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Predicting Inflation in Euroland —
The Pstar Approach

by
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Abstract:

Inflation is a monetary phenomenon. While this statement is widely accepted in terms of a long-run relationship, the quantity theory has been made operational also for the short-run dynamics of inflation by so-called Pstar models. An error correction model with quarterly data for the Euro Area is estimated to test whether the price gap has an impact on consumer price inflation. The response of the HICP is strongly positive. Other factors such as raw material prices and unit labor costs also have some explanatory power. The model is used for shock analysis and out-of-sample forecasts. All in all, the Pstar model can be a useful tool for predicting inflation also in Euroland.

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1   Introduction

Inflation forecasts are important not only for central banks but also for business cycle analysis. Recently, the European Central Bank (ECB) published forecasts for inflation and output in the Euro Area (ECB 2000). It followed the example of various other central banks which have been doing this on a regular basis for some years now as part of their strategy of inflation targeting.

It is interesting to note that the money stock M3 does not play a role in the forecasts although it has a "prominent role" in the strategy of the ECB. While this may seem awkward, it has become common practice to ignore the development of M3 growth and concentrate on other variables such as the output gap or a variety of cost factors when discussing the prospects for inflation. As far as monetary policy variables are concerned, the short-term interest rate is usually included in the information set. This procedure is probably based on specific models in which the money stock becomes irrelevant given certain assumptions about the effects of interest rate changes on output and inflation.[1]

In the present paper, we pick up again the idea developed by Hallman, Porter and Small (1991) who introduced a model in which money does play an important role for inflation even in the short term. In the so-called Pstar model, which is based on the quantity theory, changes in the money stock determine the equilibrium path of the price level to which the actual price level has to adjust. This approach is attractive as it is compatible with many different types of macro models which imply that there is no immediate adjustment of the price level to changes

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[1]   See Baltensperger (2000) for a critical view on such models by Svensson.

in money while, at the same time, having the property of the long-run neutrality of money.

While the price gap plays an important role in this model, it cannot be denied that current inflation is influenced by a number of other factors such as oil prices. Since we want to construct a model which can be used for short-term inflation forecasts, we also estimate the effects of such variables.

The organization of the paper is as follows: In section 2 we describe the Pstar model and its implications. The next section deals with the empirical implementation for the Euro Area; we test for the properties of the quarterly data, estimate the model and apply it to shock analyses and out-of-sample forecasts. Policy conclusions are given in section 4.

2 The model

2.1 The long-run relationship

The starting point for deriving the Pstar model is the quantity equation (all variables are expressed as logs):

$$m_t + v_t \equiv p_t + y_t \tag{1}$$

where m is the money stock, v is velocity, p is the price level, and y is real output. This identity must hold in the short- as well as in the long-run. The definition of p^* is:

$$p_t^* \equiv m_t + v_t^* - y_t^* \tag{2}$$

with the equilibrium velocity v_t^*, the equilibrium price level p_t^*, and potential output y_t^*. For given equilibrium values of y and v, which are assumed to be independent of m, the equilibrium price level is completely determined by money. Combining Equations (1) and (2), one can define the price gap as the sum of the output gap and the velocity gap[2]:

$$\left(p_t^* - p_t\right) = \left(y_t - y_t^*\right) + \left(v_t^* - v_t\right). \tag{3}$$

If p_t^* and p_t are cointegrated, the actual price level will, in the long run, equal its equilibrium value. In the short run, there may be differences which will, however, disappear over time: A positive price gap $\left(p_t^* > p_t\right)$ will result in an acceleration of inflation to bring p_t closer to p_t^* and vice versa. This adjustment process is visualized in Figure 1. Up to time t', p_t and p_t^* are the same and rise with a certain rate. An acceleration of monetary expansion at time t' — by, say, two percentage points — will lead to a two percent higher growth rate of p^*. It is generally assumed that prices do not adjust instantaneously which results in a price gap at date t''. But this gap has to vanish in the long run, which means p_t has to rise faster than p_t^* for a while. This concept of the price gap can be exploited for a forecast of the dynamics of inflation, i.e. one can use the available information at time t'' and the following periods. Of course, the speed of adjustment may vary over time depending, for example, on the way expectations are formed — in other words: the Lucas critique is certainly relevant here. We can assume, however, that the policy regime did not change too much over time;

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[2] This expression was derived by Hallman, Porter and Small (1991). Humphrey (1989) summarizes the precursors of this approach starting, of course, with David Hume.

nevertheless, we are also testing for parameter stability in order to avoid big mistakes.

Figure 1: The effect of a permanent money supply shock on the price level
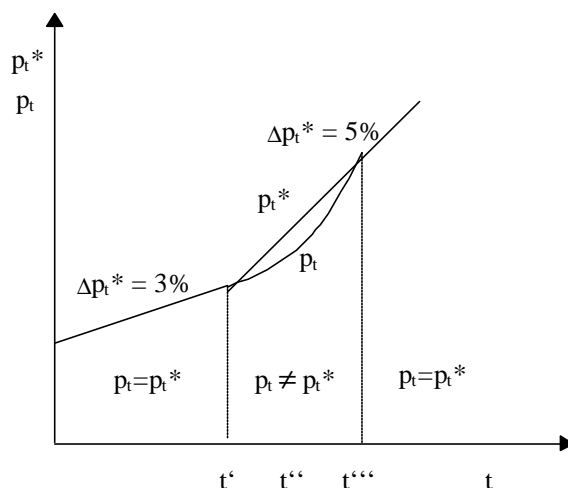
2.2 Inflation dynamics

Gerlach and Svensson (2000) assume the following dynamic relation between the inflation rate and the price gap (for quarterly data):

$$\Delta p_t = \Delta p_{t-1}^* + \left(p_{t-1}^* - p_{t-1} \right) + \Delta z_{t-1} + u_t, \tag{4}$$

where Δp_t is the change of the price level, Δp_{t-1}^* the one period lagged change of the equilibrium price level, and Δz_{t-1} is the lagged change of an exogenous cost variable that influences inflation as well. Equation (4) implies that inflation is modeled in an error correction framework. Including the equilibrium price level allows us to capture additional inflationary pressure in the case that the price gap

remains constant but the slope of both the actual and equilibrium price level steepens[3].

In contrast to the effect of an increased money stock, the effect to shocks to the exogenous variables (z_t) are assumed to have only temporary effects. For example, if oil prices increase, p_t^* will not be affected; as a consequence, a higher actual price level due to higher oil prices will result in a negative price gap and less inflationary pressure in the future[4].

3 Empirical results

3.1 The data

We use quarterly, seasonally adjusted data from the first quarter of 1980 to the third quarter of 2000[5]. Real GDP (in prices of 1995) is calculated backwards for the period prior to 1991. As the price variable, we use the harmonized consumer price index (HICP), and inflation is defined as the change of this price level against the previous quarter. We use M3 as the monetary aggregate since it is also the variable for which the ECB defines a reference value; besides, previous studies have shown quite a good quality of this indicator for inflation (e.g. Krämer and Scheide 1994). To generate equilibrium values for output and ve-

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[3] Imagine an additional increase of p^* at time t''. If inflation accelerates, the price gap remains the same compared to the reference scenario. This means that the price gap does not reflect any additional inflationary pressure but Δp_{t-1}^* does.

[4] This is the case if the central bank does not accommodate the cost increase. In part, this describes the situation in the year 2000 when inflation picked up because of higher oil prices and the depreciation of the euro; in the course of 2000, money growth decelerated.

[5] See the appendix for a detailed description of the data and their sources.

locity, we apply a Hodrick-Prescott filter to the respective series. The equilibrium values are smooth, not linear and with minimalized seasonality. The model should also be able to account for short-term effects on the price level that are not caused by changes money. We will include the spot market prices for oil, and the HWWA index for raw material prices[6]. As both indices are stated in US dollars, there is an implicit proxy for the exchange rate; nevertheless, we add the nominal effective exchange rate of the euro (for a narrow group) to the analysis. It is tested whether this variable has additional explanatory power or causes only a bias to the estimators. To account for another important cost effect we include nominal unit labor costs in our model[7].

3.2 Deriving the price gap

There are two main methods for calculating the price gap:

- A long-run money demand function is estimated in which the price gap is just the residual[8].

- The equilibrium values of output and velocity are calculated which are used to define the price gap according to Equation (3).

There are several ways to measure potential output, and many institutions are providing estimates. The equilibrium velocity can be calculated in various ways.

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[6] We use the index without energy in order to avoid the problem of multicollinearity.

[7] This series was taken from the OECD; as it only available on an annual basis, we interpolated the data to get quarterly observations.

[8] See Deutsche Bundesbank (1992).

For example, Tödter and Reimers (1994) propose to model a long-run money demand function. When estimating the function

$$m_t - p_t = \boldsymbol{b}_1 + \boldsymbol{b}_2 y_t^* + u_t \tag{5}$$

we found that the residual is not really a driving force in the inflation process. Suggestions to derive other money demand functions with opportunity costs included[9] were rejected since we want to provide a tool to forecast inflation in Euroland. As we are interested in a conditional forecast for inflation, we restrict ourselves to a parsimonious set of assumptions and thus exclude the interest rate spread.

The second approach is more fruitful for our purposes. We apply the Hodrick-Prescott filter to both time series output and velocity. That is consistent as we can control for short-run fluctuations without forcing a linear or a quadratic trend on the data. Equation (3) is then used to calculate the price gap. Figure 2 shows that this variable seems to explain the ups and downs of inflation quite well. A negative price gap in the mid 1980s and late 1990s corresponds to decreasing inflationary pressure; a positive gap as observed in the late 1980s and in 1999/2000 signals a rise of inflation in the future.

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[9] Such a specification is used by Coenen and Vega (1999), and Lütkepohl and Wolters (1999).

Figure 2: Price gap and inflation (quarterly changes of the HICP)
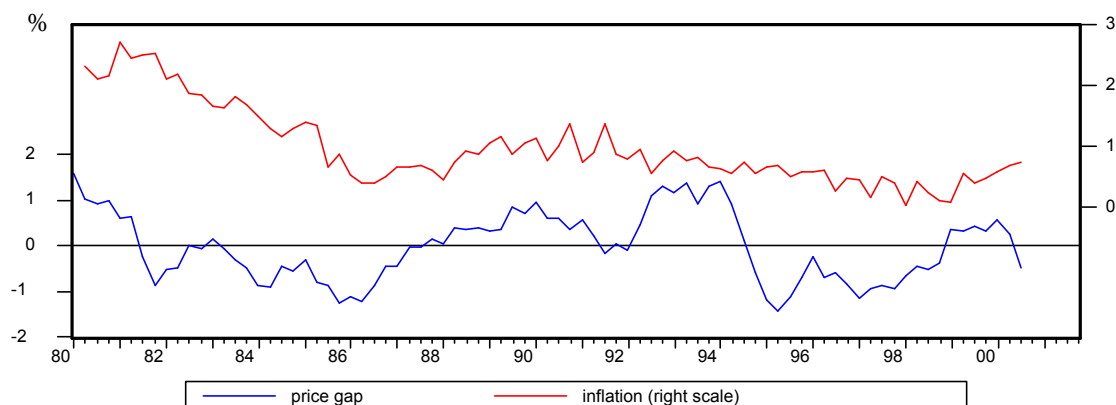
This result is supported by tests for Granger causality (Table 1). As expected, inflation has no additional information for the future price gap. In contrast, the price gap significantly helps to predict inflation in the next period.

Table 1: Granger causality tests

Null hypothesis:	F-Statistic	Probability
Inflation does not cause the price gap	0.9686	0.3280
Price gap does not cause inflation	5.665	0.0197

There is, however, one period in which the postulated relationship does not hold: Between 1992 and 1994, inflation decelerated in spite of a positive price gap. At that time, the output gap was negative due to the recession in the countries of the Euro Area. By definition, there must have been a sizable velocity gap (Figure 3). M3 increased at that time by more than 7.5 percent, whereas nominal GDP rose a lot less. The reasons for the decline of velocity may not be fully understood. Possible explanations are that this was related to the crisis in the EMS, the uncertainty about the business cycle outlook, and a negative term structure of interest rates (Figure 4) that led to shifts from long-run financial assets into M3. We control for that irregularity — that occurred only once in the whole sample

— by introducing a step dummy which is one in the period 1992:3 up to 1994:3 and zero elsewhere.

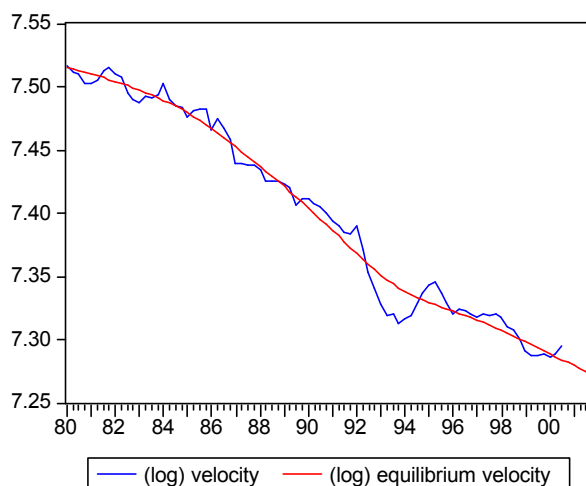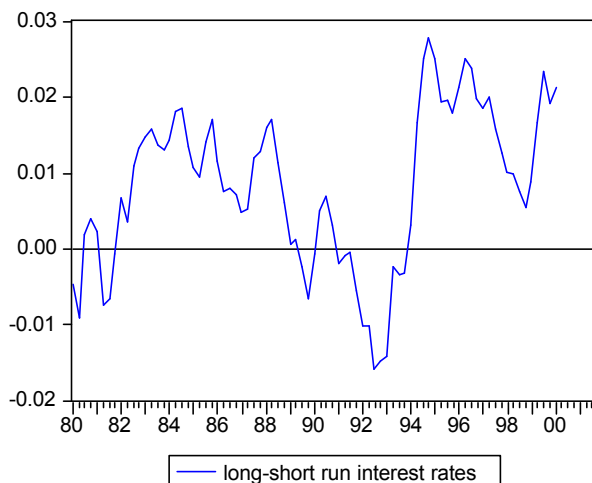*Figure 3:* Velocity and equilibrium velocity

Figure 4: Spread between long- and short-run interest rates

3.3 Testing for stationarity

Following the methodology of the model, we allow for short-run deviations of the price level from its equilibrium value but postulate that p_t and p_t^* are cointegrated — in other words: the difference between both must be stationary. The

dependent variable in the model is Δp_t, and in order to avoid the spurious regression problem it must be ensured that all explanatory variables have the same degree of integration.

Table 2: Tests of non-stationarity

Variable	ADF	Phillips-Perron
Δp_t	-3.05**	-2.27
$\left(p_t^* - p_t\right)$	-3.19***	-2.86***
$\Delta petrolp_t$	-4.97***	-7.85***
$\Delta rawp_t$	-4.57***	-5.01***
$\Delta exch_t$	-4.17***	-7.37***
Δulc_t	-3.53**	-3.32*

Note: We used Augmented Dickey-Fuller (ADF) and Phillips-Perron tests with intercept in the test regression for Δp_t, intercept and trend for Δulc_t and none for the remaining variables. *, **, *** denotes rejection of a unit root at the 10, 5 or 1 percent significance level. The variables are defined as follows: Δp_t – quarterly changes of consumer prices; $\left(p_t^* - p_t\right)$ – price gap; $\Delta petrolp_t$ – quarterly changes of oil prices; $\Delta rawp_t$ – quarterly changes of raw material prices (excl. energy); $\Delta exch_t$ – quarterly changes of the effective exchange rate of the euro; Δulc_t – quarterly changes of nominal unit labor costs.

In Table 2, all variables are listed that will enter in our final equation. We do not present the statistics for the levels of the variables because they are monotone rising functions. According to the Augmented Dickey-Fuller tests, the degree of integration is one for all series. Only for the inflation rate, the result is ambiguous in terms of the two test procedures: While the ADF test rejects the null hypothesis of a unit root at the 5 percent level, the Phillips-Perron test rejects this

only at a significance level around the 20 percent quantile. We decided to give more weight to the ADF results and assume inflation to be an I(0) process.[10]

3.4 The error correction model

As described above, we set up an error correction model (ECM) to explain inflation[11]. The price gap works as the long-run relationship, and other variables are added to the regression to capture the short-run dynamics.

Following the general to specific selection strategy (Gilbert 1987), the following relationship shows the best results (t-values in parentheses):

Box 1: Regression results — Equation (6)

$$\Delta p_t = \underset{(4.37)}{0.0014} + \underset{(8.14)}{0.54}\,\Delta p_{t-3} + \underset{(2.92)}{0.19}\,\Delta p_{t-5} + \underset{(5.85)}{0.18}\,pgap_{t-1} + \underset{(3.47)}{0.0043}\Delta petrolp_{t-1}$$

$$+ \underset{(4.19)}{0.016}\,\Delta rawp_{t-4} + \underset{(2.31)}{0.009}\,\Delta rawp_{t-6} + \underset{(2.59)}{0.10}\,\Delta ulc_{t-1} - \underset{(-4.9)}{0.031}\,\Delta exch_{t-1}$$

$$- \underset{(-4.0)}{0.0026}\,D_{92:3-94:3} + u_t$$

(adj.)R^2=0.93; SEE=0.001365; RMSE=0.001331; F-statistic=108.98 [0.00000];
JB=0.43[0.81]; LM(1)=0.93[0.34]; LM(2)=0.49[0.61]; LM(4)=1.34[0.26]; LM(8)=1.28[0.27];
ARCH(1)=1.00 [0.32]; ARCH(2)=0.36[0.70]; ARCH(4)=1.08 [0.37]; WHITE=1.46[0.14];
RESET1=4.77[0.03]; RESET2=2.36[0.10]; CHOW(93:3)=0.51[0.88]; T=76; sample 1981:4 - 2000:3.

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[10] This result is not unusual if compared to other studies.

[11] See Engle and Granger (1987).

According to Equation (6), inflation depends on lagged inflation, the price gap and on lagged exogenous cost variables. The loading coefficient of the price gap is quite high[12]. It implies that a price gap of one percent today leads to almost 0.2 percent more inflation tomorrow (i.e. in the next quarter). Oil prices, unit labor costs and exchange rates enter the equation with lag 1[13]. It is interesting that lagged inflation as well as raw material prices are entering the relationship with lags not smaller than 3. Obviously, it takes time to translate increases in raw material prices into inflation whereas this is not the case for the oil price. Furthermore, the change in the equilibrium price level $\left(\Delta p_{t-1}^{*}\right)$ does not seem to play a role; contrary to expectations and also to Equation (4), it turns out that this regressor is insignificant. Most of the *t*-values are very high, this is true in particular for the price gap, and the fit is quite good (Figure 5). The general structure of the equation implies that inflation depends only on lagged endogenous and on exogenous variables. It is the main idea of this paper that conditional out-of-sample forecasts should be made quite easily and that we should be able to detect turning points with relatively high precision because of the leading indicator property of the price gap.

Figure 6 shows that the model is able do replicate the inflation process quite well. A dynamic n-step forecast[14] from 1981:4 to 2000:3 comes close to the true values in most of the cases.

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[12] It is considerably higher than the coefficients Tödter and Reimers (1994) and Krämer and Scheide (1994) found for Germany.

[13] The problem of multicollinearity can be neglected because the additional regressor exchange rate does not change the coefficients of the other variables. Moreover, the introduction reduces the absolute value of the constant.

[14] The model generates forecasts from a starting point *t* and takes the forecasted value to predict period *t+1*.

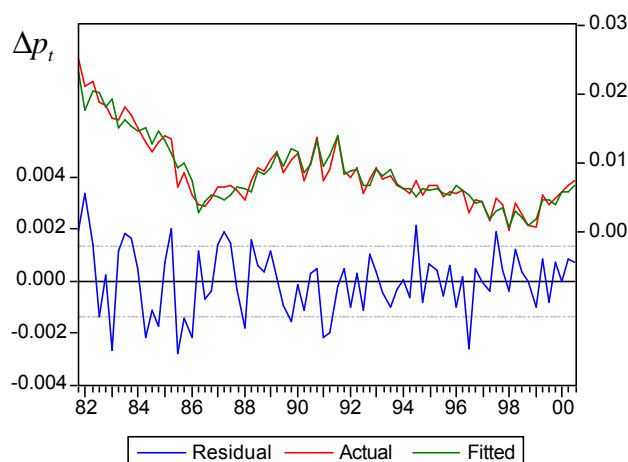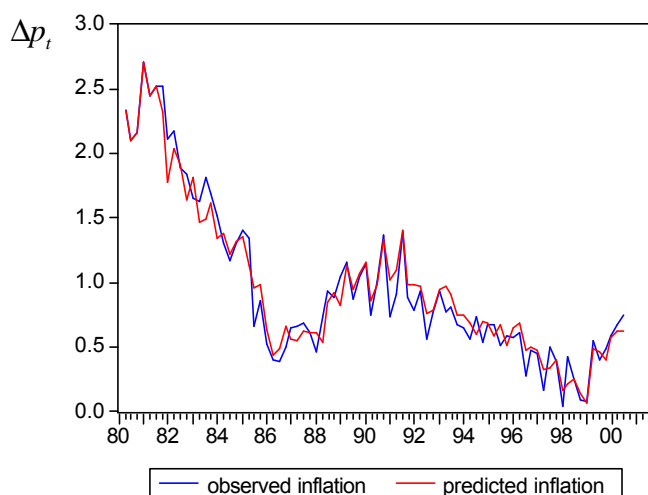*Figure 5:* Residuals, actual and fitted values of Equation (6)

Figure 6: Dynamic-in-sample forecast of Δp_t from 1981:4 to 2000:3 in percent


3.5   Stability properties

In order to evaluate the stability of the model, we analyze the stability of the specific regressors and the residual behavior if the model is estimated recursively. For this purpose, we look the recursive coefficients, the CUSUM and CUSUM SQUARES tests and the recursive residual results. The number of the recursive coefficient corresponds to the order they appear in the regression (Equation (6)).

*Figure 7:* Recursive coefficients, CUSUM Tests and recursive residuals
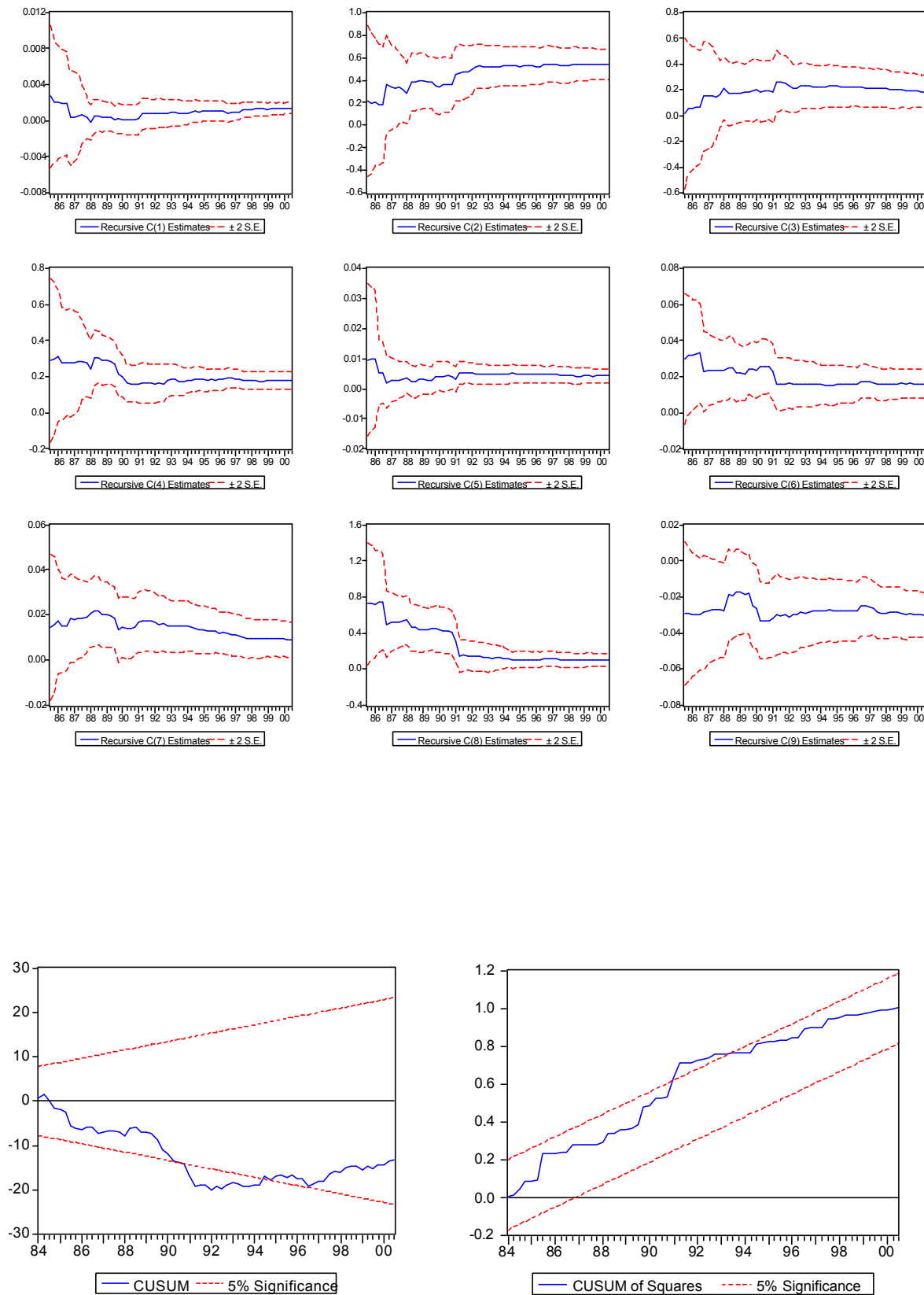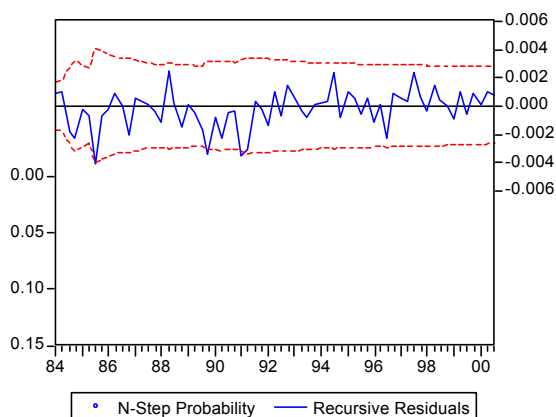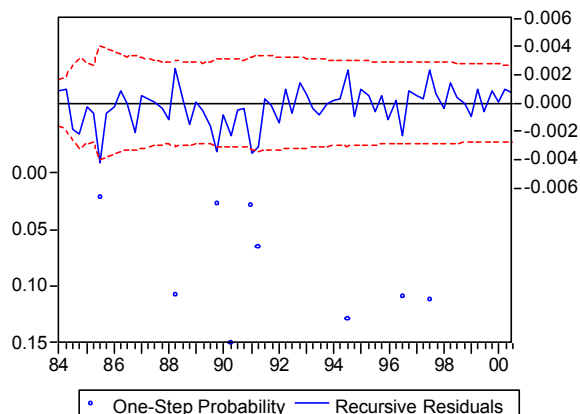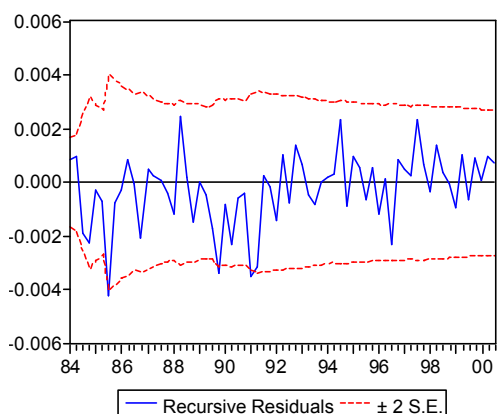
The recursive coefficients show a relatively fast convergence to their final values. The CUSUM test and the CUSUM SQUARES test reject the hypothesis of a stable model at the 5 percent significance level for the period around 1992, but it is obvious that the model is stable at the 10 percent significance level; also, the null hypothesis of having only one model cannot be rejected. The recursive residuals as well as their one step and n-step probability of being an outlier are satisfactory regarding model stability. The CHOW test for a structural break at 1993:3 indicates that the inclusion of the dummy variable is useful.

3.6   Shock analysis

In this section, we check how inflation responds to shocks in the money stock and/or in short-run variables from the real side of the economy. According to the quantity theory on which the Pstar model is based, only changes in m, y_t^* and v_t^* can alter the equilibrium price level p_t^*; all other variables are restricted to have only temporary effects on inflation. In order to check whether our model is in line with this hypothesis, we raise the values of each variable by one percent over the whole sample to model a permanent shock; the new path of the simulation is then compared to the results in the baseline. It turns out that a permanent increase of M3 by one percent raises the price level by one percent in the long run, and that the adjustment is characterized by fluctuations around the new equilibrium (Figure 8). Also, the results for permanent shocks in unit labor costs, oil prices, raw material prices and the exchange rate are plausible. Higher labor costs and higher oil prices lead to transitorily higher inflation. As we assume that the central bank does not accommodate the demand for more money, so that p_t^* remains unchanged. In the Pstar model, this implies that the higher actual price level produces a negative price gap which in turn will lead to less inflationary pressure in the future, i.e. inflation will be lower so that in the long run, p_t^* and p_t are again equal. It is interesting that the price level shows a peak at roughly the same time for all short-run variables. This phenomenon can be explained by the lag structure of the model.

Figure 8: Responses of the price level (in percent) to one percent permanent innovations to the model variables
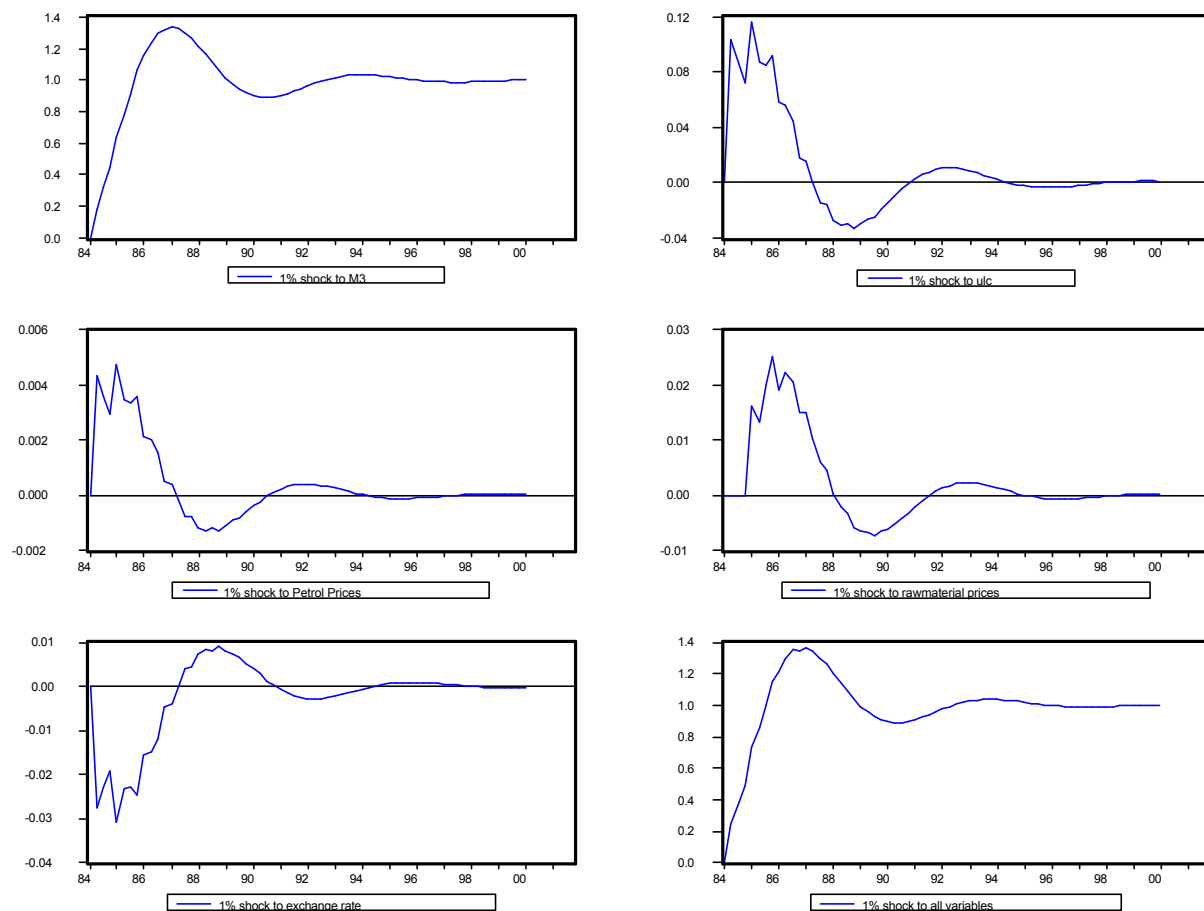

3.7 Out-of-sample forecast

After we have checked the in-sample properties of the model, we now turn to a true out-of-sample prediction. The latest observed values are available for the third quarter of 2000. For all explanatory variables, we use the assumptions made in December 2000 by the Kiel Institute of World Economics (Gern et al. 2000). For example, it is assumed there that money growth will be 5 percent until the end of 2001. One main target of this paper was to develop a model that is able to predict inflation with parsimonious assumptions. The in-sample forecasts have shown that if the assumptions are correct, the model is able to replicate the

inflation process. Our linear unbiased estimator should also be able to deliver unbiased conditional forecasts.

According to Equation (1), we need an assumption about equilibrium velocity in the forecast period. We forecast this relatively smooth time series by an ARIMA model which delivers almost the same results as those reported by the ECB, i.e. equilibrium velocity decreases by about one percent per year. The out-of-sample forecast procedure is to predict the HICP for period t using the inflation Equation (6). With that estimate we can compute the price gap at time t and are able to predict inflation and the HICP for time $t+1$ and so on. This iterative process is continued up to 2001:4.

Figure 9: Out-of-sample prediction of inflation and the price gap (percentage changes over previous year). Forecast horizon 2000:4 to 2001:4
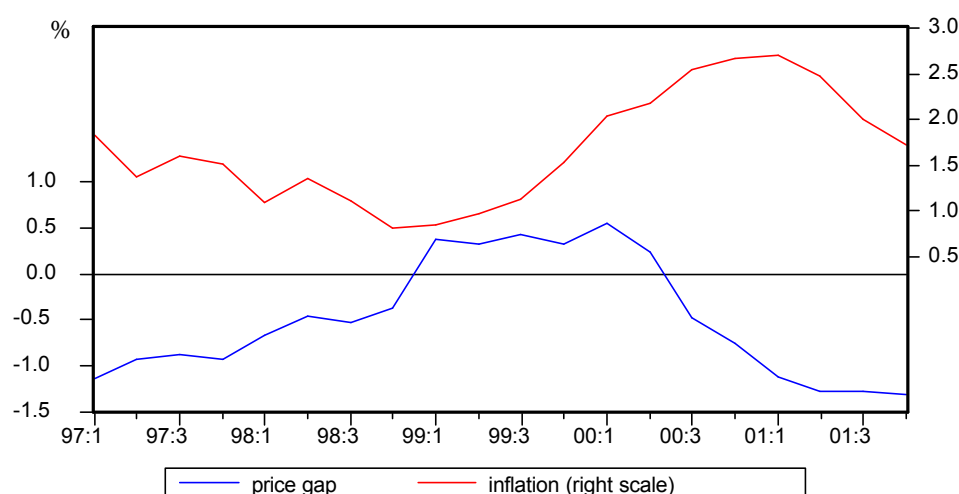
The annualized quarterly change of the consumer price level reaches its peak in 2000:3 with almost 3 percent and will decline to 1.3 percent in 2001:4; in the final quarter, the year-over-year increase will be 1.7 percent (Figure 9). The simulated value for the price gap in the final quarter is negative which means that inflationary pressure will decrease in the future. On the basis of the model and

the assumptions made, we get an average inflation rate in 2000 of 2.36 percent (+/-0.13) and 2.22 percent (+/-0.13) in 2001.

4   Conclusions

The Pstar model presented in this paper is a useful tool for predicting inflation in the Euro Area. Its performance in the estimation period is quite satisfactory, and the out-of-sample forecasts show promising results. We think of the model as being an attractive analytical tool as it is based on a theory with well-documented properties (Lucas 1996). The idea that money growth has also been a useful indicator for Euro Area inflation in the 1990s was analyzed, for example, by Gern et al. (1999): At the beginning of that decade, money growth had been much higher than at the end of the 1990s, and so has inflation which then declined continuously in line with lower money growth.

While questions such as the controllability of M3 or the pros and cons of monetary targeting are not discussed here, the fact that M3 has predictive power for inflation should, at least, mean that central banks — in this case the ECB — should be concerned if money growth is continuously higher than compatible with the target of price stability. All this does not mean that inflation is not affected by other variables in the short run; in fact, our estimates confirm that several cost factors do play a role. This implies that the inflation forecast requires assumptions about those variables as well, but that is true for any forecast. Nevertheless, the effect stemming from those variables is only temporary, just as the theory predicts. In the medium term, inflation is determined by money growth which supports the notion that "inflation is a monetary phenomenon", a view which is held also by the ECB.

5 Appendix: Variables and data sources

We use quarterly seasonally adjusted data from the first quarter of 1980 to the third quarter of 2000.

GDP: real quarterly values of GDP (in prices of 1995) from the datastream database (code: EMESGD95D). For the time prior 1991 this variable is calculated backwards. The variable *y* is log GDP.

Price index: quarterly index of harmonized consumer prices (HICP; 1996=100) from the datastream database (code: EMCP....F). Inflation is defined as the change of this price level against the previous quarter. The variable *p* is the logarithm of HICP.

M3: nominal quarterly index of M3 from the datastream database (code: EMECBM3.E). The variable *m* is log M3.

Oil prices: nominal quarterly values of spot market prices for oil from the datastream database (code: WDI76AAZA). The variable *petrolp* is the logarithm of the spot market oil prices.

Raw material prices: nominal monthly HWWA index for raw material prices without energy on US$ basis (1990=100; HWWA code: S204). Monthly data are extrapolated to quarterly observations. The variable *rawp* is the logarithm of the HWWA index without energy.

Exchange rate: nominal quarterly effective exchange rate of the euro for a narrow group from the datastream database (code: EMECBEXNR). For the time prior 1991 we calculated the series backwards. The variable *exch* is the logarithm of the nominal exchange rate of the euro.

Unit labor costs: nominal yearly index of unit labor costs (1995=100) from the OECD Economic Outlook (CD-ROM 2/2000). Annual data are interpolated to quarterly observations. The variable *ulc* is the logarithm of unit labor costs.

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