the less restricting assumption of the unbiasedness of the assessment of past inflation.

The GfK data are now quantified on the basis of formulae (10) and (11). However, the monthly figures are converted in advance to quarterly values using a simple mean value transformation, and the responses in the category "don't know" are distributed proportionately among the other categories in accordance with the usual procedure. Figure 2 shows the actual inflation rate and that expected in t-4 for the period t.

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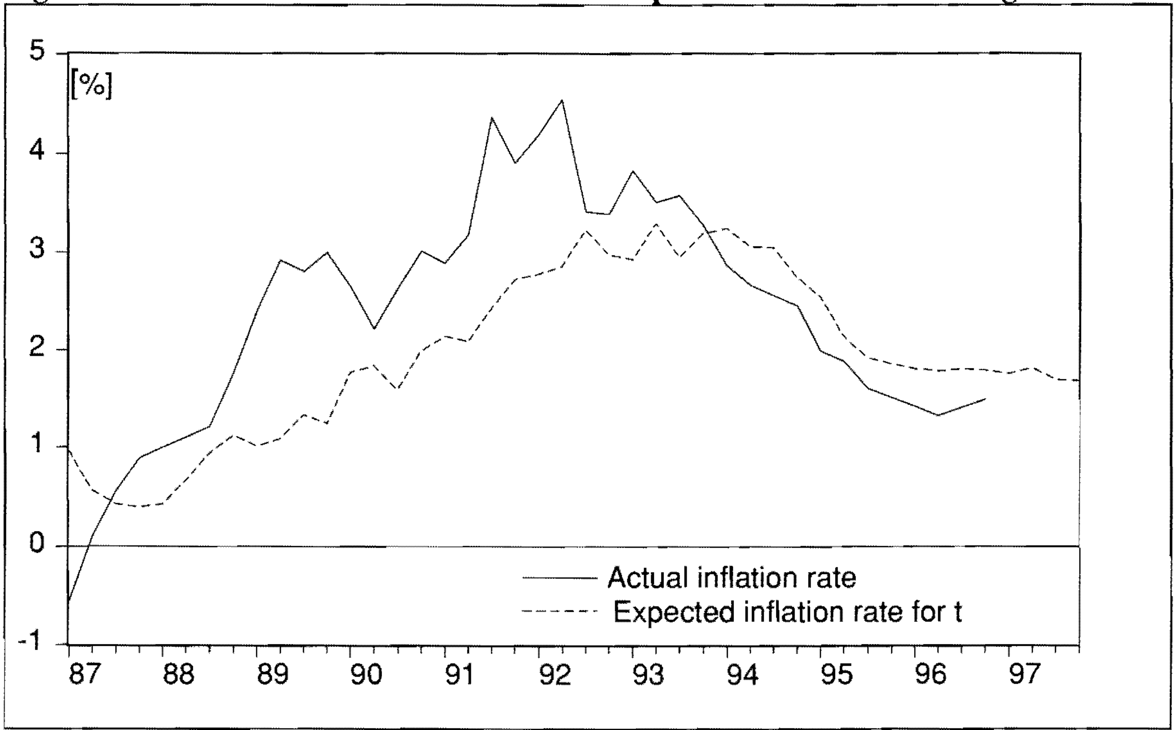
[25] See Figure 1, and Table 6, for the allocation of the shares to the response categories.

[26] Batchelor and Orr do not give any derivation for this. For derivations, see Appendix A.

By way of comparison, the expected inflation rate is also calculated assuming a normal distribution.[27] It becomes apparent that the inflation expectations quantified with the normal distribution are very similar to those expectations calculated on the basis of the logistic distribution.

Figure 2: Actual inflation rate and inflation expectations calculated using GfK data



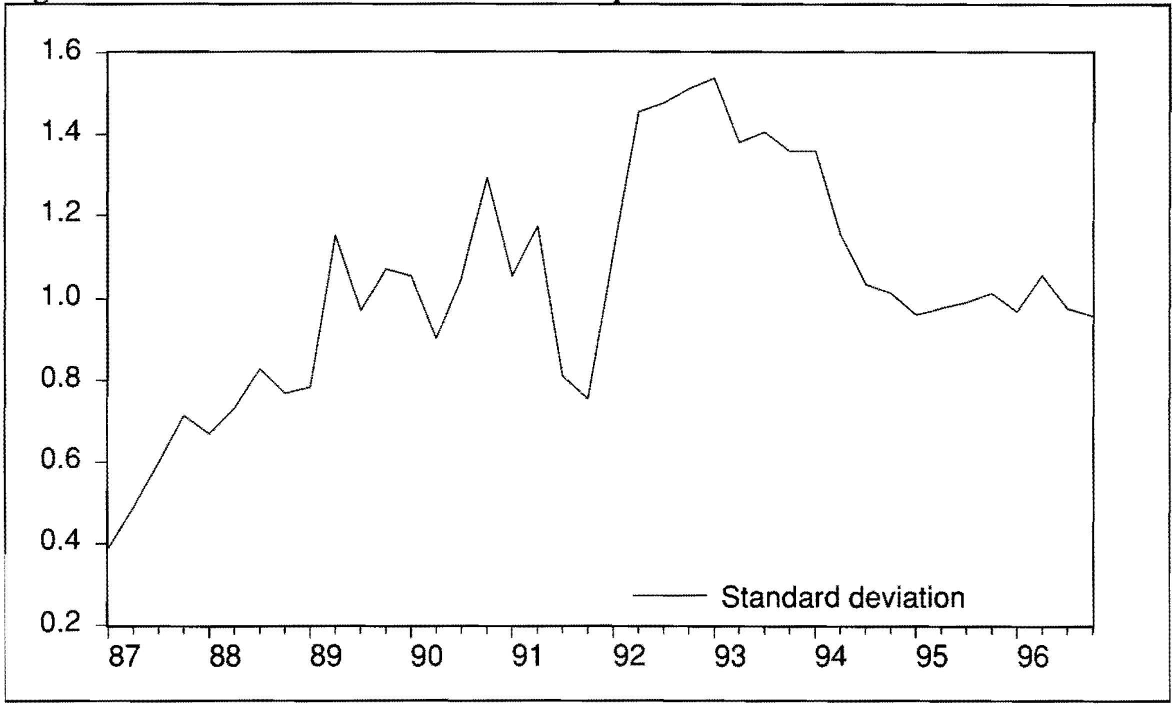
The initial impression is that the inflation expectations are shaped by extrapolation, since they follow the actual trend in inflation to a greater or lesser degree. Closer inspection reveals, however, that other explanatory factors must play a part in expectation formation in addition to an extrapolative component. Firstly, for example, major fluctuations in inflation, such as the downward one in 1986 and upward ones in 1989 and in 1991-2, are only partly taken into consideration in expectation formation. Secondly, in the period of falling inflation rates from 1993, the actual and expected curves run together far more closely than in the period of rising inflation, and the expectations finally stabilise at just under 2 % from 1995, although there has been a further fall in actual inflation.[28] An attempt will be made in

[27] The computation of the quantiles of the standard normal distribution is performed using the algorithm AS 241 from Applied Statistics (1988), Volume 37, No. 3, which is reproduced as a program in Hall, R. E. (1995).

[28] This picture is confirmed if the old time series of consumer prices before the September 1995 revision is used as a comparison.

the following chapter to examine the expectation formation process behind this in greater detail.

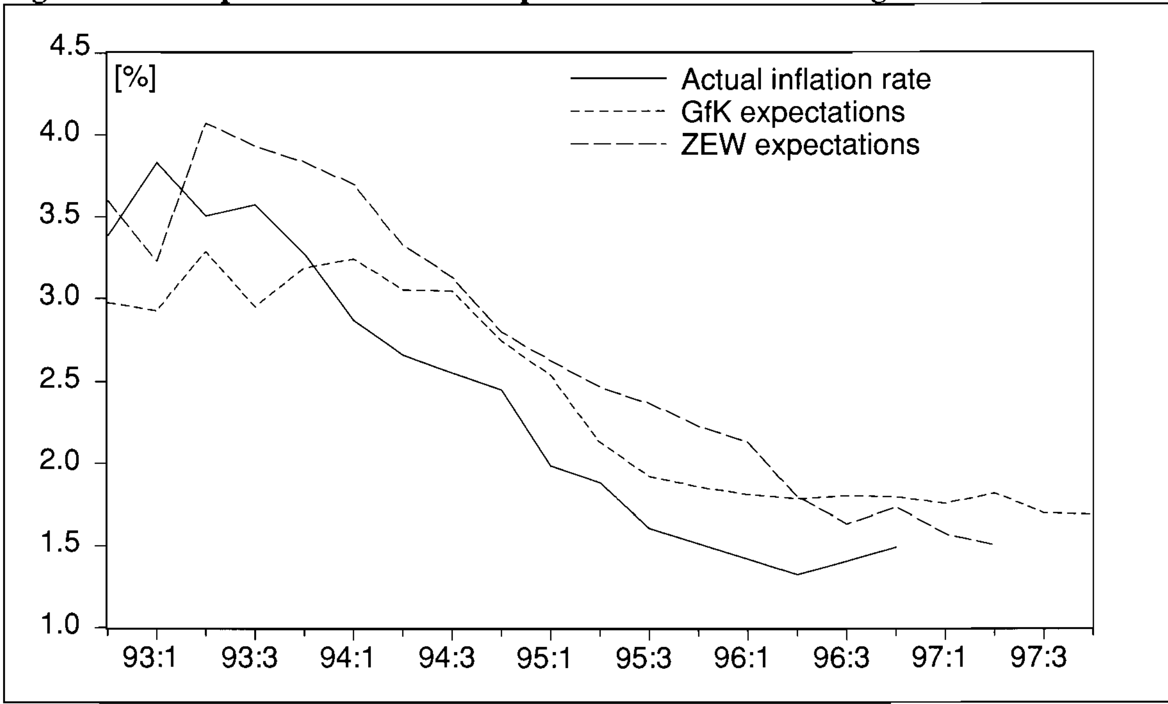
Figure 3: Standard deviation of inflation expectations



In addition to determining the expectations, the available data can also be used to determine the standard deviation of inflation expectations as well as the order of magnitude and the temporal movement of the noticeability thresholds. The standard deviation of inflation expectations may be interpreted as a measure of prevailing inflation uncertainty. Figure 3, as expected, shows that inflation uncertainty increases when inflation expectations rise and declines when they fall. At the end of the investigation period, the standard deviation remains at a certain level, however, and does not decline further in line with the trend in expectations. The temporal movement of the noticeability thresholds is, on the whole, comparable.

Finally, the inflation expectations ascertained from the GfK data are compared with the expectations calculated on the basis of the ZEW data. Both time series are shown in Fig. 4. In the period for which the ZEW data are available, their development likewise appears to be determined to a great extent by extrapolation. The movement and the expectation errors of the two expectation variables are very similar despite the different forecasting horizons. In contrast to the GfK data, there is a fall below 2 % in the ZEW expectations at the end of the series. As a general statement, it may be said that the consumers' and financial market experts' expectation formation - insofar as it is possible to judge, given the short period of comparison - are largely identical.

Figure 4: Comparison of inflation expectations calculated using ZEW and GfK data



Before using the directly determined inflation expectations for analysing the inflation-output relationship, they are subjected to a somewhat more detailed analysis in the following section.

II.3 Analysis of the expectation formation process

The first step is to examine the validity of the rational expectation hypothesis for the inflation expectations which are calculated using the GfK data. Tests of rational expectations are directly possible using survey data, without the need to specify the form or assumptions of a detailed theoretical model. Following this, an attempt is made at specifying the underlying expectation formation process more closely and, as appropriate, to model it.

The investigation undertaken in the preceding section, which is based more on graphical evidence, raised some doubts concerning the validity of the rational expectation hypothesis for the present data. A detailed analysis is conducted below using various tests of rationality. The first test is an examination of the hypothesis of the unbiasedness of expectations. This is because one of the conditions applying to rational expectations is that they must be unbiased on average. This condition can be verified by estimating equation (12). If expectations are rational, the coefficient α must equal zero and the coefficient β must equal one.

(12) $\pi_t = \alpha + \beta \cdot {}_{t-4}\pi^e_t,$ where $\alpha = 0, \beta = 1$ and

${}_{t-4}\pi^e_t$ = inflation rate at time t expected at time t-4

This test is not possible for data which have fewer than four categories or for data that do not incorporate the assessment of the past trend, since the assumption of unbiasedness must be imposed automatically in those cases for the quantification of the qualitative data. In our case, that assumption is needed only for determining the assessment of the past trend and not for calculating the inflation expectations themselves. The result of the estimation of equation (12) is shown in Table 2.

Since autocorrelation may lead to biased estimates of the standard errors, Newey-West corrected standard errors are determined.[29] The assumption of unbiasedness and hence the rational expectations hypothesis cannot necessarily be rejected on the basis of the estimation. A Wald test with the coefficient restrictions $\alpha = 0$ und $\beta = 1$ as the null hypothesis confirms that result, since the null hypothesis cannot be rejected.[30] For the reasons stated in the previous section of this chapter, the possibility of the results being falsified by potential measurement errors in the expectation variable is, if anything, slight. But even if there were measurement errors, that could only lead to a bias in α away from zero and in β towards zero.[31] Measurement errors would thus tend to lead more to a rejection than to an acceptance of unbiasedness. An estimate using the instrumental variables method (IV-method) conducted as a further verification confirms the results in Table 2.

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[29] See Hamilton, J.D. (1994), pp. 281 and Newey, W. and West, K. (1987).

[30] The F-statistics of the Wald test with the null hypothesis C(1) = 0 and C(2) = 1 amounts to 1.68.

[31] See Maddala, G.S. (1992), pp. 450.

Table 2: Test for unbiasedness of the expectation variables[32]

W4PLHW = C(1) + C(2)· W4PLHWE					
	Name	Coefficient	Standard error[a]	t statistic[a]	
C(1)	Constant	0.486787	0.466477	1.043538	
C(2)	W4PLHWE	0.958895	0.202844	4.727243	
Sample	1987:1 - 1996:4				
R2bar	0.519		BG-LM(1)	47.12	[0.00]
F statistics	43.12		BG-LM(4)	12.43	[0.00]
Durbin-Watson	0.371		White	1.058	[0.36]

a Newey-West HAC standard error.

The above tests alone are not sufficient for not rejecting the rational expectations hypothesis. A further test of rationality is the test for serial correlation in the expectation errors. If the rational expectation hypothesis is valid, the expectation errors must not be correlated with variables belonging to the information set, where past expectation errors are generally included in the information set. If they were correlated, the forecast could be improved with these variables, and this would contradict the assumptions of the rational expectation hypothesis.

Table 3 shows the autocorrelation coefficients and the values of the Ljung-Box Q-statistics.[33] The autocorrelation coefficients are significantly different from zero up to the seventh order, which is confirmed by the Q-statistics.[34] It should be noted, however, that the respondents' expectation horizon - amounting to one year - does not match the data survey interval of one quarter. As a result, surprise shocks can lead not only to expectation errors in the last forecast but also to similar errors in the forecasts of the preceding periods. This may cause autocorrelation up to the maximum fourth order. The resulting autocorrelation does

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32 With W4PLHW = inflation rate (π_t) and W4PLHWE = inflation rate at time t expected at time t-4 (${}_{t-4}\pi^e_t$). For the precise definition of the variables, see also Section III.1.
In square brackets after the test procedure = p-values; R2bar = adjusted coefficient of determination; Durbin-Watson = Durbin-Watson statistics; BG-LM(n) = Breusch-Godfrey LM test for n-th-order autocorrelation; White = White's heteroscedasticity test with cross-terms; on the tests, see, for example, Maddala, G.S. (1992) and Hall, R.E., etc. (1995).

33 The Ljung-Box Q-statistics test is a test of the null hypothesis that all observed autocorrelations are equal to zero (H_0: $\rho_j = 0$ for all j). The values of the test statistics result from
$Q_{LB} = T\cdot(T+2)\cdot\Sigma_{j=1,..,n} (\rho_j{}^2/(T-j))$ where T = number of observations,
ρ_j = j-te autocorrelation and n = number of lags.
For the application of the Q_{LB} or Box-Pierce test for fourth and higher-order autocorrelation, see Batchelor, R.A. (1982), pp. 14.

34 The standard error of the autocorrelation coefficients, calculated using the Bartlett method, given forty observations, amounts to 0.158. See Pindyck, R.S., Rubinfeld, D.L. (1991), pp. 446.

not justify rejecting the rational expectation hypothesis, however. Therefore, autocorrelation of the fourth or the fifth order is specifically examined using the Q-statistics. Overall, significant autocorrelation is also apparent here in the expectation errors, and, for that reason, the rational expectation hypothesis must be rejected.

Table 3: Autocorrelation structure of the expectation errors from the GfK survey data

k	AK	Q-Stat j = 1,...,k	Q-Stat j = 4,...,k	Q-Stat j = 5,...,k
1	0.729	22.900 [0.00]	-	-
2	0.571	37.339 [0.00]	-	-
3	0.514	49.313 [0.00]	-	-
4	0.363	55.479 [0.00]	6.492 [0.01]	-
5	0.334	60.843 [0.00]	11.04 [0.00]	5.3546 [0.02]
6	0.345	66.737 [0,00]	17.385 [0,00]	11.236 [0,00]
7	0.231	69.451 [0.00]	20.102 [0.00]	13.952 [0.00]
8	0.075	69.743 [0.00]	20.397 [0.00]	14.248 [0.01]

With AK_j = j order autocorrelation coefficient; standard errors of autocorrelation coefficients according to Bartlett = 0.158.

To corroborate the result, a simple test for orthogonality is also performed. This examines whether additional information, which is accessible to the public and was available at the time of the expectation formation, can contribute to reducing the expectation error. If that is the case, the rational expectation hypothesis must be rejected. A comparatively simple empirical analysis already reveals that expectation errors would have been sharply reduced by the inclusion of past inflation values (W4PLHW), capacity utilisation (GAPIFOGD) and changes in the nominal external value (W4AWU).[35]

[35] For the precise definitions of the variables, see also Section III.1.

Table 4: Orthogonality test with verification of the explanatory power of selected information variables for the expectation error

$ER^a = C(1) + C(2)\cdot W4PLHW(-5) + C(3)\cdot GAPIFOGD(-5) + C(4)\cdot W4AWU(-5)^b$

	Name	Coefficient	Standard error[c]	t statistic[c]	
C(1)	Constant	1.031224	0.378851	2.721980	
C(2)	W4PLHW(-5)	-0.342907	0.101198	-3.388464	
C(3)	GAPIFOGD(-5)	0.160780	0.030222	5.319958	
C(4)	W4AWU(-5)	-0.081564	0.037152	-2.195427	
Sample	1987:1 - 1996:4				
R2bar	0.502		BG-LM(1)	10.26	[0.00]
F statistics	14.10		BG-LM(4)	4.200	[0.01]
Durbin-Watson	0.878		White	1.164	[0.35]

a ER = W4PLHW - W4PLHWE = expectation error.
b W4AWU = nominal external value vis-à-vis the currencies of 18 industrial countries.
c Newey-West HAC standard error.

The rational expectations hypothesis for consumers' price expectations must therefore be rejected. That then leads to the question of what the consumers' actual expectation formation process looks like. To address this question a number of alternative expectation formation hypotheses based on the GfK data will be investigated. The models used most widely in the literature are the extrapolative, the adaptive and the return-to-normality models. The extrapolative expectation formation hypothesis may be represented in a reduced form as:

(13) $$\pi^e_t = \pi_{t-1} + \alpha\cdot(\pi_{t-1} - \pi_{t-2}), \qquad \text{where } \alpha > 0$$

If α takes the value zero, this model corresponds to the naive expectation formation model and, for α smaller than zero, the autoregressive expectation formation model. The adaptive single-order model becomes:

(14) $$\pi^e_t = \pi^e_{t-1} + \alpha\cdot(\pi_{t-1} - \pi^e_{t-1}), \qquad \text{where } \alpha > 0$$

Finally, the return-to-normality model has the following form:

(15) $$\pi^e_t = \pi_{t-1} + \alpha\cdot(\pi^n - \pi_{t-1}), \qquad \text{where } \alpha > 0$$

Following the reasoning given in section II.1, the Bundesbank's medium-term price assumption is chosen here for the normal level of the inflation rate (π^n) of the return-to-normality approach. As an alternative, the normal level can be approximated by the moving average of the inflation rate over a given time horizon.

Above and beyond these standard approaches in the literature, other variables which may have an influence on expectation formation may also be taken into consideration. These may be variables, for example, that are known to the general public and that are assumed to have a transmission or forecasting relationship with inflation. Variables that come into consideration are those already used in determining the inflation-output equation. In addition, various definitions of monetary growth, the yield curve, and, as an alternative for import prices, exchange rates are incorporated in the analysis. The choice of variables should not be regarded as complete, but are sufficient for an initial analysis.

First, the empirical investigation assumes an unrestricted approach which embraces all the above expectation formation models and all additional relevant variables described above, with all the irrelevant variables then eliminated in succession.[36] Secondly, starting with the individual expectation hypotheses, these are extended in succession by the components and variables which were previously not included. Various lag specifications are examined for both approaches. In the estimation of the comprehensive model as well as in the estimation of the individual expectation formation models, the additional explanatory variables prove to be insignificant. Of the various components of the expectation hypotheses, only the extrapolative elements turn out to be statistically significant. Among these approaches, the return-to-normality model with the Bundesbank's medium-term price assumption (PZIEL) as a proxy for the normal level provides the best explanatory power and the best statistical attributes. The relevant estimation result is listed in Table 5. The variable for the expected inflation rate (W4PLHWE) stands for the inflation rate expected at time t-4 obtained from the GfK data, which applies at time t. If it is now assumed that the actual inflation rate of the current period is not yet known at time t-4, and that the economic agents know only the inflation rate of the preceding period, the actual inflation rate must be entered into the equation only with a minimum five lags. Above and beyond that, greater lags of the inflation have proved to be non-significant.

[36] See equations (13), (14) and (15), but each with a more detailed lag structure.

A problem is posed, again, by autocorrelation, which is therefore taken into consideration when calculating the standard errors and covariances. The cause of autocorrelation may arise from the fact that the survey and expectation horizons have differing lengths and/or from the expectation formation process or the relevant variables being incompletely captured. The explanatory power of the approach is comparatively high, however, with an adjusted determination coefficient of 82 %.

Table 5: Expectation formation model for consumers' price expectations

W4PLHWE = (1-C(1))·PZIEL(-4) + C(1)·W4PLHW(-5)

	Name	Coefficient	Standard error[a]	t statistic[a]	
C(1)	W4PLHW(-5)	0.576429	0.045825	12.57884	
Sample	1987:1 - 1996:4				
R2bar	0.819		BG-LM(1)	21.22	[0.00]
F statistics	-		BG-LM(4)	8.763	[0.00]
Durbin-Watson	0.715		White	0.876	[0.43]

a Newey-West HAC standard error

In terms of the above requirements, the return-to-normality approach would appear be the best reflection of the general public's actual expectation formation behaviour in the period under observation. According to that approach, the economic agents based their expectation formation primarily on extrapolation. The past inflation rate enters the equation with a coefficient of approximately 0.6. Besides that, however, the economic agents expect that the price trend will readjust to the normal level after a certain time. The Bundesbank's medium-term price assumption proves to be a good proxy variable for the normal level.[37] The adjustment of the economic agents' expectations to that price assumption will be almost 90 % complete within one year.

[37] The credibility of the price target and the acceptance of the fact that this variable matches the basic rate of inflation expected over the long term or the "normal level" of the inflation rate, may also be explained by the relevant price levels moving identically over a long period. The price level calculated on the basis of the price targets moves away from the actual price level at times, but subsequently moves back towards it. This impression is confirmed by a test for cointegration, which shows that the level variables can be regarded as cointegrated.

In summary, it may be stated that, according to the available results, the economic agents' price expectation formation does not conform to the rational expectation hypothesis. Expectation formation is not purely extrapolative in nature either, however, since, with the return-to-normality component, it is ultimately forward-looking. That is because, in the long term, expectation formation, and hence the inflation trend, is shaped crucially by expectations of the "normal level" of inflation. For Germany, the Bundesbank's medium-term price assumption seems to represent a suitable proxy variable for that variable which is difficult to quantify - something which is undoubtedly due, not least, to the Bundesbank's high level of credibility.

It is important, however, to point out once again that the empirical analyses are based on a comparatively short time span, which essentially embraces only one upswing and one downswing. The results obtained may be construed as initial indications of the structure of expectation formation and their significance for monetary policy. More significant data may be expected when the survey data for the period before 1986 are available again.

III. Empirical analysis of the inflation-output relationship

III.1 Determination of the variables

Following the reasoning in section II.1, the consumer price index is used as a price variable for the analysis undertaken here. The estimations are based on the consumer price index for western Germany (PLHW), since price movements in eastern Germany were still being severely distorted by a large number of special influences, e.g. rises in rent and fees, up to the beginning of 1994.[38] After that both price indices show an almost identical trend. Of the various indices that are available, the consumer price index (which includes all households) is used.[39]

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38 The consumer price index for Germany as a whole is also available only from 1991.

39 The consumer price index is calculated using the Laspeyres formula with fixed weights. For that reason, this index is subject to a change in the basket of goods and in parts also of the methodology every five years. For the period under investigation, statistical breaks may therefore occur as of January 1 in each of the years 1980, 1985 and 1991, which may have to be taken into account in the estimation.

Variables calculated in a number of different ways are used for the output gap in order to examine how sensitively the econometric results react to output gaps established in different ways. Firstly, capacity utilisation based on the results of the ifo business survey for manufacturing in western Germany is used, supplemented by the capacity utilisation for construction (GAPIFOG).[40] The ifo capacity utilisation is standardised at an average value of zero in order to ensure comparability with other output gaps.

Secondly, the output gap is defined as a logarithmic ratio of real gross domestic product (Y) to real production potential (Y*).

$$(16) \quad gap = \log(Y / Y^{*}) \cdot 100$$

Both variables are calculated at 1991 prices and apply to for western Germany up to and including the second quarter of 1990 and for Germany as a whole thereafter.[41] The potential according to calculations based on the Bundesbank model is used (GAPBM) as the production potential. These potential estimations are based on a Cobb-Douglas production function with the factors labour and capital, taking account of technological progress. The production potential states the overall economic performance that can be produced with the available production factors given normal utilisation and incorporating technological progress.[42] Additionally, a potential produced by our own calculations (GAPT0) is included as an alternative production potential. To do this, real GDP is regressed on a higher-order polynomial of the time trend.[43]

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[40] The rates of capacity utilisation for manufacturing and construction are included with moving weights in the overall rate of utilisation in accordance with their shares in gross national product. A parallel trend is assumed in the rate of utilisation in construction and in installation and building-completion work.

[41] The break in the time series caused by reunification is negligible on account of the ratio formation and eastern Germany's relatively minor weight.

[42] Potential output which is included in the derivation of the money stock is not considered here as it is determined only for the annual, and not for the quarterly, figures. Both potential outputs have a similar curve, however. For general remarks on the production potential, see Deutsche Bundesbank (1995), pp. 41, for example.

[43] The equation for the real production potential (POTRT), with T as the time trend and D90396 as a dummy for reunification is:
$POTRT = 383{,}34 + 3{,}0158 \cdot T - 0{,}0208 \cdot T^2 + 0{,}0002 \cdot T^3 + 53{,}00 \cdot D90396$.

Table 6: Overview of definitions of the key variables[44]

Name	Definition
PLHW	Consumer price index for western Germany
GAPIFOG	Output gap calculated with capacity utilisation from the ifo business survey for manufacturing and construction
GAPBM	Output gap with production potential, calculated using a Cobb-Douglas production function
GAPT0	Output gap, calculated with temporal trend using a third degree polynomial
MWSS	Turnover tax rate
MOESSA	Mineral oil tax rate
PIM	Overall import prices
PZIEL	The Bundesbank's medium-term price assumption
W4PLHWE	Inflation rate expected in period t-4 for the period t, calculated using GfK data

Among potential price shocks which influence price movements, explicit account is taken of import prices and certain tax rate changes. Besides overall import prices (PIM), more narrowly defined import price indices are also tested, e.g. import prices for raw materials, semi-finished products and intermediates, the HWWA overall index of raw material prices and the import prices for petroleum and mineral oil products. A large part of indirect taxes, in particular, is of importance for price movements. Some taxes which are relevant for price movements (including tobacco tax, motor vehicle tax, other consumer and insurance taxes) are not considered on account of their comparatively minor revenue compared with turnover and mineral oil tax, and because of their complicated structure.[45] In concrete terms, turnover tax (MWSS) and mineral oil tax (MOESSA) are taken into consideration. Those two taxes had a roughly 85 % share in the tax revenue of the relevant indirect taxes from the middle of the period under investigation. The rates of change or the absolute changes in the respective tax rates are included in the estimation.[46] The standard rate is

[44] "W" and "W4" placed before the variable name denotes a rate of change from the previous quarter and a rate of change from the corresponding quarter of the previous year, respectively.

[45] Tobacco tax yields the largest revenue among these taxes. Since it is a combined quantitative and ad valorem tax, modelling it would too elaborate.

[46] The rate of change in the turnover tax rate (WMWSS) is calculated as
WMWSS = log((1+MWSS/100) / (1+MWSS(-1)/100))

Since $\pi = \log(P/(P(-1)) = \log((P^N \cdot (1+MWSS/100)) / (P^N(-1) \cdot (1+MWSS(-1)/100))$
$= \log(P^N / P^N(-1)) + \log((1+MWSS/100) / (1+MWSS(-1)/100))$
$= \pi^N + WMWSS$,

where P^N are the net prices, i.e. the prices less value added tax (VAT) assumed as a basis for turnover tax.[47] The rate of tax for petrol, which is calculated according to the shares of the tax rate for leaded and unleaded petrol, has been used to represent the various mineral oil tax rates.

In case the productivity trend in equation (2) is not completely cancelled out or captured using the output gap - in contrast to the argument presented in section II.1 - that variable is added as a separate variable in the estimation for verification. Table 6 lists the variables together with their definitions. The estimations are based on seasonally adjusted quarterly data.

The Bundesbank's price assumption between 1975 and 1984 inclusive corresponds to the "inevitable" inflation rate used by the Bundesbank for determining the monetary target. This "inevitable" rate of inflation is not to be interpreted as the a long-term inflation rate aimed for by the Bundesbank but rather as a pragmatic and achievable target for each of the years in question. Since the end of 1984, the price assumption used by the Bundesbank for deriving the monetary target has been defined as the maximum tolerable inflation rate over the medium term, and may therefore be construed as a long-term price assumption. The Bundesbank's price assumption is shown in Table 7.

Table 7: The Bundesbank's medium-term price assumption from 1975 to 1998[48]

Year	Price assumption	Year	Price assumption	Year	Price assumption
1975	6.0	1983	3.5	1991	2.0
1976	4.5	1984	3.0	1992	2.0
1977	3.5	1985	2.0	1993	2.0
1978	3.25	1986	2.0	1994	2.0
1979	3.0	1987	2.0	1995	2.0
1980	4.0	1988	2.0	1996	2.0
1981	3.75	1989	2.0	1997	1.75
1982	3.5	1990	2.0	1998	1.75

[47] Apart from the tax rate change of January 1, 1993, the reduced rate has changed in the same ratio as the normal rate.

[48] See various volumes of the Annual Reports and Monthly Reports of the Deutsche Bundesbank.

The variables must be tested for their degree of integration before the estimations are performed. Only if the time series used are stationary, i.e. have a zero degree of integration, can the OLS method be applied and, where appropriate, the instrumental variables method, without the fear of obtaining biased estimates of the coefficients and biased test statistics or of showing spurious correlations.

The KPSS test is used for testing stationarity.[49] In contrast to the augmented Dickey-Fuller test (ADF test) and the Phillips-Perron test (PP test), the KPSS test assumes the null hypothesis of stationarity of the time series to be observed.[50] The ADF and the PP tests examine the null hypothesis that the variable is non-stationary and, in contrast to the KPSS test, favour non-stationarity since it is well known that the null hypothesis of non-stationarity is rejected too rarely on account of the low power of those tests on small samples.

Table 8: KPSS test for the variables' degree of integration[51]

Variable	KPSS test
WPLHW	0.2711
WPIM	0.2332
GAPBM	0.1059
GAPIFOG	0.3366
GAPTO	0.1182
W4PLHW	0.2957
W4PIM	0.2819

49 See Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. (1992). For empirical verification, programs are used which have been written by H.-J. Hansen and M. Scharnagl of the Bundesbank's Economics Department.

50 See, for example, Maddala, G.S. (1992), pp. 581, MacKinnon, J.G. (1991), and Phillips, P.C.B. and Perron, P. (1988).

51 The asymptotic critical values are 0.347 (10 %), 0.463 (5 %) and 0.739 (1 %); the error probabilities are stated in brackets. The estimation period begins in 1976 and ends in 1996. The Barlett window's cut-off parameter has the value 8. See Table 1 for the names of the variables. The Bundesbank's medium-term price assumption and the variables for the rates of taxation are exogenously set variables, which move in jumps and may be assumed to be stationary.

For the results of the KPSS tests shown in Table 8, the cut-off parameter of the Bartlett window was set at the value 8. Kwiatkowsi *et al.* have suggested that value as a compromise, since biases occur with a low cut-off parameter and result in a too-frequent rejection of the null hypothesis. On the other hand, with too great a cut-off parameter, the power of the tests is too low and the alternative hypothesis is accepted too rarely. The table shows that the null hypothesis of stationarity cannot be rejected given a significance level of 10 % for all the variables. The results of the ADF and PP tests, which are not shown separately, likewise do not generally argue against stationarity of the time series, although they are not as unambiguous as the KPSS test. At all events, independent of these test results, there are theoretical grounds for assuming stationarity of all the variables.

III.2 The inflation-output relationship with inflation expectations determined from the survey data

Using the expectations calculated in section II.2, the inflation-output equation may now be estimated directly taking explicit account of the directly measured inflation expectations. The starting point of the estimate is equation (5). In line with the arguments presented in the first section of the previous chapter, both leads and lags of the endogenous variable are taken into consideration. Since the expectation variable relates to a one-year horizon, the estimates are performed only as differences from the comparable quarter of the previous year and not from the preceding quarter. This obviates any problems caused by "breaking down" the expectation values into quarterly values.

On account of the data problems discussed above, the estimation period is shortened to the period from the first quarter of 1986 to the fourth quarter of 1996. Since it has 44 quarters, however, it may still be regarded as sufficiently large. The adjusted determination coefficient is comparatively high at 97.0 %, and the other test statistics are, with one exception, likewise to be rated as satisfactory. Analysing the residuals gives indications of third and fourth-order autocorrelation, which are probably due to the chosen difference formation rather than to specification errors.[52] For that reason, the calculations are performed using a covariance matrix corrected by the Newey-West method in order to obtain t- and F-statistics that can be interpreted. An additional problem may be caused by

[52] See Chapter III.3

measurement errors in the expectation variable, which may be due to the sample chosen or the quantification procedure. The OLS estimates may then be biased or inconsistent. However, the large size of the sample in the GfK survey, the inclusion of the respondents' assessment of the past trend, the subdivision into five response categories and the inclusion of the response category "don't know" help to reduce the problem.[53] Nevertheless, an IV estimate with the contemporaneous independent variables, and the lagged independent and dependent variables as instruments is performed as a control. Only marginal differences from the OLS estimate are revealed, however.

Recursive estimates are derived to verify stability. The coefficients are determined recursively by reestimating the corresponding function from the start of the estimation period using successively greater periods. Instabilities may be identified by one or more jumps occurring in the coefficients or by the coefficients not converging towards a given value. All the coefficients show a comparatively stable movement without major structural breaks in both the forward- and backward-looking calculations.

Table 9: Inflation-output equation with survey data[54]

W4PLHW = (1-C(2))·W4PLHWE(4) + C(2)·(W4PLHW(-1)) + C(3)·GAPIFOGD(-1)
+ C(4)·W4PIM + C(5)·W4MOESSA

	Name	Coefficient	Standard error[a]	t statistic[a]	
C(2)	W4PLHW(-1)	0.569619	0.071654	7.949606	
C(3)	GAPIFOGD(-1)	0.031898	0.007854	4.061394	
C(4)	W4PIM	0.037620	0.003640	10.33582	
C(5)	W4MOESSA	0.026783	0.005459	4.906491	
Sample	1986:1 - 1996:4				
R2bar	0.970		BG-LM(1)	3.231	[0.08]
F statistics	467.0		BG-LM(4)	3.738	[0.01]
Durbin-Watson	1.487		White	1.005	[0.49]

a Newey-West HAC standard error.

The coefficients all have a plausible order of magnitude and are significantly different from zero. The VAT variable is not taken into consideration as only one increase in turnover tax

53 See Fluri, R. and Spörndli, E. (1987), pp. 163, Oppenländer, K.-H. (1996), pp. 122 and, for an empirical study on the subject, Batchelor, R.A. (1986).

54 With GAPIFOGD=0.31·GAPIFOG+0.27·GAPIFOG(-1)+0.23·GAPIFOG(-2)+0.19·GAPIFOG(-3).

has taken place in the shortened estimation period since 1986, and the corresponding variable would merely have the effect of a dummy variable. Among the other potential exogenous price shocks described above, the import price index in the broadest definition and the variable for the changes in the rate of mineral oil tax turn out to be relevant. Among the various calculated output gaps, the best results are achieved using the output gap established on the basis of the ifo capacity utilisation, in which a weighted average of the last four quarters (with declining weights) is used following the examination of various lag structures (GAPIFOGD).

The lag-lead structure of the endogenous variables turns out to be relatively straightforward, even after systematically examining different variants to Fuhrer and Moore's theoretical model - although this is not necessarily surprising under the conditions set by the data. The essential components of the theoretical model are present, however. Restricting the coefficients of the expectations variable and the endogenously lagged variables to one for theoretical reasons, is likewise investigated. To do this, the equation is estimated without the restriction, and the null hypothesis of the restriction of the coefficients to one is subsequently examined using a Wald test. The result shows that the null hypothesis cannot be rejected.

An interesting point is that the lagged inflation rate is significant even when the forward-looking expectations are explicitly taken into account. At all events, this indicates a certain persistence in the inflationary trend, which is not without significance for the conduct of monetary policy. The overall strength of this element cannot be judged until the momentum behind the expectation formation process is included in the analysis. To do that, the price expectation term in the inflation-output equation in Table 9 is now replaced by the expectation formation model estimated in the preceding chapter by inserting the equation in Table 5 into the equation in Table 9. The equation for the expectation formation model of consumers' price expectations

$$\text{(17)} \qquad W4PLHWE = 0.4234 \cdot PZIEL(-4) + 0.5764 \cdot W4PLHW(-5)$$

inserted into the inflation output equation with survey data (Table 9)

$$(18) \quad W4PLHW = 0.4304 \cdot W4PLHWE(4) + 0.5696 \cdot W4PLHW(-1) + f(X)$$
$$\text{with } X = (GAPIFOGD(-1), W4PIM, W4MOESSA)$$

then gives

$$(19) \quad W4PLHW = 0.1823 \cdot PZIEL + 0.8177 \cdot W4PLHW(-1) + f(X).$$

Assuming that the expectation formation model (equation (17)) captures the trend in actual expectation formation relatively accurately, the persistence of the inflationary trend is deemed to be as comparatively high.

It remains to be noted that a stable relationship between inflation and the output gap with a relatively high persistence in inflation is produced even with the inclusion of the directly measured expectations - although the results must be regarded with caution on account of the comparatively short estimation period. For that reason, a more far-reaching analysis of the equation and a detailed interpretation of the coefficients is performed by way of comparison with an inflation-output equation based on a longer estimation period. For that purpose, in the next section the directly determined inflation expectations in the inflation-output equation is replaced by the expectation formation model derived from those inflation expectations. In doing so, the expectation parameters, however, are estimated indirectly. Firstly, the estimation period is longer as a result and, secondly, this procedure implies a further, indirect verification of the assumed expectation formation process. Furthermore, this allows estimation with quarter-on-quarter changes, which may be more advantageous empirically.

III.3 The inflation-output relationship with modified extrapolative inflation expectations

The starting point for the following empirical investigation is equation (2). This time, however, instead of the directly measured inflation expectations, the modified extrapolative expectation formation hypothesis determined in section II.3, which assumed a gradual adjustment of expectations to a basic inflation rate π^*, is included in the inflation-output equation in a general form, i.e. without specifying coefficient values. In doing this, the basic inflation rate π^* is specified as the Bundesbank's medium-term price assumption, shown in Table 7, (PZIEL). The expectation parameters - with the exception of the restrictions specified in equation (3) - are then freely estimated and can be compared with the parameters of the expectation formation model determined using the GfK inflation expectations. As an alternative, the other expectation formation models presented above are investigated. The following remarks relate initially to estimations based on quarter-on-quarter changes.[55] Following this, results are presented based on year-on-year changes in quarterly data as a direct comparison of the coefficients with the estimations of the preceding section.

The estimation period starts in the first quarter of 1976 and goes up to the fourth quarter of 1996. The observation period comprises 84 quarters and is hence twice as long as the previous investigations. The first quarter of 1976 is chosen as a starting date, since the changeover to a flexible exchange rate system and the associated processes of adjustment can be considered as having been completed by the beginning of 1975, following the collapse of the Bretton Woods system in March 1973. The estimates do not begin until 1976 since multiple lagged variables may occur in the estimations. The investigation period therefore roughly covers two complete economic cycles in Germany. The model is estimated using quarterly data and the data are seasonally adjusted.

The estimations are performed using the OLS method. An instrumental variable estimator (IV estimator) should be applied, however, if the contemporary output gap is included in the equation, since the contemporaneous output gap cannot necessarily be regarded as weakly exogenous. The IV estimation produces only slightly different results, however.[56]

Of the various extrapolative or adaptive expectation hypotheses, the modified extrapolative expectation formation model discussed in the previous section proved to be the most

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[55] The price assumption is converted to a quarterly basis using the fourth root for that purpose (PZIELQ).

[56] The multiple lagged long-term interest rates and real external values are included as instruments in addition to the lagged output gaps and the other predetermined variables of the price equation. The relevance of the two first-named variables is apparent if the price equation is seen in the context of a small macromodel with interest rate, output and exchange rate equations.

suitable for reflecting price movements. Table 10 shows that the explanatory power of the inflation-output relationship estimated using this expectation hypothesis is a good one with an adjusted determination coefficient of 78.8 % for a function estimated in first differences. The coefficients have the theoretically expected plus or minus signs and plausible orders of magnitude. The test statistics are likewise highly satisfactory. Only the White heteroscedasticity test without cross-terms (which, because of the higher number of degrees of freedom, is used in addition to the White test with cross-terms) points to signs of heteroscedasticity. On the usual assumptions, heteroscedasticity results in unbiased but inefficiently estimated, coefficients and in biased estimated standard errors. The estimation was hence performed additionally with the White correction for heteroscedasticity, which ensures a consistent determination of the covariance matrix and corrected t-values.[57] Very similar results were produced for the test statistics, however.

Table 10: Inflation-output equation with modified extrapolative expectations[58]

$$WPLHW = PZIELQ \cdot (1-C(2)-C(3)) + C(2) \cdot WPLHW(-1) + C(3) \cdot WPLHW(-3)$$
$$+ C(4) \cdot GAPIFOGD(-1) + C(5) \cdot WPIM + C(6) \cdot WMWSS + C(7) \cdot WMOESSA$$

	Name	Coefficient	Standard error	t statistic	
C(2)	WPLHW(-1)	0.266466	0.071266	3.739018	
C(3)	WPLHW(-3)	0.285866	0.072451	3.945652	
C(4)	GAPIFOGD(-1)	0.023179	0.005792	4.002055	
C(5)	WPIM	0.080750	0.011970	6.745946	
C(6)	WMWSS	0.458647	0.075998	6.034947	
C(7)	WMOESSA	0.031404	0.007819	4.016240	
Sample	1976:1 - 1996:4				
R2bar	0.788		BG-LM(1)	3.240	[0.08]
F statistics	62.76		BG-LM(4)	0.839	[0.51]
Durbin-Watson	2.284		White	1.400	[0.14]

An influence on price movements can be demonstrated for all the listed definitions of the production potential. The examination of various lag specifications shows the best results using a weighted average of the last four quarters with declining weights (GAPIFOGD). The differences from the other lag specifications are comparatively slight, however. The corresponding short-term coefficient then amounts to 0.0232. The long-term coefficient is

[57] See Maddala, G.S. (1992), pp. 209 and White, H. (1990).
[58] With PZIELQ = price assumption rounded down to a quarterly basis and GAPIFOGD=0.31·GAPIFOG+0.27·GAPIFOG(-1)+0.23·GAPIFOG(-2)+0.19·GAPIFOG(-3).

clearer, however; when extrapolated to yield an annual inflation rate, this amounts to between 0.2 and 0.3, depending on the potential definition and the number of lags considered. It assumes the value 0.23 for the specification listed in Table 10.

The persistence of the inflationary trend, which is captured by the lagged endogenous variable, results in adjustments being completed by just over 50 % after one year. After two years, the adjustment amounts to 85 % and can hence be regarded as almost completed.

Of the variables for the other price shocks described in section III.1, both the rate of change for turnover tax rates (WMWSS) and the change in mineral oil rates (WMOESSA) turn out to be statistically significant. A one percentage point change in the rate of turnover tax thus leads to a maximum rise in the annual inflation rate of 0.76 percentage point. The overall effect on the general price level amounts to roughly one percent. It might be expected, however, that this effect is smaller than one since not all goods contained in the basket of goods of the consumer price index are subject to turnover tax. The overall effect may be greater, however, if enterprises exploit increases in turnover tax for hidden price rises and/or if any other influences obtaining at those times also affect that variable (which throughout the investigation period assumes a value other than zero at only four points in time). A dummy (which did not turn out to be significant, however) was set for the differing change in the normal and the reduced rate of taxation on January 1, 1993. The long-term effect on the general price level of an increase in mineral oil tax of one pfennig amounts to 0.07 percentage point, and is hence on a plausible scale if the absolute level of mineral oil tax and the share of mineral oil products in the basket of goods (approx. 4 %) is taken into consideration.[59]

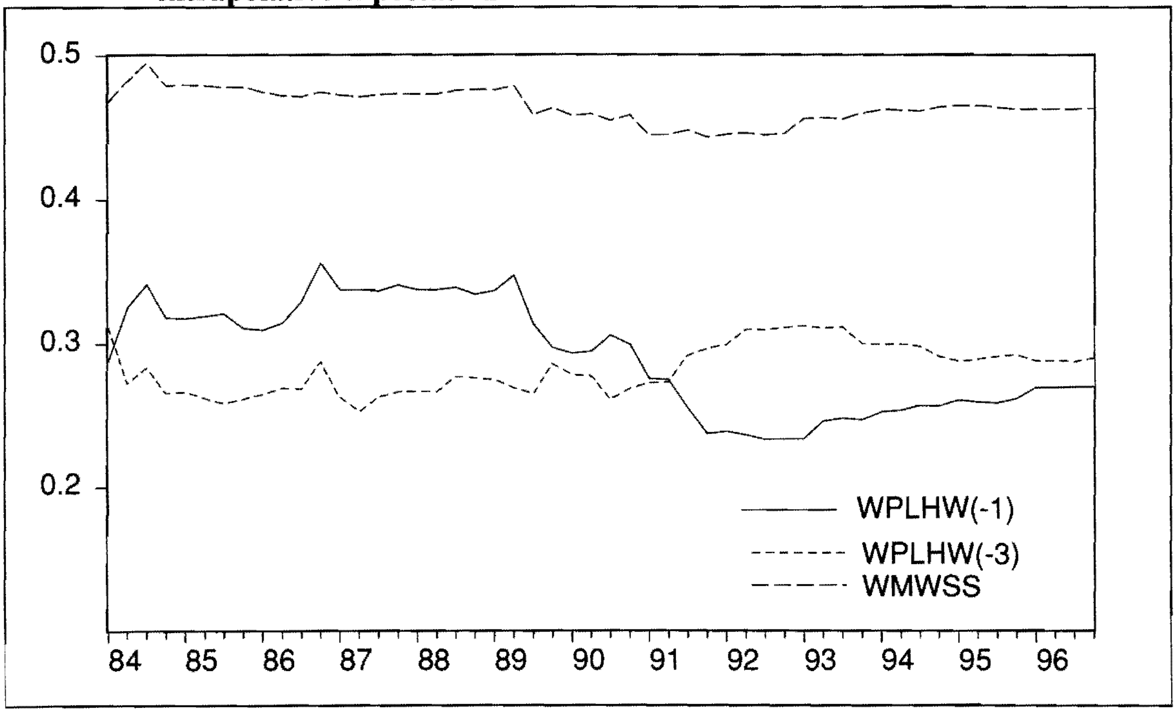
Furthermore, the variable for the overall rate of change in import prices (WPIM) shows itself to be statistically significant. The corresponding long-term coefficient of just under 0.2 relative to the annual inflation rate is of a plausible magnitude. The above-mentioned more narrowly defined import prices are likewise significant, but produce slightly worse statistical results.

[59] Indirect effects, too, such as tax-related rises in costs entering consumer prices indirectly via bought-in goods and services, may have an influence on the size of the overall effect.

The productivity variable, defined as the rate of change in real GDP per hour worked by employed persons, proves to be non-significant. The adjustments made every five years to the basket of goods of the consumer price index do not have any implications for the estimates either.

Examining the function's stability is of particular interest for the empirical assessment of the function and the further analysis of the relationships. Among the various procedures that are available, the recursive calculation of the coefficients has proved to be a particularly suitable method in empirical practice. In addition to that, a recursive Chow breakpoint test is carried out.

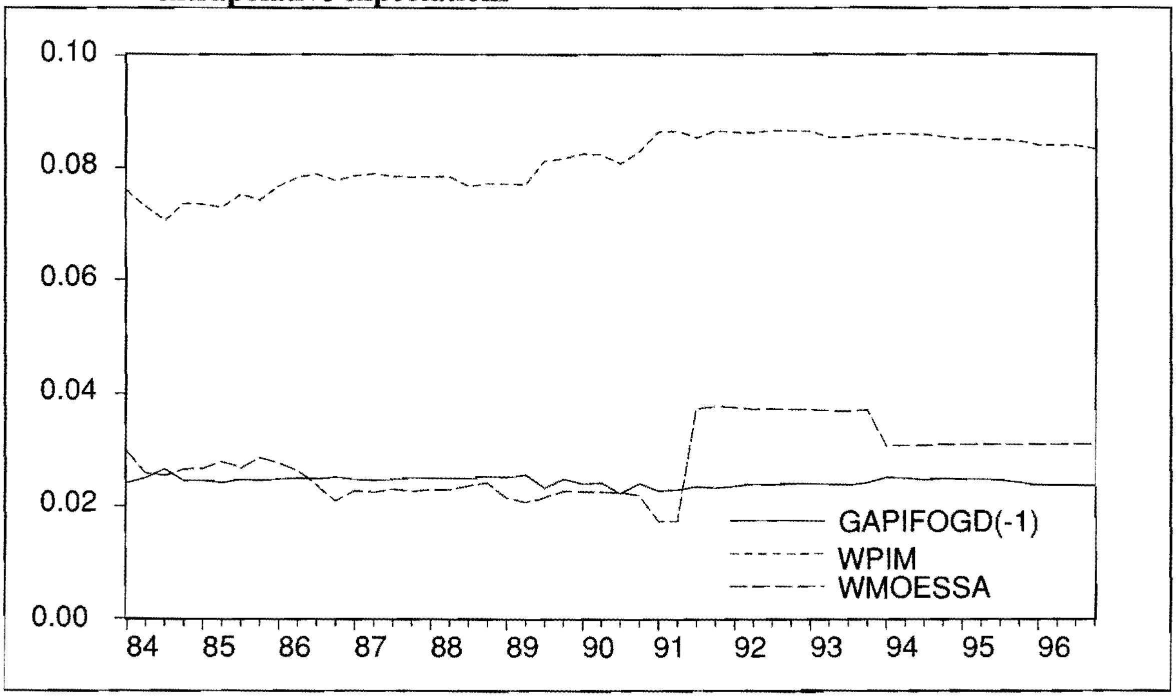
Figure 5: Recursive coefficients of the inflation-output equation with modified extrapolative expectations



The recursively calculated coefficients are shown in Figures 5 and 6. The charts show that the coefficients are comparatively stable over time and do not indicate any major structural break. Major fluctuations, which can generally be attributed to reference periods that are initially still too short, occur only at the beginning of the investigation period. The decline of the coefficient of the endogenous variable lagged once from 1990 onwards is partially offset by an increase in the other adjustment coefficient (Fig. 5). Taken together, both coefficients are around 0.57. The coefficient of the output gap turns out to be very stable.

Over time there is a slight increase for the coefficient of import prices. The parameter of the mineral oil taxation rate displays minor jumps, which are due to this variable assuming a value other than zero only at a very few points in time and jumps then being able to occur at those times (Fig. 6).

Figure 6: Recursive coefficients of the inflation-output equation with modified extrapolative expectations



The results of the retrospectively calculated recursive estimation ascertained for control purposes, in which the estimations are successively calculated backwards from the end of the investigation period for increasingly longer periods, indicate somewhat greater variation, particularly in the turnover tax rate, but otherwise corroborate the results.

As the next step, the movement of the parameters over time is observed. To do this, a moving estimation of the function shown in Table 10 is undertaken for 10 years in each case. The estimations start in the first quarter of 1972 and each comprise 40 quarters. The intention of this is to achieve a compromise between the power of the estimations, which generally increases with the number of observations, and the number of moving coefficients. The results of the recursive estimates are generally confirmed. The increase in the coefficient of the import prices is clearer, however, and thus reflects the increasing share of imports in GDP over the observation period as a whole. The inflation-output equation is hence based on stable coefficients even for the shortened estimation periods and for various sub-periods.

In conclusion, the Chow breakpoint test is applied.[60] The null hypothesis that there is no structural break cannot be rejected for the period between 1981 and 1992.

Table 11: Inflation-output equation with modified extrapolative expectations in differences from the quarter of the preceding year

W4PLHW = PZIEL·(1-C(2))+C(2)·W4PLHW(-1) +C(3)·GAPIFOGD(-1)

+C(4)·W4PIM +C(5)·W4MWSS +C(6)·W4MOESSA

	Name	Coefficient	Standard error[a]	t statistic[a]	
C(2)	W4PLHW(-1)	0.782574	0.044336	17.65118	
C(3)	GAPIFOGD(-1)	0.042001	0.009438	4.450279	
C(4)	W4PIM	0.039655	0.006707	5.912760	
C(5)	W4MWSS	0.149453	0.094797	1.576568	
C(6)	W4MOESSA	0.017431	0.007853	2.219608	
Sample	1976:1 - 1996:4				
R2bar	0.951		BG-LM(1)	2.27	[0.12]
F-statistics	407.6		BG-LM(4)	4.148	[0.01]
Durbin-Watson	1.666		White	0.998	[0.49]

a Newey-West HAC standard error

In addition to the calculation based on quarter-on-quarter changes, the inflation-output relationship is also examined for the equation based on year-on-year changes in quarterly data. Table 11 shows the relevant estimation. Of the various expectation formation hypotheses examined, the method using a gradual adjustment to basic inflation, which is approximated by the Bundesbank's medium-term price assumption, proved to be the most suitable in this context. The adjusted determination coefficient attains a value of 0.95. The other test statistics are likewise relatively good and, as a problem, indicate only a certain measure of autocorrelation, which is taken into account by a Newey-West correction. In addition to heteroscedacity, the Newey-West correction also takes into account autocorrelation in determining a consistent covariance matrix. It is likely that the

60 In the Chow breakpoint test, the investigation period is subdivided into two periods at the assumed point of the structural break and the function is estimated separately for both periods. The resulting unrestricted sums of the square residuals are then compared with the sum of the squared residuals of the estimation for the entire period. Using an F and LR test, a decision is then made on whether the null hypothesis that there is no structural break, i.e. the coefficients for the partial estimates are identical, has to be rejected. These tests are performed successively for all the possible points in time. See Maddala, G.S. (1992), p.156 ff.

autocorrelation is due to the estimation being in preceding years' rates. An estimation using values that have not been seasonally adjusted does not alleviate the problem, which implies that seasonal adjustment can probably be ruled out as a cause.

The results of the calculations in the first differences are generally confirmed. Only the long-term effect of a one percentage point increase in turnover tax is slightly smaller, with a rise in the price level of less than 0.9 percentage point. The processes of adjustment develop identically, with the exception of the first three quarters, in which the adjustment is somewhat lower for the estimation in the first differences. Otherwise, the coefficients correspond to those of the estimation in first differences. The long-term parameter of the output gap is 0.21. The recursive and moving estimations indicate lower volatility in the case of the adjustment coefficients and a somewhat higher one for the output gap and the rates of taxation. The coefficient of the import prices rises slightly, as in the first estimation. The results of the Chow breakpoint test are slightly worse than for the first differences, but no significant indication of a structural break can be found.

Finally, the results of these estimations (Tables 10 and 11) are to be compared with those based on the directly measured inflation expectations (Table 9). This reveals that the adjusted coefficient of determination in the estimation with modified extrapolative expectations is only around 2 percentage points less than the estimations with the directly measured inflation expectations. This result is also confirmed if, for the sake of comparability, the same estimation period from 1986 to 1996 is used as a basis for the estimation of the equation in Table 11.[61] This may be seen as an initial indication that the postulated expectation formation process (return-to-normality model) approximates the actual process relatively accurately.

At first glance, the long-term coefficients of the estimation with the directly measured inflation expectations (Table 9) of the previous section appear to be lower than in the estimations in Tables 10 and 11. This impression is corrected, however, if explicit account

[61] For the estimation period from 1986Q1 to 1996Q4, the inflation-output equation with modified extrapolative expectations (Table 11) gives

$$\begin{aligned} W4PLHW = {} & 0.2272 \cdot PZIEL + 0.7728 \cdot W4PLHW(-1) + 0.0372 \cdot GAPIFOGD(-1) + 0.0473 \cdot W4PIM \\ & + 0.0174 \cdot W4MOESSA \end{aligned}$$

and thus reveals only minor deviations from equation (19).

is taken of the momentum of the expectation formation process lying behind the expectation variable, as may be seen from equation (19). The long-term coefficients of the inflation-output relationship in Table 9, produced by taking explicit account of the momentum of the price expectation formation process estimated in section II.3, are then of roughly the same order of magnitude as the corresponding long-term coefficients of Tables 10 and 11. Hence, the comments made in this section concerning the interpretation of the coefficients are also applicable to the inflation-output equation with directly measured inflation expectations.

The inflation-output equation with survey data can thus be transformed, taking into account the estimated expectation formation model, into the inflation-output equation with the modified extrapolative expectations (return-to-normality model). Calculated in different ways, firstly using the directly measured inflation expectations and secondly by the verification of various expectation hypotheses over a longer reference period, the same expectation formation model shows itself to be relevant. The inflation-output model estimated in this section, thus appears to give a relatively accurate approximation of the actual expectation formation process derived from the directly measured inflation expectations.

In summary, it may be said that a significant and stable relationship between inflation and output can be established between inflation and output for Germany during the past 20 years. In doing so, various variable specifications have been examined. The functions with the best statistical properties are shown in Tables 10 and 11. The long-term coefficient for the output gap based on the ifo capacity utilisation is 0.23. Moreover, the assumption that the economic subjects' expectations have gradually adapted to their expected basic rate of inflation π^*, approximated by the Bundesbank's medium-term price assumption, proves to be superior to various other expectation formation hypotheses tested. According to the available results, the persistence of inflationary developments is comparatively high; adjustments are more or less completed only after about two years. The question of how far the equations specified here are suitable for inflation forecasts is examined in the next section.

III.4 Ex-post and ex-ante simulations

The forecasting properties of the inflation-output equation will be examined below. Since the inflation-output model with the GfK expectations is available only for a relatively short estimation period, and because, with that model, the GfK expectations would themselves have to be predicted for forecasts going beyond the observation period, the model specified in chapter III (Tables 10 and 11) is used for the forecast studies. This model has good statistical properties, as the investigations have shown. Furthermore, the analyses have confirmed the hypothesis that the actual expectations are modelled comparatively well by the assumed modified extrapolative expectation process. Finally, for forecasts beyond the end of the series, it is not necessary, using this approach, to forecast the expectations themselves since the expectations are modelled endogenously. Only the Bundesbank's medium-term price assumption would have to be specified using this method but this is generally known in advance.

Various simulations are carried out in order to obtain an impression of the forecasting properties which is as sophisticated as possible. Firstly, an ex-post (in sample) forecast is prepared. To do this, the forecasts are based on the equation that has been estimated over the entire investigation period. This method has only limited informative value for assessing the predictive quality since, in this approach, information is used at a given forecasting time which was not yet available at that point.[62] For that reason, supplementary ex-ante (out of sample) forecasts are calculated, too. To do this, the forecast equation is estimated only up to the forecasting date and the resulting parameters are used for the forecast. In other words, only that information is used which is actually available at the time of forecasting.[63] Finally, ex-ante forecasts are also calculated using an equation that is determined over a moving ten-year estimation period. All forecasts are dynamic, i.e. the previously forecast (and not the actually occurring) endogenous variables are used for the following periods. The actual values are inserted for the exogenous variables. If major errors occur in forecasting these variables, less accurate inflation forecasts are produced accordingly. The analyses are

[62] This is because all the observations of the investigation period are used for estimating the equation, i.e. including observations which go beyond the forecasting date.

[63] The sole exception is the assumption concerning the functional form, which is determined on the basis of the investigations over the entire observation period. Since this has a standard form which has already been discussed for a long while in the literature, this objection is not to be classified as significant.

carried out with a forecasting horizon of one and two years, since those periods of time are the most important ones for monetary policy.

The mean absolute error of prediction (MAE), the mean absolute percent error of prediction (PMAE), the root mean square error of prediction (RMSE), the matching percentage value of the RMSE (PRMSE), Theil's inequality coefficient (TU1) and the bias proportion (UM), regression proportion (UR) and the disturbance proportion (UD) of the mean square error of prediction and the correlation coefficient (COR) are used as test variables for assessing the forecast quality. The formulas for calculation are listed in Appendix B. It should be noted that the correlation coefficient does not take account of systematic biases. The percentage values PMAE and PRMSE are related to the average actual inflation rate. Theil's inequality coefficient states the error of the model forecast in relationship to the static forecast. It is zero if the simulated values match the observed values, and it is one if the model forecast is the same as the naive static forecast. Theil's inequality coefficient does not have an upper limit.[64] In studies, Theil's inequality coefficient is often broken down into a bias, variance and covariance component. This breakdown is not meaningful in certain cases, however, and, for that reason, use is made of the subdivision of the above-mentioned mean square error.[65] The bias component gives the share in this error that is attributable to the difference between the average forecast value and the average inflation rate. The regression component captures the share produced by the deviation of the slope of the regression from the actual values on the forecast values from one. Both these errors may be regarded as systematic errors, whereas the other coincidental influences are subsumed in the residual.

Tables 12 and 13 show the described test variables for different sub-periods. The definitions of the investigation periods for the out-of-sample estimations and the moving estimations are determined on statistical grounds, since a certain minimum number of observations is advisable for the estimations. The calculations are performed using both the functions based on quarter-on-quarter changes and on year-on-year changes in quarterly data, and with the output gap based on the ifo capacity utilisation and the output gap determined using the production function. Because the dynamic is revealed more clearly using the model in

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64 See Theil, H. (1966), pp. 26.
65 See Maddala, G.S. (1988), pp. 344.

preceding quarter differences and on account of the somewhat better results using the ifo output gap, only those results are presented here.

Table 12: One-year forecasts based on the inflation-output equation with modified extrapolative expectations (Table 10)[a]

	Ex-post forecast (in sample)			Ex-ante forecast (out-of-sample)		Ex-ante forecast with moving estimation
Period	1977Q1-1996Q4	1984Q1-1996Q4	1987Q1-1996Q4	1984Q1-1996Q4	1987Q1-1996Q4	1987Q1-1996Q4
MAE	0.390348	0.343434	0.322236	0.391440	0.372547	0.340795
PMAE	0.134328	0.159406	0.135850	0.181688	0.157060	0.143674
RMSE	0.491881	0.422884	0.384737	0.485481	0.451490	0.428173
PRMSE	0.169268	0.196283	0.162199	0.225338	0.190341	0.180511
TU1	0.148061	0.170134	0.145506	0.195318	0.170752	0.161934
UM	0.094893	0.326973	0.289322	0.202236	0.150873	0.121367
UR	0.012425	0.015288	0.074206	0.016915	0.049083	0.052736
UD	0.892682	0.657739	0.636472	0.780849	0.800045	0.825898
COR	0.957436	0.960961	0.964873	0.938200	0.938362	0.942906

a Calculated on the basis of annual inflation rates.

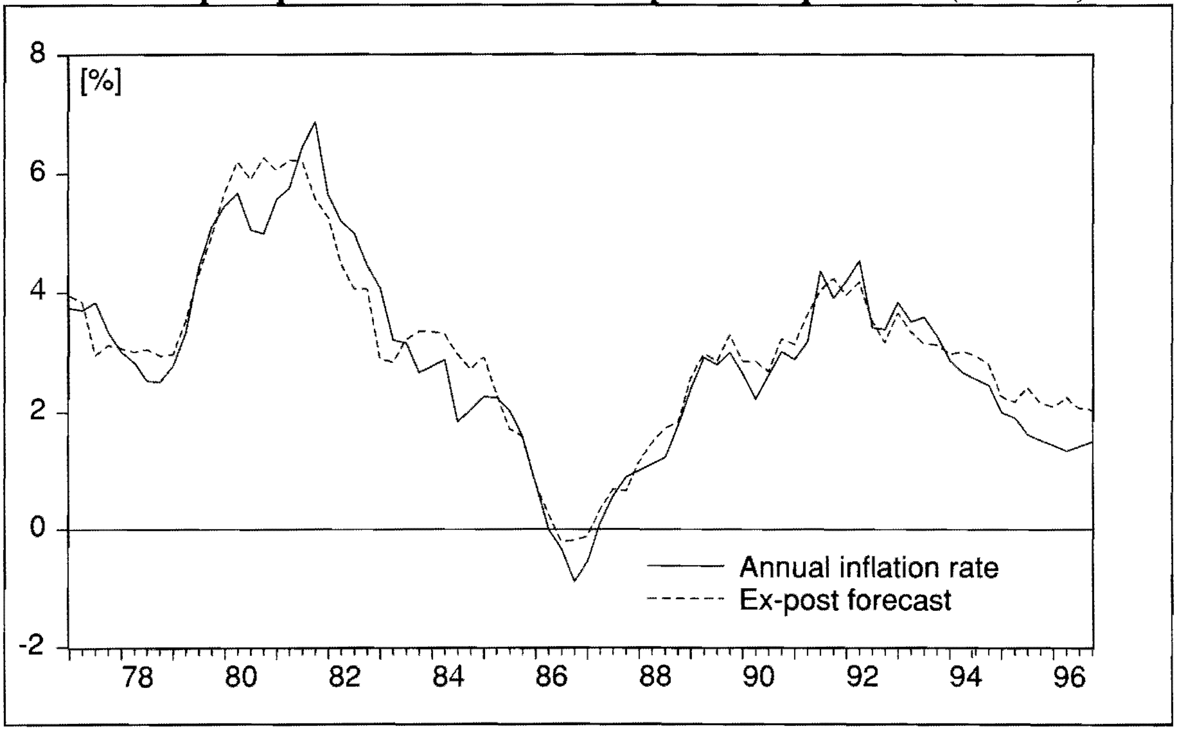
As was to be expected, the in-sample forecasts are somewhat better than the out-of-sample forecasts. The out-of-sample forecasts show a mean absolute error of 0.39 or 0.37, which corresponds to a percent error of 18 % or 16 %. The RMSE are slightly higher. At 0.19 and 0.16, Theil's inequality coefficients are close to zero. An additional positive feature is that the systematic error shares are comparatively small. The forecasts for the shorter and more recent period from 1987 are slightly better than those for the period from 1984. The two-year forecasts, with mean absolute percent errors of 22 % or 19 % and similar orders of magnitude for the other test variables, are not as good as the one-year forecasts. They are not markedly poorer, however, and therefore still have to be rated as good.

Table 13: Two-year forecasts based on the inflation-output equation with modified extrapolative expectations (Table 10)[a]

	Ex-post forecast (in sample)			Ex-ante forecast (out-of-sample)		Ex-ante forecast with moving estimation
Period	1978Q1-1996Q4	1984Q1-1996Q4	1987Q1-1996Q4	1984Q1-1996Q4	1987Q1-1996Q4	1988Q1-·1996Q4
MAE	0.392127	0.402198	0.377912	0.478561	0.454188	0.386424
PMAE	0.136795	0.186682	0.159322	0.222126	0.191478	0.148179
RMSE	0.493281	0.495666	0.460679	0.576858	0.524226	0.479920
PRMSE	0.172083	0.230066	0.194215	0.267751	0.221005	0.184031
TU1	0.149322	0.199416	0.174228	0.232081	0.198261	0.172628
UM	0.118017	0.459079	0.400792	0.372843	0.307727	0.275270
UR	0.013410	0.016100	0.077208	0.012565	0.071388	0.141600
UD	0.868572	0.524821	0.522000	0.614592	0.620885	0.583130
COR	0.960003	0.957120	0.958561	0.931071	0.935412	0.924823

a Calculated on the basis of annual inflation rates.

Figure 7: Annual inflation rate and one-year ex-post forecasts based on the inflation-output equation with modified extrapolative expectations (Table 10)



The graphs showing the actual and expected development of the inflation rate in Figures 7 and 8 confirm the previous analyses. Only the short-term slumps and peaks in 1984Q3, 1986Q4, 1990Q2 and 1992Q2 are not captured properly. Special influences, such as marked changes in raw material prices, occurred at those times, however, which cannot be modelled adequately by the inflation-output equation. The deviation in 1995 may partly be explained by the fact that the "coal penny" levy on electricity bills was abolished. On the whole, the forecasts show a good match with the actual inflation rate and the turning points are likewise predicted correctly in all cases.

Figure 8: Annual inflation rate and one-year ex-ante forecasts based on the inflation-output equation with modified extrapolative expectations (Table 10)

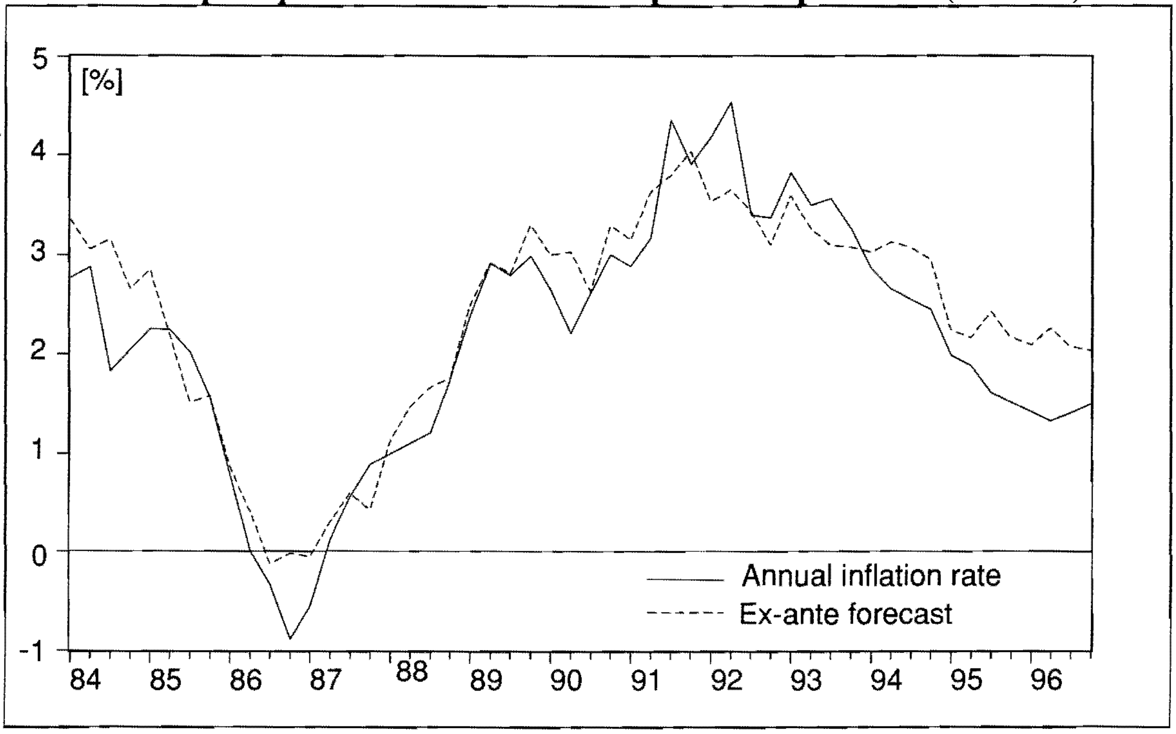


Table 14 shows a comparison of the documented results with the results based on the GfK expectations and the ZEW forecasts. The GfK expectations with mean percent errors of 31 % and a Theil inequality coefficient of 0.34 have errors which are roughly twice as high as the out-of-sample forecasts in Table 12. A comparison with the ZEW forecasts is not particularly meaningful since a comparison can be made only from the fourth quarter of 1992. For that period, the quality of the ZEW forecast - although it is only a half-year forecast - proves to be slightly poorer than that of the two other forecasts.

It should be noted that the forecasting properties of the inflation-output equation for Germany using the return-to-normality expectation formation approach must be rated as relatively good on the basis of the investigations so far. Nevertheless, the inflation-output equation can be regarded only as an instrument that supplements other forecasting approaches.

Table 14: Comparison of GfK expectations and the ZEW half-year forecast with the one-year forecasts based on the inflation-output equation with modified extrapolative expectations (Table 10)[a]

	GfK		Ex-ante forecast with inflation-output equation		ZEW
Period	1987Q1-1996Q4	1992Q4-1996Q4	1987Q1-1996Q4	1992Q4-1996Q4	1992Q4-1996Q4
MAE	0.731558	0.399481	0.372547	0.463263	0.532656
PMAE	0.308414	0.166649	0.157060	0.193257	0.222205
RMSE	0.897527	0.436840	0.451490	0.515153	0.564768
PRMSE	0.378383	0.182234	0.190341	0.214904	0.235601
TU1	0.339442	0.171621	0.170752	0.202388	0.221881
UM	0.204597	0.095986	0.150873	0.333864	0.669983
UR	0.001655	0.190190	0.049083	0.327760	0.000086
UD	0.793748	0.713824	0.800045	0.338376	0.329932
COR	0.729083	0.902260	0.938362	0.936713	0.925398

a Calculated on the basis of the annual inflation rates.

To improve the application of the forecast, there is - if necessary - the possibility of endogenising the exogenous variables in a further investigation, for which the inflation-output equation can be supplemented by a small structural model. Endogenisation of the output gap by modelling an aggregate demand function would be a possibility. Additionally, an exchange rate equation could be implemented. The external prices would continue to be specified exogenously for determining the import prices, however, as endogenising these variables would be too time-consuming. An interest rate equation and a yield curve equation could also be implemented to complete the model. Simulation studies could then be carried out using a small structural model of this kind, e.g. for determining the sacrifice ratio or, in general, on the implications of a disinflationary policy or for verifying various policy rules in the event of shocks occurring.

Finally, some aspects of a more general nature in connection with inflation forecasts should be mentioned. Firstly, there is the question of whether the general public's inflation expectations or forecasts should be adopted by central banks for their inflation forecasts. Woodford counters that by arguing that this can lead to instabilities in the relationship between changes in monetary policy and changes in the relationship between the information variables and the inflation rate, and vice versa. A further counterargument is put forward by Romer and Romer who have noted that central banks' forecasts are generally more accurate. Their conclusions are supported by the results in chapters III. and IV. with regard to consumers' price expectations.[66] Regardless of that, however, the economic agents' expectation formation should be taken explicitly into account in studies on inflation, as has been done here.

The implications of the Lucas criticism should also be noted. Although the Lucas criticism is tempered by the explicit modelling and inclusion of the expectation formation, major structural breaks in monetary policy would be reflected in changes in the inflation rate expected over the long term and possibly lead to changes in the adjustment parameters. A key role is played in this by the credibility of the central bank and/or the actual price assumption of the central bank expected by the economic agents. A major structural break of this kind might result from the introduction of EMU, all depending on how credibly the ECB can establish itself. In terms of the national inflation-output equations, the founding of EMU may produce not only changes in the expectation parameters, however, but also in the other coefficients. Thus, the coefficient of the import prices is likely to become lower, and the national coefficients of the output variables will approximate to each other in the long term, depending, for example, on what future wage negotiations in EMU will be like.[67] In the short term, however, the impact on the expectation variables and coefficients is of greater importance. The implications for the national equations will differ widely in their force, depending on the nature of the respective expectation formation process, how

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66 See Woodford, M. (1994), pp. 102, and Romer, C.D. and Romer, D.H. (1996). For a more accurate comparison, the previous analyses would have to be supplemented by forecast investigations which include the values of the exogenous variables forecast at the respective points in time.

67 In an extreme case, the entire relationship might collapse.

credible the central bank was previously and, for example, how high the respective national share of imports was. Overall, however, a convergence of the coefficients is to be expected.

V. Summary and outlook

The present paper has attempted to analyse and specify the relationship between inflation and output in Germany taking particular account of the role played by expectation formation. For the first time in Germany the explicit expectations of the economic agents gained from surveys have been used for determining inflation expectations.

The analysis of those (directly captured) expectations of the economic agents has shown that the rational expectation hypothesis must be rejected for the economic agents' expectation formation. Expectation formation is not purely extrapolative in nature either, however, but may be explained instead by a modified or extended extrapolative process that is partially forward-looking. Accordingly, the economic agents form expectations through a basic inflation rate, which has been modelled approximately here by the Bundesbank's medium-term price assumption, and they expect the actual inflation rate to adjust to it over a given time horizon. This produces the extrapolative element in expectation formation. However, it should be pointed out that, although the analysis is based on a period of 44 quarters (1986-1996), only one upswing and one downswing phase as well as one period of consolidation in the inflationary trend occurred during that time. That is perhaps not entirely adequate for a precise specification of the expectation formation process. Further studies are therefore advisable as soon as the data for the period before 1986 become available.

The estimated inflation-output equation with the modified extrapolative expectation formation process, which was derived from the survey data, shows good statistical properties. The relationship is stable, as the various recursive estimations and further examinations have shown, and it can be demonstrated that the output gap has a significant and stable influence on the trend of inflation. It is only possible to speculate on the extent to which this relationship will be affected by the changeover to EMU. Depending of the ECB's credibility, however, the expectation parameters will be particularly affected initially.

Above and beyond that, what is significant in monetary policy terms is the persistence in the trend of inflation indicated by the analysis - with adjustments of up to two years. This persistence makes early identification and appropriate early action by the central bank desirable given increasing inflationary tendencies. A crucial role in this is played by the price assumption and thus by the central bank's credibility as an anchor of expectation formation.

Finally, the suitability of the inflation-output equation for inflation forecasts and simulation studies is of importance from a monetary policy perspective. Using a series of models based on different methods and philosophies is advisable for the analysis because of the complexity of the economic relationships and the broad range of economic issues which arise in connection with monetary policy measures. The inflation-output equation calculated here can be understood as a possible approach to this. The ex-post and ex-ante simulations show good forecasting properties overall, especially in comparison with the economic agents' inflation expectations that are captured directly. A comparison with the ZEW forecast appears to confirm this result.

Appendix A

Derivation of the conversion of qualitative expectations into quantitative expectations

On the basis of equations (8) and (9) as well as the comments made in section II.2, the following is produced as an equivalent for the five-category case:

$$W(\rho_{t+1} \leq -\delta_t \mid \Omega_t) = F_t(-\delta_t) = {}_tA_{t+1}$$
$$W(-\delta_t < \rho_{t+1} \leq \delta_t \mid \Omega_t) = F_t(\delta_t) - F_t(-\delta_t) = {}_tB_{t+1}$$
$$W(\delta_t < \rho_{t+1} \leq \pi'_t - \varepsilon_t \mid \Omega_t) = F_t(\pi'_t - \varepsilon_t) - F_t(\delta_t) = {}_tC_{t+1}$$
$$W(\pi'_t - \varepsilon_t < \rho_{t+1} \leq \pi'_t + \varepsilon_t \mid \Omega_t) = F_t(\pi'_t + \varepsilon_t) - F_t(\pi'_t - \varepsilon_t) = {}_tD_{t+1}$$
$$W(\rho_{t+1} > \pi'_t + \varepsilon_t \mid \Omega_t) = 1 - F_t(\pi'_t + \varepsilon_t) = {}_tE_{t+1} \qquad \text{and}$$

(A1) $$W(\rho_{t+1} \leq -\delta_t \mid \Omega_t) = F_t(-\delta_t) = {}_tA_{t+1}$$

(A2) $$W(\rho_{t+1} \leq \delta_t \mid \Omega_t) = F_t(\delta_t) = {}_tA_{t+1} + {}_tB_{t+1}$$

(A3) $$W(\rho_{t+1} \leq \pi'_t - \varepsilon_t \mid \Omega_t) = F_t(\pi'_t - \varepsilon_t) = {}_tA_{t+1} + {}_tB_{t+1} + {}_tC_{t+1}$$

(A4) $$W(\rho_{t+1} \leq \pi'_t + \varepsilon_t \mid \Omega_t) = F_t(\pi'_t + \varepsilon_t) = {}_tA_{t+1} + {}_tB_{t+1} + {}_tC_{t+1} + {}_tD_{t+1}.$$

If the logistic cumulative density function $F_L(x)$ is now taken for $F(x)$:

$$F_L(x) = 1 / (1 + \exp(-(x-\alpha)/\beta)),$$

with α = mean value of x, β = scale parameter and exp = exponential function

and inserted into equation (A1) with $\alpha = \pi^e_{t+1}$, then

$$F_L(-\delta_t) = 1 / (1 + \exp(-(-\delta_t - \pi^e_{t+1})/\beta))$$
$$\Leftrightarrow \quad (-\delta_t - \pi^e_{t+1})/\beta = \log(F_L(-\delta_t) / 1 - F_L(-\delta_t))$$
$$\Leftrightarrow \quad (-\delta_t - \pi^e_{t+1})/\beta = \log({}_tA_{t+1} / 1 - {}_tA_{t+1})$$

These conversions are likewise performed for equations (A2) to (A4):

(A5) $$(-\delta_t - \pi^e_{t+1}) / \beta = a_t$$

(A6) $$(\delta_t - \pi^e_{t+1}) / \beta = b_t$$

(A7) $$((\pi'_t - \varepsilon_t) - \pi^e_{t+1}) / \beta = c_t$$

(A8) $$((\pi'_t + \varepsilon_t) - \pi^e_{t+1}) / \beta = d_t$$

with
$$a_t = \log({}_tA_{t+1} / (1 - {}_tA_{t+1}))$$
$$b_t = \log(({}_tA_{t+1} + {}_tB_{t+1}) / (1 - ({}_tA_{t+1} + {}_tB_{t+1})))$$
$$c_t = \log(({}_tA_{t+1} + {}_tB_{t+1} + {}_tC_{t+1}) / (1 - ({}_tA_{t+1} + {}_tB_{t+1} + {}_tC_{t+1})))$$
$$d_t = \log(({}_tA_{t+1} + {}_tB_{t+1} + {}_tC_{t+1} + {}_tD_{t+1}) / (1 - ({}_tA_{t+1} + {}_tB_{t+1} + {}_tC_{t+1} + {}_tD_{t+1})))$$

Equation (A5) solved after δ and inserted into (A6), gives:

(A9) $$\beta = - 2\,\pi^e_{t+1} / (a_t + b_t)$$

Equation (A7) solved after ε_t and inserted into (A8), gives:

(A10) $$d_t = ((\pi'_t + \pi'_t - \pi^e_{t+1} - c_t \cdot \beta) - \pi^e_{t+1}) / \beta$$

Equation (A9) inserted into (A10) and solved after π^e_t, gives

(A11) $$\pi^e_{t+1} = \pi'_t \cdot (a_t + b_t) / (a_t + b_t - c_t - d_t)$$

The empirical survey data are used for deriving π'_t, the mean perceived inflation, over the last 12 months. Again, on the basis of equations (8) and (9) as well as the comments made in section II.2, the following is produced:

$$W(\rho'_{t+1} \leq -\delta'_t \mid \Omega_t) = F_t(-\delta'_t) = {}_tA'_{t+1}$$
$$W(-\delta'_t < \rho'_{t+1} \leq \delta'_t \mid \Omega_t) = F_t(\delta'_t) - F_t(-\delta'_t) = {}_tB'_{t+1}$$
$$W(\delta'_t < \rho'_{t+1} \leq \pi^m_t - \varepsilon'_t \mid \Omega_t) = F_t(\pi^m_t - \varepsilon'_t) - F_t(\delta'_t) = {}_tC'_{t+1}$$
$$W(\pi^m_t - \varepsilon'_t < \rho'_{t+1} \leq \pi^m_t + \varepsilon'_t \mid \Omega_t) = F_t(\pi^m_t + \varepsilon'_t) - F_t(\pi^m_t - \varepsilon'_t) = {}_tD'_{t+1}$$
$$W(\rho'_{t+1} > \pi^m_t + \varepsilon'_t \mid \Omega_t) = 1 - F_t(\pi^m_t + \varepsilon'_t) = {}_tE'_{t+1}$$

Following similar conversions to those above, it follows:

(A12) $$\pi'_t = \pi^m{}_t \cdot (a'_t + b'_t) / (a'_t + b'_t - c'_t - d'_t)$$

with
$$a'_t = \log({}_tA'_{t+1} / (1 - {}_tA'_{t+1}))$$
$$b'_t = \log(({}_tA'_{t+1} + {}_tB'_{t+1}) / (1 - ({}_tA'_{t+1} + {}_tB'_{t+1})))$$
$$c'_t = \log(({}_tA'_{t+1} + {}_tB'_{t+1} + {}_tC'_{t+1}) / (1 - ({}_tA'_{t+1} + {}_tB'_{t+1} + {}_tC'_{t+1})))$$
$$d'_t = \log(({}_tA'_{t+1} + {}_tB'_{t+1} + {}_tC'_{t+1} + {}_tD'_{t+1}) / (1 - ({}_tA'_{t+1} + {}_tB'_{t+1} + {}_tC'_{t+1} + {}_tD'_{t+1})))$$

Here, π^m designates the moderate rate of inflation which represents the respondents' best guess at the permanent or trend rate of inflation. As a suitable approximation for a specification, Batchelor and Orr suggest (on the assumption of unbiasedness) the average value of the actual rate of inflation over the observed period and assume the inflation rate determined in this way corresponds to the moderate rate of inflation. A more accurate modelling of the moderate rate of inflation would be possible if quantitative survey data were available for a given time horizon in addition to the qualitative survey figures.[68]

The standard deviation of the logistic distribution is defined as:

(A13) $$\sigma = \beta \cdot \Pi / 3^{1/2}, \qquad \text{mit } \Pi = 3{,}1415926...$$

After inserting (A9) and (A11) into (A13), this produces the standard deviation of the inflation expectations:

(A14) $$\sigma_t = -2 \cdot \Pi \cdot \pi'_t / 3^{1/2} \cdot (a_t + b_t - c_t - d_t)$$

[68] See Batchelor, R.A. and Orr, A. (1988), p. 322.

Appendix B

Definition of the test statistics for the quality of the forecast

Correlation coefficient:

$$COR = Var(A_t, P_t) / [Var(A_t, A_t) \cdot Var(P_t, P_t)]^{1/2}$$

Mean absolute error of prediction:

$$MAE = \sum_{t=1}^{T} |A_t - P_t| / T$$

Mean absolute percent error of prediction:

$$PMAE = MAE / \sum_{t=1}^{T} A_t / T$$

Mean square error of prediction:

$$MSE = \sum_{t=1}^{T} (A_t - P_t)^2 / T$$

Root mean square error of prediction:

$$RMSE = \left[\sum_{t=1}^{T} (A_t - P_t)^2 / T \right]^{1/2}$$

Percentage value of the root mean square error of prediction:

$$PRMSE = RMSE / \sum_{t=1}^{T} A_t / T$$

Theil's inequality coefficient

$$TU1 = \left[\sum_{t=1}^{T} (A_t - P_t)^2 / \sum_{t=1}^{T} A_t^2 \right]^{1/2}$$

Bias component of the mean square error of prediction

$$UM = \left[\sum_{t=1}^{T} A_t / T - \sum_{t=1}^{T} P_t / T \right]^2 / MSE$$

Regression component of the mean square error of prediction:

$UR = [Var(P_t, P_t)^{1/2} - COR \cdot Var(A_t, A_t)^{1/2}]^2 / MSE$

Disturbance component of the mean square error of prediction

$UD = (1 - COR^2) \cdot Var(A_t, A_t) / MSE$

Where A = actual value

P = predicted value

T = number of observations

Var = variance

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