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Heterogeneous expectations, learning and European inflation dynamics

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Abstract:

This paper is the first attempt to investigate the performance of different learning rules in fitting survey data of household and expert inflation expectations in five core European economies (France, Germany, Italy, Netherlands and Spain). Overall it is found that constant gain learning performs well in out-of-sample forecasting. It is also shown that households in high inflation countries are using higher best fitting constant gain parameters than those in low inflation countries. They are hence able to pick up structural changes faster. Professional forecasters update their information sets more frequently than households. Furthermore, household expectations in the Euro Area have not converged to the inflation goal of the ECB, which is to keep inflation below to but close to 2% in the medium run. This contrasts the findings for professional experts, which seem to be more inclined to incorporate the implications of monetary union for the convergence in inflation rates into their expectations.

Key Words: Monetary policy, heterogeneous expectations, adaptive learning, survey expectations

JEL-Classification: E31, E37, D84

Non technical summary

Optimal monetary policy by central banks is increasingly seen as being sensitive to the expectation formation process of economic agents. It is hence of crucial importance for any central bank to be aware of the exact process by which expectations are formed. This paper investigates whether learning by economic agents is a plausible assumption for the Euro area and whether there is heterogeneity between countries and between households and professional forecasters. Furthermore it is analysed whether the learning process of agents converges towards equilibrium and specifically whether economic agents are able to learn the inflation goal of the European Central Bank, which is to maintain inflation close to but below 2% in the medium run.

In order to examine whether expectations in Europe result from a learning process, the paper assesses the performance of different forecasting models with time varying parameters in terms of their ability to fit actual data on inflation and inflation expectations. Data on household and expert expectations for five core countries participating in the single currency, namely Germany, Spain, France, Italy and the Netherlands, is used. It is found that for European countries, inflation expectations result from a learning process and therefore are not rational. Furthermore professional forecasters use higher constant gain parameters than households. They hence update their information sets more frequently and are able to pick up structural changes faster. A possible explanation of this is that households find it more costly to update their information sets than professional experts. It is also shown that in countries with higher inflation agents update their information sets more frequently. A possible explanation lies in Sims' theory of 'Rational Inattention' according to which agents will pay more attention to new information coming available when inflation is high as their opportunity cost of being inattentive is significantly higher during these periods.

In addition to assessing the importance of learning in the formation of inflation expectations, it is crucial to investigate whether the learning process converges to equilibrium and whether expectations are anchored at the policy goal of the ECB. It has often been argued that inflation differentials in the monetary union should disappear in the medium to long run and that expectations should have converged to the inflation goal of the ECB. However, as the results in this paper show household expectations so far have not been anchored at the inflation goal of the ECB whilst professional forecasters are more inclined to incorporate the implications of monetary union into their expectations than households.

Nicht-technische Zusammenfassung

Es wird heute allgemein davon ausgegangen, dass eine optimale Geldpolitik vom Erwartungsbildungsprozess der privaten Marktteilnehmer abhängt. Deshalb ist es für Zentralbanken wichtig zu wissen, wie diese ihre Erwartungen bilden. Die vorliegende Studie untersucht, ob sich die Inflationserwartungen in Ländern des Europäischen Währungsraums durch einen Lernprozess beschreiben lassen und ob es dabei Unterschiede zwischen privaten Haushalten und professionellen Prognostikern sowie zwischen den Ländern gibt. Schließlich wird geprüft, ob der Lernprozess der Marktteilnehmer zu einem Gleichgewicht konvergiert und ob Haushalte und professionelle Prognostiker das Inflationsziel der EZB, die Inflationsrate nahe aber unter 2 % zu halten, lernen können.

Um die empirische Relevanz des Lernprozesses einschätzen zu können, wird die Effizienz verschiedener Vorhersagemodelle mit zeitvariablen Parametern untersucht. Dazu wird ein Datensatz mit Umfragedaten für die Inflationserwartungen in Deutschland, Spanien, Frankreich, Italien und den Niederlanden verwendet. Es zeigt sich, dass die Inflationserwartungen in diesen Ländern Ergebnis eines Lernprozesses und deshalb nicht rational sind. Außerdem legen professionelle Prognostiker ein höheres Gewicht auf neue Erfahrungen (verwenden höhere ‚Constant Gain' Parameter) als Haushalte und sind deshalb schneller in der Lage, strukturelle Veränderungen in der Inflationsrate in ihre Erwartungen aufzunehmen. Eine mögliche Erklärung könnten höhere Kosten der Informationsbeschaffung für Haushalte sein. Das Papier zeigt weiter, dass in Ländern mit hohen Inflationsraten in der Vergangenheit neue Informationen schneller gesammelt werden. Dieses Ergebnis stimmt mit der Theorie der 'Rationalen Unaufmerksamkeit' von Sims überein, wonach es bei hohen Inflationsraten für Agenten kostspieliger ist, neuen Informationen keine Beachtung zu schenken.

Neben der Frage, ob die Inflationserwartungen von Haushalten und professionellen Prognostikern das Ergebnis eines Lernprozesses sind, ist es auch wichtig zu analysieren, ob sich die Inflationserwartungen der Marktteilnehmer zu einem Gleichgewicht hinbewegen und ob dies das Inflationsziel der EZB ist. Sehr oft wird argumentiert, dass in der Währungsunion die Inflationsdifferenzen zwischen einzelnen Ländern auf mittlere und lange Sicht verschwinden und die Erwartungen sich tatsächlich dem Inflationsziel der EZB angenähert haben sollten. Diese Studie zeigt, dass die professionellen Prognostiker eher geneigt sind, diese Implikationen der Währungsunion in ihre Erwartungen einzubeziehen, während die Erwartungen der Haushalte in den verschiedenen Ländern noch nicht mit dem Inflationsziel der EZB übereinzustimmen scheinen.

Contents

Heterogeneous Expectations, Learning and European Inflation Dynamics[1]

1 Introduction

Inflation expectations of economic agents are crucial for the monetary policy design of a central bank. Central banks hence have had a long interest in monitoring expectations and in understanding the process by which they are formed. From the 1970s the idea that expectations are rational has dominated much of the literature. Lately a new view on expectations has been introduced, which views economic agents as econometricians when forecasting (for an overview of this literature see Evans and Honkapohja (2001)). This approach, referred to as the adaptive learning approach, assumes that agents are boundedly rational but employ statistical forecasting techniques, which may allow the possibility for a rational expectations equilibrium to be learnt in the long run. One important insight from the adaptive learning literature is that policies, which may be optimal under rational expectations are not when agents use a learning process (Orphanides and Williams (2002)). Orphanides and Williams argue that the optimal monetary policy under a learning process should respond more aggressively to inflation and become more narrowed to inflation stability than if expectations were purely rational. They show that policies emphasizing tight inflation control can facilitate learning and provide better guidance for the formation of inflation expectations. Given that the optimal policy of the central bank is sensitive to the expectations formation process, it is hence of crucial importance to be aware of the exact process by which expectations are formed.

The contribution of this paper is twofold: First it investigates whether learning by economic agents is a plausible assumption for the Euro area and whether there is heterogeneity between countries and between households and professional forecasters. The second contribution of this paper is to analyse whether the learning process of agents converges towards equilibrium and specifically whether economic agents are able to learn the inflation goal of the European Central Bank, which is to maintain inflation close to but below 2% in the medium run[2].

[1] The paper reflects the author's personal opinions and does not necessarily reflect the views of the Deutsche Bundesbank. I would like to thank Sandra Eickmeier for guidence and helpful discussion. I am grateful to Christina Gerberding for access to her data on expectations as well as her comments. I appreciate helpful comments by Olivier Basdevant. I am grateful for discussions with Chryssi Giannitsarou and Albert Marcet. Finally I would like to thank Seppo Honkapohja and participants in the Macro Workshop, Faculty of Economics, Cambridge University, May 2007, as well as participants in the Bundesbank Seminar, January 2007, for useful comments. All remaining errors are my own.
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[2] According to Basdevant (2005), the Kalman filter framework allows one to test whether expectations

In order to examine whether expectations in Europe result from a learning process, the paper assesses the performance of different forecasting models with time varying parameters in terms of their ability to fit actual data on inflation and inflation expectations. Data on household and expert expectations for five core countries participating in the single currency, namely Germany, Spain, France, Italy and the Netherlands, is used. It is found that for European countries, inflation expectations result from a learning process and therefore are not rational. Furthermore professional forecasters use higher constant gain parameters than households. They hence update their information sets more frequently and are able to pick up structural changes faster. A possible explanation of this is that households find it more costly to update their information sets than professional experts. It is also shown that in countries with higher inflation agents update their information sets more frequently. A possible explanation lies in Sims' theory of 'Rational Inattention'. Sims (2003, 2006) argues that when inflation is higher agents will pay more attention to new information coming available as their opportunity cost of being inattentive is significantly higher during these periods.

In addition to assessing the importance of learning in the formation of inflation expectations, it is crucial to investigate whether the learning process converges to equilibrium and whether expectations are anchored at the policy goal of the ECB. It has often been argued that economic agents should understand the implications of monetary union and hence conclude that inflation differentials cannot last in the medium to long run (see for example ECB (2003)). Empirical evidence typically finds large persistent inflation differentials between European countries (Rogers (2001), Berk and Swank(2002) and Ortega (2003)). However, if actual inflation is influenced by inflation expectations of economic agents through wage and price setting behaviour, then convergence in inflation expectations should ultimately lead to convergence in inflation rates across countries. It is hence important to analyse convergence of expected household inflation rates and expected inflation rates of professional forecasters as this may give us some indication on the likely convergence of future actual inflation rates. The results in this paper show that professional forecasters are more inclined to incorporate the implications of monetary union into their expectations than households.

The outline of this paper is as follows: Section 2 gives an overview of the data. Section 3 discusses the general model that will be used throughout this paper. Section 4 presents an analysis of the fit of simple learning rules in the European Union. Section 5 tests for convergence of expectations to equilibrium. Section 6 concludes.

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converge towards the rational expectations equilibrium. However, this assumes that agents use the correct model of the economy. If the model used for forecasting is incorrect, expectations may converge towards a so called 'restricted perceptions equilibrium' (Evans and Honkapohja (2001)).

2 Data

2.1 Data Sources

This paper uses household expectations derived from the European Commission's Consumer Survey as well as expectations of professional experts extracted from Consensus Economics. Data for the following countries is used: Germany, France, Netherlands, Italy and Spain. We also use Euro area inflation and inflation expectations, where the data is compiled by aggregating the country data using weights based on each country's share in total Euro area private domestic consumption expenditure[3].

The EC Consumer Survey asks approximately 20000 consumers in the Euro area for information regarding their expectations of future and past price developments. The survey is conducted on a monthly basis and consumers are asked to about their expectations of inflation 12 months ahead. Questions and response categories of the survey are shown in table 1[4]:

How do you think that consumer prices have developed over the last 12 months? They have...	**By comparison with the past twelve months, how do you expect consumer prices to develop over the next twelve months?They will...**
Fallen	Fall
Stayed about the same	Stay about the same
Risen slightly	Increase at a slower rate
Risen moderately	Increase at the same rate
Risen a lot	Increase more rapidly
Don't know	Don't know

Table 1: The EC Consumer Survey

The data derived from the EC consumer survey is hence qualitative in nature and needs to be quantified. This paper uses data which has been quantified by Gerberding (2006) who uses a modified version of the probability method of Carlson and Parkin (1975) and follows Berk (1999) in estimating the perceived rate of inflation using the results from the question pertaining price developments in the past 12 months in the EC Consumer Survey.[5]

The data of professional experts expectations is provided by Consensus Economics, a London based firm. More than 700 professional forecasters are recruited from major banks,

[3]The most recent weights that are assigned to each country are published by Eurostat with the release of the January data each year under HICP country weights (http://sdw.ecb.int/reports.do?currentNodeId=100000298)

[4]This table is adapted from Gerberding (2006).

[5]See Gerberding (2006) and Doepke (2005) for a detailed discussion of their quantification method.

economic research institutes and investment firms. Every quarter, Consensus economics asks these experts to provide quantitative forecasts on key macro variables, including consumer prices. These forecasts are available for each of the following one to six quarters. Simple arithmetic means of these quarterly forecasts are then published for each country.

Further details on the data sources including those sources used to construct time series of actual inflation can be found in Annex 2.

It has to emphasised that there are limits to data compatibility in this paper. First of all, observations for households are monthly whilst data on expectations of professional forecasters are quarterly. Secondly, household expectations have to be quantified whilst expert expectations are an average of quantitative forecasts. There are limitations to the probability method. These include the rather strict assumption of normality of the underlying aggregate distribution function. This assumption has been criticized by Carlson (1975) and Pesaran (1987) who find non-normal features of the aggregate distribution function. However, as noted by Nielsen (2003) and Berk (1999) alternatives to the normal distribution make little difference to the derived expectations series.

An advantage of the probability approach is that it does not impose unbiasedness as an a priori property of the measure of future expectations of inflation. This is important as in this paper, it is tested whether households are boundedly rational. Nevertheless, the limitations of the probability approach have to be taken into account when evaluating the results of this paper.

2.2 Preliminary look at data

Figure 1 shows data of actual inflation as well as household expectations from 1990-2006 for the different countries in our sample[6]. Consensus forecasts and actual inflation are also plotted from 1990-2006. These series are shown in Figure 2.

The expectations series are dated back one year, that is twelve months for households and four quarters for experts. Hence, the vertical differences between the series in each figure measure the forecast errors of households and professional experts. From the graphs, it looks as if professional forecasters are on average better at forecasting inflation than households. This is confirmed by computing mean squared errors, which are larger for households than for professional forecasters. It is possible to test whether these differences in mean squared errors are significant for the period from 1990Q1 to 2006Q3[7]. Equal forecast accuracy can

[6] There were some missing observations in the quanitifed consumer expectations series, which reflect the fact that the quantification method breaks down when the share of respondents in one category is equal to zero (Berk, 1999). However, the consumer expectations series were interpolated using the cubic spline function in Matlab. This was needed for some of the computations conducted in this paper.

[7] In order to test for equal forecast accuracy, we had to transform household expectations, for which monthly data is available, into quarterly data. This was done by computing average expectations for each

be tested using the method proposed by Diebold and Mariano (1995). The small sample correction for the Diebold/Mariano statistic as introduced by Harvey et al (1997) is used. It is found that with the exception of France and Spain, the differences between the mean squared errors of professional forecasters and households are significant at the 10% level[8].

Besides testing for equal forecast accuracy, it is also possible to test for unbiasedness of expectations. Several studies have investigated whether expectations of households and professional forecasters are unbiased. For example, Forsells and Kenny (2004) using the same data set as in this paper, find that consumer expectations are a somewhat biased predictor of inflation twelve months ahead. Rationality is tested by running the following regression:

$$\pi_t = \alpha + \beta \pi_t^e + \varepsilon_t \tag{1}$$

π_t denotes the actual inflation rate in period t and π_t^e denotes the expected inflation rate formed in $t-12$. If the joint null hypothesis $H_0 : (\alpha, \beta) = (0, 1)$ cannot be rejected, than it follows that expectations are unbiased in a statistical sense. The above rationality test is conducted for both data on household and expert inflation expectations. It is found that for household expectations the hypothesis that expectations are unbiased can be rejected at the 1% and 5% level for each country and the EU Area as a whole. For expert expectations, it is found that we can reject the hypothesis of unbiasedness at the 1% and 5% levels for most countries and the EU Area with the exception of Germany and the Netherlands. However, as Holden and Peel (1990) have shown, if the null hypothesis cannot be rejected this is sufficient for rationality but not necessary. Holden and Peel (1990) suggest to regress the forecast error on a constant instead and test whether the constant is significantly different from zero:

$$\pi_t - \pi_t^e = \alpha + \varepsilon_t \tag{2}$$

It can be shown that the condition $\alpha = 0$ is both necessary and sufficient for rationality. The test is conducted for household and expert expectations. For households, it is found that we can reject the null of unbiasedness at the 1% and 5% level for each country and the Euro Area with the exception of Italy. For experts, we can reject the null hypothesis of unbiasedness for Italy and Spain and the Euro Area as a whole at the 1% and 5% level[9].

quarter.

[8] P-values and Diebold/Mariano statistics can be provided by the author upon request.

[9] Results for these unbiasedness tests are available from the author upon request.

3 The Model

This section follows Branch and Evans (2006) and Basdevant (2005) and outlines a general state space forecasting model that will be able to nest alternative models.

Let π_{t+1} denote inflation in period $t+1$. It is assumed that agents' model of inflation is given by

$$\pi_{t+1} = b_t' x_t + \varepsilon_{t+1} \tag{3}$$

where

$$b_t = (b_{1t}, b_{2t}, b_{3t}, ..., b_{(n+1)t})' \text{ and } x_t = (1, y_{t-1})'$$

and

$$E(\varepsilon_t) = 0 \text{ and } E(\varepsilon_t \varepsilon_t') = H_t$$

Let y_t with dimension nx1 denote variables of general interest. Thus n is the number of independent variables in our model. These could be lagged values of inflation, output growth or interest rate growth for example. It is hence assumed that agents view inflation in $t+1$ as a function of a constant and lagged variables of general interest. Furthermore agents are seen as forming their expectations for the value of inflation for the next period before they observe the current values of variables of interest such as inflation and output growth. Once the current value is known agents update their beliefs in order to avoid making systematic mistakes.

Together with the assumption that

$$b_t = b_{t-1} + \eta_t \tag{4}$$

where

$$E(\eta_t) = 0 \text{ and } E(\eta_t \eta_t') = Q_t$$

the above corresponds to a general state space model.

The parameter vector b_t can be estimated using the Kalman filter. The recursion can be written as follows:

$$\widehat{b}_t = \widehat{b}_{t-1} + k_t(\pi_{t+1} - \widehat{b}_{t-1}' x_t) \tag{5}$$

$$k_t = \frac{P_{t-1} x_t}{H_t + x_t' P_t x_t} \tag{6}$$

$$P_t = P_{t-1} - \frac{P_{t-1} x_t x_t' P_{t-1}}{H_t + x_t' P_{t-1} x_t} + Q_t \tag{7}$$

where

$$P_t = E(b_t - \widehat{b}_t)(b_t - \widehat{b}_t)'$$

As shown by Marcet and Sargent (1989a,b) the learning process converges only to equilibrium when the law of motion of parameters is time invariant. In other words, convergence requires $Q_t = 0$. Within the Kalman filter framework it is hence possible to test whether learning is perpetual or whether it converges to equilibrium by examining whether the variance of the state variables is significantly different from zero.

If $Q_t = 0$ and $H_t = 1$, (5)-(7) is equivalent to recursive least squares (RLS) as shown by Sargent (1999). The system can thus be written as

$$\widehat{b}_t = \widehat{b}_{t-1} + \gamma_t R_t^{-1} x_t(\pi_{t+1} - \widehat{b}'_{t-1} x_t) \tag{8}$$

$$R_t = R_{t-1} + \gamma_t(x_t x'_t - R_{t-1}) \tag{9}$$

where $\gamma_t = t^{-1}$ and R_t is the matrix of second moments of x_t. As shown by Evans and Honkapohja (2001) recursive least squares is a recursive formulation of ordinary least squares.

When

$$Q_t = \frac{\gamma}{1-\gamma} P_{t-1} \text{ and } H_t = 1 - \gamma$$

the system becomes equivalent to the constant gain version of recursive least squares (Sargent 1999). Past observations are discounted at a geometric rate $1 - \gamma$. Hence constant gain least squares is more robust to structural change than RLS.

4 Simple Learning Rules

This section compares the performance of alternative recursive forecasting models. It assesses the ability of different simple learning models to fit data on actual inflation and inflation expectations. It is thereby examined whether learning is a plausible description of household and professional forecaster behaviour. It will also be investigated to what extent recursive least squares and constant gain least squares, which are the two most commonly used learning mechanisms described in the theoretical literature, provide a good description of forecaster behaviour. Estimates of the constant gain parameters are provided for each country and we analyse whether there is country heterogeneity with respect to learning. Heterogeneity between households and professional forecasters is also examined. It will then be assessed to what extent the results are plausible and specifically whether they agree with other economic theories, such as Sims's theory of rational inattention.

4.1 Estimation Procedure

We follow Branch and Evans (2006) and divide our sample for each country in three parts: A pre-forecasting period in which prior beliefs are formed by estimating (3). An in-sample period in which optimal gain parameters are determined for the case of constant gain least squares. For RLS the gain sequence continues to be updated as t^{-1}. Finally, there is an out-of-sample forecasting period.

For household expectations, a fairly long pre-forecasting period, 1981M1-1989M12 is chosen in order to avoid over-sensitivity of initial estimates. The in-sample period is 1990M1-1998M4. The out-of-sample period is hence 1998M5-2006M9[10]. Given the monthly frequency of the data we follow Pfajfar and Santoro (2006) and define the dependent variable vector x_t as $(1, y_{t-1})'$. Agents' perceived law of motion (PLM) is hence given by

$$\pi_{t+12|t} = b_t' x_t + \varepsilon_t \tag{10}$$

When agents estimate the PLM, all available information up to period $t-1$ is used. As new data becomes available agents update their estimates according to either constant gain learning or recursive least squares learning.

To calculate optimal in-sample constant gain parameter choices, we minimise the in-sample mean square forecast error:

$$MSE_{IN}(\pi) = \frac{1}{T}\sum_{t=t_0}^{T}(\pi_t - \widehat{\pi}_t)^2$$

by searching over all $\gamma \in (0,1)$ with t_0 =1990M1 and T =1998M4. The distances between grids are set as 0.01. $\widehat{\pi}_t$ denotes the forecast made in period $t-12$ for t. This is generated by starting the recursion, which is given in (8) and (9) with the initial values calculated for the pre-sample period and then using the recursion to calculate $\widehat{b}_t$. We then use the fact that $\widehat{\pi}_t = \widehat{b}'_{t-12} x_{t-12}$ to generate values for $\widehat{\pi}_t$. The grid search is conducted by systematically searching for the value of $\gamma \in (0,1)$ that minimises the in-sample mean square error. When using recursive least squares updating equations, there is no need to compute an optimal gain parameter as $\gamma = t^{-1}$. However, we can compute mean square errors by updating the sequence for $\widehat{b}$ with t^{-1} and then using the fact that $\widehat{\pi}_t = \widehat{b}'_{t-12} x_{t-12}$ to generate values for $\widehat{\pi}_t$. These values can then be used as before in order to calculate in-sample mean square errors.

Having determined the optimal in-sample values of the constant gain, out of sample MSE's

[10]This sample period was chosen so that the in- and out-of-sample periods correspond to the period for which household expectations are available. The period from 1990M1-2006M9 was then split in half to generate the in- and out-of-sample periods.

can be computed for each country as

$$MSE_{OUT}(\pi) = \frac{1}{T}\sum_{t=1}^{T}(\pi_t - \widehat{\pi}_t)^2$$

where t ranges from 1998M5 to 2006M9.

It is also possible to find best fitting constant gain parameters for households. These are computed by minimising the in-sample mean square comparison error

$$MSCE_{IN}(\pi) = \frac{1}{T}\sum_{t=t_0}^{T}(\pi_t^F - \widehat{\pi}_t)^2$$

by searching over by searching over all $\gamma \in (0,1)$ with t_0 =1990M1 and T =1998M4. π_t^F denote household expectations for period t. The distances between grids are set as 0.0001. Best fitting constant gain parameters are computed to determine whether the best fitting gains for household expectations are equivalent to the optimal gains needed to fit actual data on inflation in the period. This is important to investigate as Branch and Evans (2006) find that for explaining the forecasts of professional forecasters in the US, the best fitting gain is substantially below the optimal gain for fitting data on actual inflation. Similarly as before, using the best fitting gains for household expectations, the out-of-sample mean square comparison forecast error is determined. This is given by

$$MSCE_{OUT}(\pi) = \frac{1}{T}\sum_{t=1}^{T}(\pi_t^F - \widehat{\pi}_t)^2$$

where t ranges from 1998M5 to 2006M9.

For RLS learning, we calculate the in-sample and out-of sample MSCE as above. The gain sequence is updated with t^{-1}.

In addition to absolute mean square comparison errors, we also compute relative MSCEs for each country for the model that yields the smallest mean square comparison forecast error. This follows Forni et al (2003) and Schumacher (2006). Relative MSCEs are computed out-of-sample relative to the variance of series that we are trying to predict, i.e. household inflation expectations. Computing relative MSCEs is related to the concept of predictability of a series (see for example Diebold and Kilian (2001)). It could be the case that household expectations are more predictable in some countries, which results in lower MSCEs for those countries. Computing the variances of these series gives us some indication about how predictable the different series are.

For professional forecasters the method is identical to the one described above with the exception that we are now dealing with quarterly data. We use quarterly data on inflation from 1961Q1-2006Q3. Forecasts of experts for four quarters ahead are used in order to make results comparable between households and professional forecasters[11]. The sample is divided as follows: Data on inflation from 1961Q1-1975Q4 is used as the pre-sample period. The in-sample period consists of data from 1976Q1-1990Q3. The out-of-sample period was chosen so that it corresponds to the sample of professional forecasters: 1990Q4-2006Q3. Professional Forecasters' perceived law of motion (PLM) is given by

$$\pi_{t+4|t} = b_t' x_t + \varepsilon_t \tag{11}$$

It should be noted that because of relatively few observations for expert expectations, we can only determine in-sample best fitting gains and in-sample mean square comparison errors. There is no out-of-sample period in this case.

We estimate four different models. Model 1 is a simple AR(1) model where the dependent variables are a constant and the lagged value of inflation. Model 2 is a simple AR(2) model with a constant and lagged values of inflation[12]. Model 3 includes a constant, lagged inflation and lagged output growth, which is approximated by growth in industrial production[13]. Model 4 in addition to the variables in model 3 includes interest rate growth. Models 1-4 for households can thus be written as follows:

$$\pi_{t+12|t} = b_{1t} + b_{2t}\pi_{t-1} + \varepsilon_t \tag{Model 1}$$

$$\pi_{t+12|t} = b_{1t} + b_{2t}\pi_{t-1} + b_{3t}\pi_{t-2} + \varepsilon_t \tag{Model 2}$$

$$\pi_{t+12|t} = b_{1t} + b_{2t}\pi_{t-1} + b_{3t}z_{t-1} + \varepsilon_t \tag{Model 3}$$

$$\pi_{t+12|t} = b_{1t} + b_{2t}\pi_{t-1} + b_{3t}z_{t-1} + b_{4t}w_{t-1} + \varepsilon_t \tag{Model 4}$$

where z_t denotes industrial production growth and w_t denotes interest rate growth. For quarterly data, models 1-4 are identical except for the fact that the dependent variable is now denoted as $\pi_{t+4|t}$. In addition, for quarterly data, data on GDP is available and hence we do not need to approximate output growth by industrial production.

[11] Household expectations are averaged so that rather than having monthly data we get quarterly data for household expectations as well. Results for households are derived using the exact same method as for experts. They are provided together with the results for professional forecasters for direct comparison purposes.

[12] Results for higher order AR models were also computed but it was found that the AR(1) and AR(2) models outperformed higher order models.

[13] We followed Branch and Evans (2006) in using output growth as one of the explanatory variables. Conventional New Keynesian Phillips curve estimations typically use the output gap instead. We tried using the output gap (defined as $y = \ln(Y) - \ln(Y^*)$ where Y is GDP seasonally adjusted and Y^* is potential output estimated as the HP filtered Y) instead of output growth and found very similar results.

4.2 Results

4.2.1 'Households: Learning Matters'

In order to assess whether we are able to fit actual inflation with a learning model, we first compute the optimal constant gain minimising the MSE for the in-sample period for different countries. These are shown in table 2.

1990M1-1998M4	γ			
	Model 1	Model 2	Model 3	Model 4
Germany	0.1400	0.0960	0.1740	0.1300
France	0.1870	0.1280	0.1700	0.1360
Netherlands	0.2410	0.1580	0.1420	0.1150
Italy	0.1790	0.1490	0.0950	0.0670
Spain	0.1750	0.1480	0.1752	0.1090

Table 2: Optimal Constant Gain Parameters, Minimising MSE

We also assess the ability of different specifications of the model to fit actual inflation and thereby examine whether RLS or CGLS generates better predictions of actual inflation. Table 3 shows out-of-sample mean square forecast errors using both constant gain as well as recursive least squares learning.

Out-of-Sample Period: 1998M5-2006M9								
	RLS				Constant Gain			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Germany	0.4929	0.4859	0.4864	0.5350	0.0720	0.0879	0.1220	0.4129
France	0.3269	0.3200	0.3217	0.3520	0.0457	0.0613	0.1648	0.0430
Netherlands	0.7602	0.4580	0.7584	0.4349	0.0440	0.0784	0.0806	0.0670
Italy	0.2153	0.2243	0.2147	0.2170	0.0198	0.0260	0.0535	0.0346
Spain	0.7727	0.7680	0.7631	0.8599	0.0664	0.0611	0.1397	0.0688

Table 3: Mean Square Forecast Errors

It can be seen that constant gain clearly dominates RLS in terms of forecast accuracy[14].No single model seems to fit best for all countries though. However, it can be seen that the simple model with constant gain learning and just lagged inflation and a constant as the independent variables does well for all countries. Figure 3 shows actual inflation together with forecasts generated using the optimal gain and model for the different economies. This figure highlights the fact, that constant gain recursive least squares performs well in fitting actual inflation.

[14]We performed modified Diebold/Mariano tests with the null of equal forecast accuracy to test whether the differences in MSEs between RLS and CGLS are significant. We test whether the difference between the largest MSE under CGLS and the smallest MSE under RLS is significant. It is found that the null hypothesis of equal forecast accuarcy can be rejected at the 5% level of signifiance for each country. P-values and modified Diebold/Mariano statistics can be provided by the author upon request.

It is also important to analyse, which model best fits data on expectations. We compute best fitting gains by minimising the in-sample mean square comparison errors and are hence able to assess whether there is heterogeneity regarding the optimal constant gain parameters between countries. The best fitting gains for each country and model are shown in table 4.

1990M1-1998M4	γ			
	Model 1	Model 2	Model 3	Model 4
Germany	0.0010	0.0020	0.0010	0.0010
France	0.0002	0.0082	0.0001	0.0051
Netherlands	0.0010	0.0010	0.0210	0.0010
Italy	0.0270	0.0280	0.0260	0.0240
Spain	0.0530	0.0510	0.0640	0.0460

Table 4: Optimal Constant Gain Parameters to Minmise MSCE

From table 4, it can be seen that best fitting gains are much smaller than the optimal constant gains and that households in so-called high inflation countries such as Spain and Italy are using higher constant gain parameters than households in 'low inflation' countries such as Germany and the Netherlands. Mean square comparison forecast errors are then computed for household expectations for data generated with the RLS algorithm as well as with data generated by using best fitting constant gains. Hence, we are able to examine whether learning matters for inflation expectation formation of households and which dependent variables households use when predicting inflation. We can also assess whether recursive least squares or constant gain learning provides a better description of household behaviour and whether there is country heterogeneity with respect to learning. The results are found in Table 5.

Out-of-Sample Period: 1998M5-2006M9								
	RLS				Constant Gain			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Germany	0.5589	0.5508	0.5609	0.6502	**0.5349**	0.5631	0.5360	0.6858
France	0.3226	0.3096	0.3229	0.3549	0.4491	0.3532	0.3812	**0.2958**
Netherlands	0.5278	0.3320	0.5325	0.3657	0.4500	0.5753	0.6906	**0.2774**
Italy	0.3781	0.3785	0.3805	0.3229	0.3095	0.2991	0.3082	**0.2402**
Spain	1.7622	**1.7565**	1.7661	1.9075	1.9083	1.9885	2.0407	2.1847

Table 5: Mean Square Comparison Forecast Errors

Table 5 shows that expectations in France, the Netherlands and Italy can be fitted better with our simple models than expectations in Germany and Spain. Specifically model 4 seems to perform well in those countries, which suggests that agents use more complicated models than those simply including lagged inflation. In the case of Spain, given the large forecast errors, there is little evidence that agents are using any of our linear forecasting models. We also compute relative MSCEs for each country for the model that yields the smallest mean square comparison forecast error. Relative MSCEs for the optimal model for each country are shown in Table 6.

Out-of-Sample Period: 1998M5-2006M9	
	Relative MSCE
Germany	0.7865
France	0.5096
Netherlands	0.5660
Italy	0.0619
Spain	0.9494

Table 6: Relative Mean Square Comparison Forecast Errors

Table 6 shows that the relative MSCE is still smallest for Italy, meaning that we are able to fit expectations in Italy best. The difference between the relative MSCE for the best fitting model for Italy and the relative MSCE corresponding to the best fitting models for France and Netherlands is now larger than was the case with absolute MSCEs. There is hence evidence, that our simple learning model does significantly better in predicting household expectations in Italy than in predicting expectations in other countries.

Figure 4 shows household inflation expectations and our generated forecasted inflation using the optimal model and best fitting constant gain for each country. It can be seen that whilst the direction of inflation expectations can be predicted well (even in Spain), expectations are somewhat more volatile than our generated series. A possible explanation may be that whilst households use a simple linear forecasting models there are certain stochastic shocks and events to which households react and which hence also influence expectations.

4.2.2 'Professional Forecasters use higher constant gain parameters than Households'

First, we assess whether a simple learning model can fit actual quarterly data on inflation. Optimal gains for each model are shown in Table 7. Results are only shown for three countries. The reason is that there are data constraints for the Netherlands and Spain[15]. Again, these gains are higher than those typically found for the US.

[15] Data on expert expectations for the Netherlands and Spain is available from 1994Q4-2006Q3. Data on output growth is available from 1977Q2 for the Netherlands and from 1970Q2 for Spain. Data on interest rate growth is available from 1986Q2 for the Netherlands and 1977Q2 for Spain. These series would have been too short for our purposes.

1976Q1-1990Q3	γ			
	Model 1	Model 2	Model 3	Model 4
Germany	0.1380	0.1120	0.1780	0.1110
France	0.2160	0.1050	0.1230	0.1020
Italy	0.3000	0.2000	0.1570	N/A

Table 7: Optimal Constant Gain Parameters, Minimising MSE

The out of sample forecast errors for actual data on inflation are shown in Table 8. It can be seen that constant gain least squares again dominates recursive least squares in terms of out-of-sample performance and that the simplest model does well in explaining actual inflation[16]. This is also shown in Figure 5, which shows actual inflation and predicted inflation using the optimal model and optimal gain parameter for each country.

Out-of-Sample Period: 1990Q4-2006Q3								
	RLS				Constant Gain			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Germany	0.9801	1.0137	0.8508	0.8734	0.2356	0.3864	**0.2142**	0.3888
France	0.2986	0.3226	0.3043	0.4526	**0.0721**	0.1203	0.1742	0.2296
Italy	1.1611	1.3113	0.9977	N/A	**0.0658**	0.1011	0.2647	N/A

Table 8: Mean Square Forecast Errors

Table 9 shows best fitting constant gains, which can be used to examine whether there is heterogeneity between professional forecasters and households. As indicated before, we average household expectations data and then perform the same estimations with household expectations as with expert expectations in order to have a direct comparison between expectations of households and professional forecasters.

Out-of-Sample Period: 1990Q4-2006Q3								
	γ							
	Model 1		Model 2		Model 3		Model 4	
	Experts	HH	Experts	HH	Experts	HH	Experts	HH
Germany	0.1380	0.0018	0.1000	0.0010	0.1080	0.0010	0.0460	0.0012
France	0.0200	0.0080	0.0240	0.0142	0.0130	0.0060	0.0410	0.0070
Italy	0.1780	0.0720	0.1380	0.0720	0.1370	0.0930	N/A	N/A

Table 9: Best Fitting Constant Gain Parameters to Minimise MSCE

[16] Modified Diebold/Mariano tests are computed to test the hypothesis of equal forecast accuracy between the model yielding the largest MSE under CGLS and the model yielding the smallest MSE under RLS. The hypothsis of equal forecast accuracy can be rejected at the 5% level of significance. Test statistics and P-values are available from the author upon request.

Experts seem to update their information sets much more frequently than households. This could be due to the fact that households find it more costly to update their information sets than professional forecasters.

Tables 10 and 11 show mean square comparison errors for households and experts. It can be seen that there does not seem to be one model, which is best across all three countries. There is some evidence that households are more inclined to use simpler models with just lagged values of inflation compared to professional forecasters who use a larger variety of variables to predict inflation. However, this does not correspond to the findings for monthly data. This apparent contradiction between the results for household expectations for monthly and quarterly data could due the fact that by averaging data important information on household expectations is lost.

Out-of-Sample Period: 1990Q4-2006Q3								
	RLS				Constant Gain			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Germany	0.3419	0.4805	0.2930	0.3704	0.4068	0.2268	**0.2046**	0.2664
France	0.2752	0.2910	0.2765	0.4613	0.2780	0.2439	0.2707	**0.2194**
Italy	0.8475	1.0138	0.8242	N/A	**0.4300**	0.4865	0.4926	N/A

Table 10: Mean Square Comparison Errors, Experts

Out-of-Sample Period: 1990Q4-2006Q3								
	RLS				Constant Gain			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Germany	0.7816	0.9610	0.7913	0.9064	0.7197	**0.6912**	0.7113	0.9762
France	0.7233	0.7918	0.7439	0.9859	**0.3897**	0.6250	0.5403	0.4757
Italy	0.8662	0.9625	0.9711	N/A	0.6062	**0.5811**	0.8091	N/A

Table 11: Mean Square Comparison Errors, Households

Again, it is possible in line with the previous literature on forecasting to compute relative mean square forecast comparison errors. The best fitting model is used for each country. Relative MSCEs for households and experts are shown in table 12.

From table 12 it can be seen that according to relative MSCEs we are able to fit expectations in Italy best. This is different to the conclusions made from table 11. It highlights the fact that expectations in Germany and France may be somewhat more predictable than in Italy.

It seems to be the case that our simple forecasting models fit expectations of professional forecasters somewhat better than household expectations. It can be tested whether the

Out-of-Sample Period: 1990Q4-2006Q3	Relative MSCEs	
	HH	Experts
Germany	1.0710	0.2794
France	0.6938	0.4705
Italy	0.1510	0.1679

Table 12: Relative Mean Square Forecast Comparison Errors

differences in mean squared errors are significant using a modified Diebold/Mariano (1995) test with the small sample correction proposed by Harvey et al (1997). We compare the mean square comparison errors of the optimal model for each country, i.e the model that yields the smallest absolute MSCE. For example, for Germany, we use model 3 for experts and model 2 for households. The results of the modified Diebold/Mariano test are shown in Table 13.

	mod. DM statistic	P-value
Germany	2.0921	0.0487
France	1.3768	0.1906
Italy	1.1567	0.2706

Table 13: Modified Diebold/Mariano tests for Equal Forecast Accuracy

It can be seen that with the exception of Germany, the null hypothesis of equal forecast accuracy cannot be rejected at the 1% and 5% level. There is hence evidence that for France and Italy we are able to predict expectations of households and experts equally well. Figure 6 shows expert expectations and our generated series for inflation forecasts. It can be seen that the direction of expectations can be predicted well with our model. This is also the case for fitting household expectations, which figure 7 illustrates.

4.3 Discussion

Overall, there hence seems to be support for constant gain least squares learning compared to recursive least squares. This supports the results by Branch and Evans (2006) for the US economy. It is also found that the optimal gain parameters needed to fit actual data on inflation in the Euro area are somewhat higher than those found for the US. This is true for both, quarterly and monthly data and different time periods. We show that optimal gains for the European economies in our sample range from 0.07-0.30. For the US, Orphanides and Williams (2005) suggest estimates of around 0.01-0.04, Branch and Evans find values of the gain of around 0.06 and Milani (2005) finds values between 0.02-0.12 depending on the time period used. A higher gain coefficient for the Euro area than in the US implies that agents should optimally use fewer years of data to form a prediction of inflation. A possible explanation for this might be that inflation in European countries is subject to more structural breaks. Constant gain least square learning discounts past observations geometrically and hence if there are more structural breaks fewer years of data should optimally be used to generate forecasts.

We have shown that best fitting gains to fit household expectations are much smaller than optimal gains needed to fit actual data of inflation. Best fitting gain for the European economies in our sample range from 0.0001 to 0.064. These results roughly correspond with results found for the US (Pfajfar and Santoro (2006) find best fitting constant gains between 0.0008-0.001). The fact that best fitting constant gains are well below optimal constant gains might imply that households are possibly unaware of the structural breaks in the data and use a larger number of past observations to form an expectation of inflation.

It is interesting to note that households in high inflation countries such as Spain and Italy use higher constant gains than those in low inflation countries and are hence picking up structural changes faster. A possible explanation for the fact that households in the so-called high inflation countries are 'learning faster' is provided by Sims (2003, 2006). Sims (2003,2006) argues that when inflation is higher agents will pay more attention to new information coming available as their opportunity cost of being inattentive is significantly higher during these periods. It is also found that professional forecasters have higher constant gains than households. This could be caused by a greater awareness of the presence of structural breaks by professional forecasters but it could also be the case that professional forecasters are more willing to incur the costs of updating their information sets than households, which update their information sets less frequently (Carroll (2003 a,b), Döpke (2005)).

5 Testing for Convergence

5.1 Estimation procedure

This section investigates whether expectations converge to equilibrium. It is also investigated whether agents are able to learn the goal of the ECB, which is to maintain inflation close to but below 2% in the medium run. As explained above this can be tested within a Kalman filter framework by investigating whether the variance of hyper-parameters is significantly different from 0. Time-varying parameters are estimated using the model outlined in equations (3)-(7). Given that the simplest model of inflation performs quite well for all countries, it is assumed that inflation expectations are derived from the following rule:

$$\pi_{t+12|t} = b_{1t} + b_{2t}\pi_{t-1} + \varepsilon_t \tag{12}$$

for households and

$$\pi_{t+4|t} = b_{1t} + b_{2t}\pi_{t-1} + \varepsilon_t \tag{13}$$

for professional experts.

Furthermore the following assumptions are made:

$$b_{i,t} = b_{i,t-1} + \eta_{i,t} \tag{14}$$

and

$$\varepsilon_t \sim N(0, \sigma^2) \text{ and } \eta_{i,t} \sim N(0, (Q_t^i)^2)$$

It is hence assumed that the variance on the measurement equation is constant while the variance of hyper-parameters may be time dependent. The variance of the measurement equation is assumed to be constant in order to restrict the numbers of free parameters that have to be estimated within the Kalman filter. To test for convergence, it is investigated whether the variance of the state decreases over time, which would imply that the learning process is converging towards least squares estimates. Following Basdevant (2005) who uses the methods discussed in Hall et al (1997) to test for convergence, Q_t is modelled as follows

$$Q_{i,t} = \lambda^2 Q_{i,t-1} \tag{15}$$

for $i = 1, 2$.

As shown by Hall et al (1997) and Hall and St. Aubyn (1995), if $0 \leq \lambda < 1$ convergence in expectations holds. The null hypothesis $H_0 : \lambda = 1$ is tested against the alternative $H_1 : \lambda < 1$. In order to obtain the distribution of some function of λ under the null, this paper follows Basdevant (2005) in constructing the statistic proposed by Hall and St. Aubyn (1995) and St. Aubyn (1999). This is given by

$$HSA = \frac{\widehat{\lambda} - 1}{\widehat{\sigma}(\widehat{\lambda})}$$

It should be noted that $\widehat{\sigma}(\widehat{\lambda})$ is the estimated standard error of the parameter λ. Hall and St. Aubyn (1995) and St. Aubyn (1999) calculate critical values for the HSA statistic. These are -3.479 at the 1% level, -2.479 at the 5% level and -1.970 at the 10% level.

In order to obtain for convergence in practice, EViews is used in order to set up a state space model. As EViews cannot estimate equation (15) in its present form, the equation is rewritten as $Q_{i,t} = \lambda^{2t} Q_{i,0}$ where t is a time trend. In order to impose values for $Q_{i,0}$, equations (12) and (13) are estimated using OLS and the squared standard deviations of the coefficients are used as estimates of the initial variances.

5.2 Results

5.2.1 Household Expectations

This section investigates whether the learning process moves towards equilibrium. Data from 1990M1-2006M9 is used. We test $H_0 : \lambda = 1$ against $H_1 : \lambda < 1$. The results are shown in tables 11 and 12:

	λ	**Std. Error**	**HSA**
Germany	0.996640	0.000387	-8.6820***
France	0.998199	0.000525	-3.4302**
Italy	0.995096	0.000667	-7.3522***
Netherlands	0.998652	0.000579	-2.3274*
Spain	0.998010	0.000505	-3.9406***
Euro Area	0.991442	0.000543	-15.7510***
* "No convergence" rejected at 10% confidence level			
** "No convergence" rejected at 5% confidence level			
*** "No convergence" rejected at 1% confidence level			

Table 14: Households: Testing for Convergence

		Final State	**Root MSE**	**P-value**
Germany	$\widehat{b}_1$	1.4536	0.3550	0.0000
	$\widehat{b}_2$	-0.0584	0.2934	0.8422
France	$\widehat{b}_1$	2.3013	0.4103	0.0000
	$\widehat{b}_2$	0.2106	0.1934	0.2759
Italy	$\widehat{b}_1$	3.0022	0.734328	0.0000
	$\widehat{b}_2$	-0.7352	0.3493	0.0353
Netherlands	$\widehat{b}_1$	1.1782	0.4746	0.0131
	$\widehat{b}_2$	0.1214	0.1172	0.3002
Spain	$\widehat{b}_1$	4.4108	1.2780	0.0006
	$\widehat{b}_2$	-0.1406	0.2512	0.5755
Euro Area	$\widehat{b}_1$	1.7892	0.3176	0.0000
	$\widehat{b}_2$	0.2662	0.1455	0.0673

Table 15: Households: Testing for Convergence: Final State Estimates

It can be seen that there is evidence of convergence to equilibrium for all countries. However, the values fund for λ are extremely close to 1 and hence the convergence process occurs very slowly. It can also be seen that the respective weights on inflation converge to zero. This suggests that inflation expectations are becoming more anchored to a constant. However, coefficients on the constant do not converge to something just below two, which would imply that agents have learned the inflation goal of the ECB correctly. Instead, agents in Spain and Italy consistently over-estimate the inflation goal and agents in Germany and the Netherlands consistently under-estimate the inflation goal. For the European Union as a whole it can be seen that inflation have converged to a constant, which is in line with the goal of the ECB to keep inflation close to but below 2%. Figure 8 shows smoothed state estimates. It can be seen that estimates for the constant rise substantially in 2002 and then fall again in Germany and the Netherlands but stay at a high level in Italy and Spain. In 2002 there was the introduction of the European currency and this had a large effect on households' perceived inflation rate. Berk and Hebbink (2006) also conclude that the introduction of the common currency had significant effects on perceived inflation. They argue that this effect is due to a relative price increase of the most visible expenditure items in the period before the Euro introduction. The fact that household expectations are affected by the introduction of the European currency so substantially means that one has to be cautious in interpreting the results in table 12. Even though the final state estimates in table for the constant are highly significant it could be the case that as a result of this shock in 2002 our estimates for the coefficients are somewhat affected and may not have converged to their final values. A longer data period after the introduction of the currency would enable us be able to be more confident in the conclusions drawn from table 12.

5.2.2 Expectations of Professional Forecasters

Tables 13 and 14 show the results of tests of convergence with expectations of professional forecasters from 1990Q4-2006Q3.

	λ	**Std. Error**	**HSA**
Germany	0.998366	0.000199	-8.2094***
France	0.998787	0.000341	-3.5580***
Italy	0.994084	0.000368	-16.0773***
Netherlands	0.996944	0.000314	-9.7319***
Spain	0.998939	0.000394	-2.6927**
Euro Area	0.992691	0.000515	-14.1916***
* "No convergence" rejected at 10% confidence level			
** "No convergence" rejected at 5% confidence level			
*** "No convergence" rejected at 1% confidence level			

Table 16: Experts: Testing for Convergence

It can be seen that null hypothesis of 'no convergence' can be rejected at the 5% level of significance for all countries in our sample. However, λ is very close to 1, which implies that convergence takes a long time. It is again, interesting to note that with the exception of Spain and Germany the weight on lagged inflation converges to zero and expectations

		Final State	Root MSE	P-value
Germany	$\widehat{b}_1$	1.6322	0.2622	0.0000
	$\widehat{b}_2$	0.3248	0.1644	0.0482
France	$\widehat{b}_1$	1.7068	0.1753	0.0000
	$\widehat{b}_2$	-0.0021	0.0510	0.9716
Italy	$\widehat{b}_1$	1.6705	0.1825	0.0000
	$\widehat{b}_2$	0.0591	0.0872	0.4980
Netherlands	$\widehat{b}_1$	1.7160	0.1622	0.0000
	$\widehat{b}_2$	-0.0050	0.0534	0.9260
Spain	$\widehat{b}_1$	2.9048	0.3512	0.0000
	$\widehat{b}_2$	0.1007	0.0455	0.0270
Euro Area	$\widehat{b}_1$	1.7463	0.2636	0.0000
	$\widehat{b}_2$	0.1548	0.1156	0.1806

Table 17: Experts: Testing for Convergence: Final State Estimates

become more and more anchored to a constant. The coefficients on this constant seem to be more in line with the goal of the ECB than was the case for households. Only forecasters in Spain now consistently overestimate inflation. Professional forecasters hence seem to be more anchored to the correct ECB goal than households when estimating inflation. Figure 9 shows smoothed state estimates for the constant and lagged inflation. It can be seen that expectations have not been affected by the introduction of the Euro currency. The graphs in fact give further evidence that coefficients have converged to their final values given in table 14.

5.3 Discussion

It is found that household expectations in European economies do not seem to have converged to the inflation goal of the ECB. If there is a link between actual inflation and expected subjective rates of inflation, via a New Keynesian Phillips curve relationship for example, this implies that we will not see convergence in inflation rates in the European Union. Instead we should observe continued differences in inflation rates between Euro Area countries even though the average Euro Area inflation rate will be on target. Our results suggest that professional forecasters are more inclined to incorporate the implications of monetary union for convergence in inflation rates into their expectations than ordinary consumers. However, this is not true for all countries as expectations in Spain are still more linked to local inflation rates rather than the goal of the ECB.

Unfortunately, given the limited nature of the data on consumer expectations, it is not possible to test whether our results hold for longer expectation horizons (i.e expectations 2 years ahead). It should be noted that our findings correspond to those by Arnold and Lemmen (2006) who use a growth theory model to test for convergence and also find that Consensus data on inflation expectations of professional forecasters demonstrates more convergence than exists among the public.

6 Conclusion

Recently, there has been a growing number of theoretical papers modelling economic agents as econometricians when forecasting. Against this background this paper has provided the first attempt to assess whether learning behaviour of economic agents is a reasonable assumption for core Euro area economies. This was analysed using survey data on household and professional expert expectations for inflation and by assessing the fit of different linear forecasting rules with this data.

Overall, this paper provides further support for constant gain algorithms as a description of actual forecaster behaviour. Heterogeneity in expectations is found between different Euro Area economies and between households and professional forecasters. Households in high inflation countries use higher gain parameters and hence update their information sets more often than households in low inflation countries. A possible explanation for this behaviour is Sims' theory of Rational Inattention. It is also shown that professional forecasters are updating their information sets more frequently than households. This can be explained by theories of sticky information, in which households update their information sets much more infrequently than experts because of the substantial costs incurred by households in this updating process.

In the second part of the analysis the paper turned to the question of whether an equilibrium can be learnt by agents and whether agents incorporate the goal of the ECB into their expectations, which is to keep inflation close to but below 2%. We find that household and expert expectations converge to equilibrium but at a very slow rate. Furthermore the results show that household expectations do not seem to have converged to the goal of the ECB, which is to keep inflation close but below 2% in the medium run. On the contrary, professional forecasters seem more inclined to incorporate the implications of monetary union into their expectations. However, even for professional forecasters this is not true for every country. If it is the case that expected inflation rates have a direct influence on actual inflation via price and wage setting as proposed by New Keynesian theories, this finding may hence explain why convergence in inflation rates across countries in the European Monetary Union so far has not been observed in practice.

Some useful directions for further research should be noted. First of all, it would be interesting to evaluate more complicated forecasting models. Data on expectations of output are available for professional forecasters and with this data it would be possible to use vector autoregressive forecasting models in order to predict inflation-output vectors. Furthermore, it would be worthwhile to include more countries into our sample. The UK would be an interesting example, as it is not part of the monetary union and has had an independent central bank since 1997 with an explicit inflation target. One could for example investigate whether different institutional setups of central banks affect learning behaviour by agents. Once longer data sets on expectations are available it would be possible to test whether optimal constant gains stay constant over time. One could then examine whether learning is faster in periods of high inflation than in periods of low inflation, an empirical finding, which would give further support to theories of rational inattention. Additionally, with longer data sets, it would be possible to test whether agents exhibit switching behaviour as outlined by Marcet and Nicolini (2003) in which they switch between constant gain least squares and recursive least squares. In periods, which are stable, it would be optimal for agents to use recursive least squares and in periods in which inflation is very variable, agents should use constant gain least squares, which is robust to structural changes. It would be interesting to examine, whether recursive least squares outperforms constant gain least squares in periods with very stable inflation, such as have been observed recently. We leave this question to be explored in future research.

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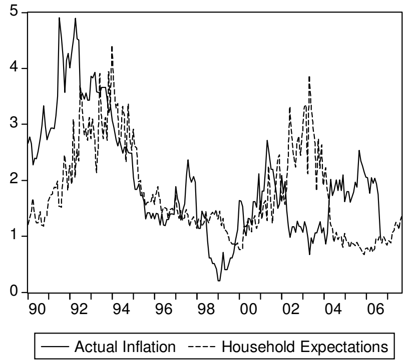
8 Annex 1: Tables and Figures

Figure 1: Actual Inflation and Household Expected Inflation from t-12 for t.



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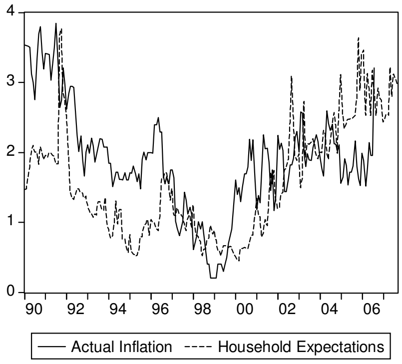

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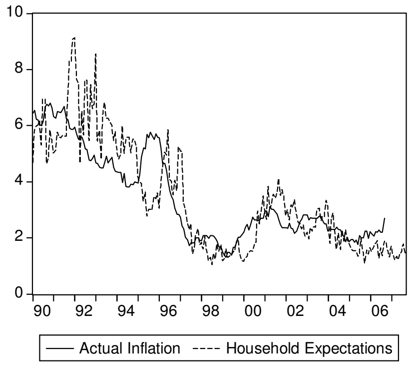

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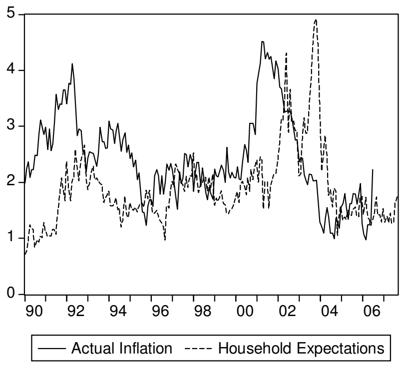

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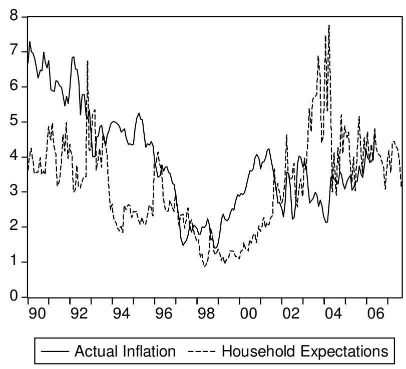

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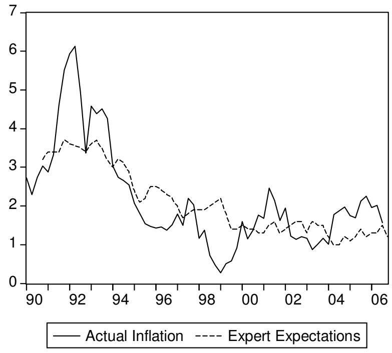
Figure 2: Actual Inflation and Consensus Forecasts from t-4 for t



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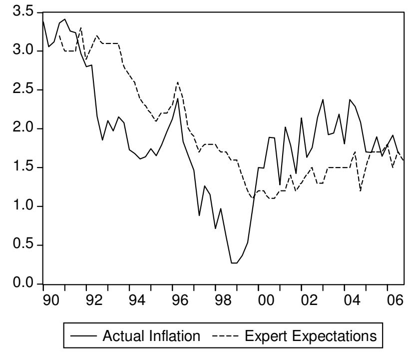

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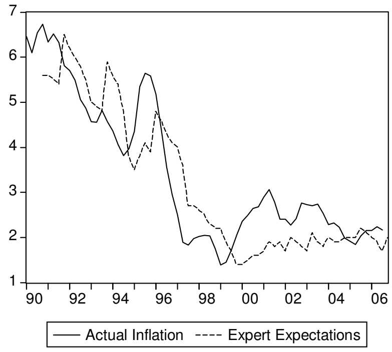

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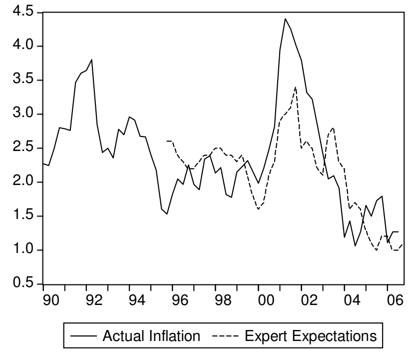

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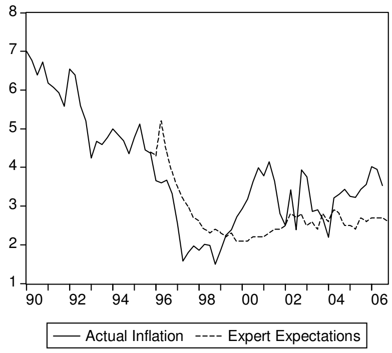

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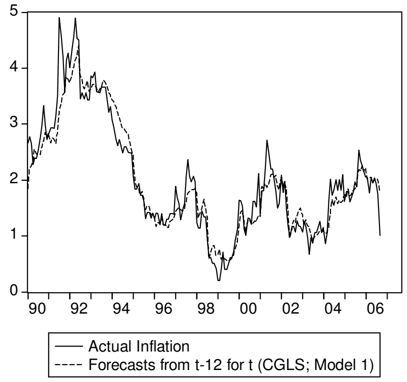
Figure 3: Actual Inflation and Forecasts from t-12 for t using Optimal Constant Gain and Model



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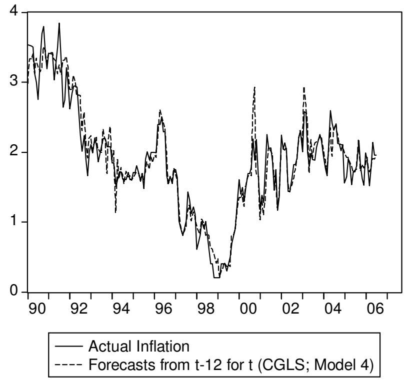

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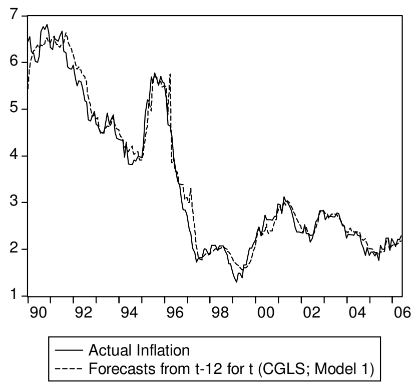

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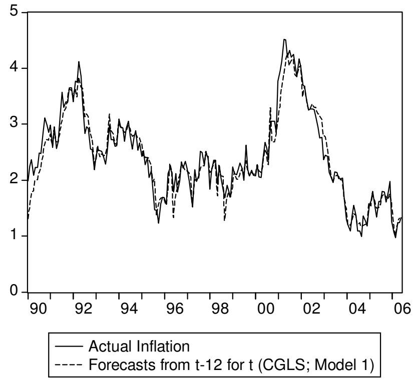

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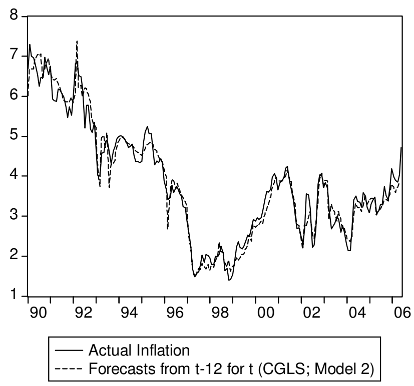

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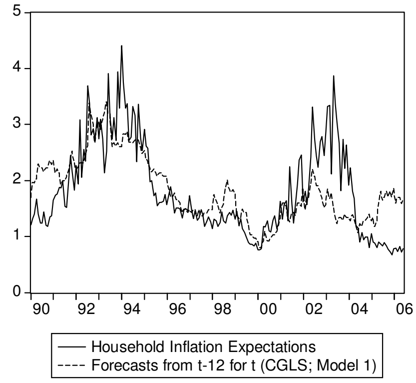
Figure 4: Household Expectations from t-12 for t and Generated Forecasts using Best-Fitting Gain Parameters and Best-Fitting Model



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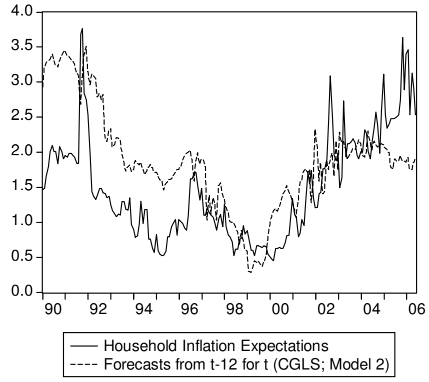

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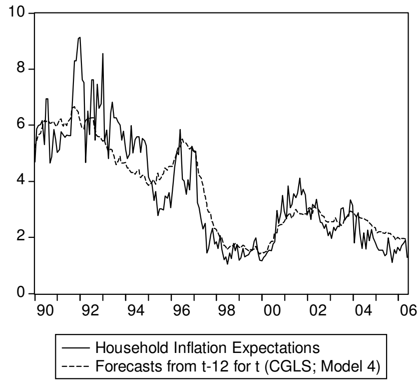

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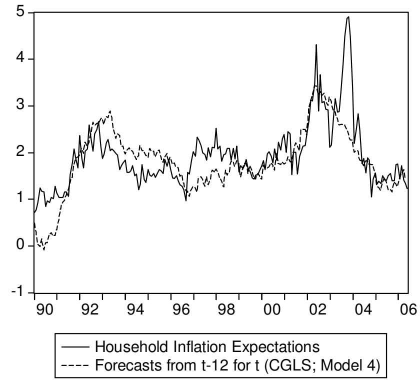

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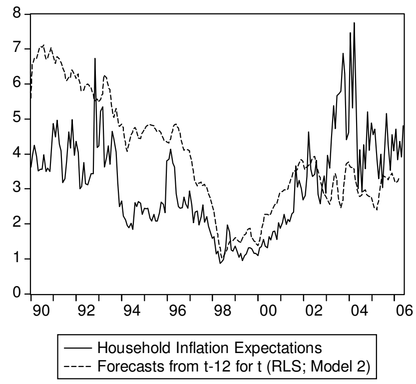

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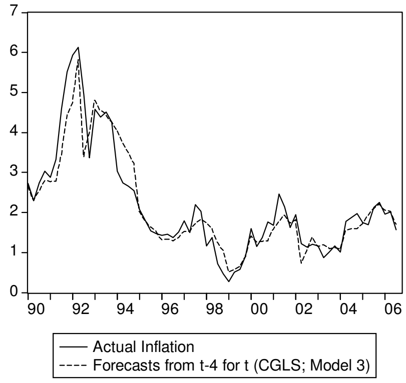
Figure 5: Actual Inflation and Generated Forecasts Using Optimal Gain Parameters and Optimal Model



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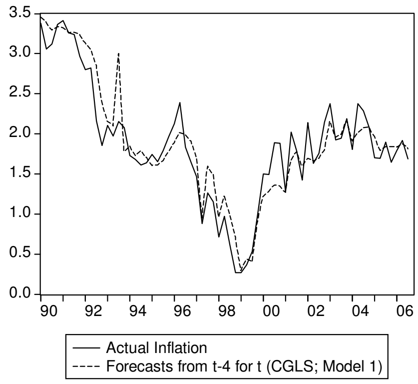

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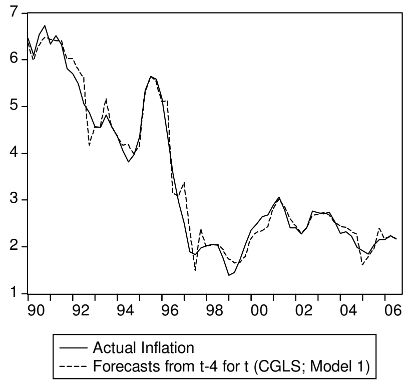

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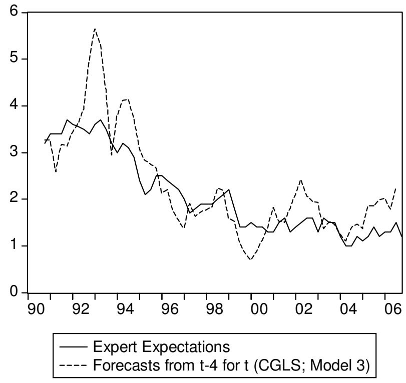
Figure 6: Consensus Forecasts from t-4 for t and Generated Forecasts using the Best-Fitting Gain and Best-Fitting Model



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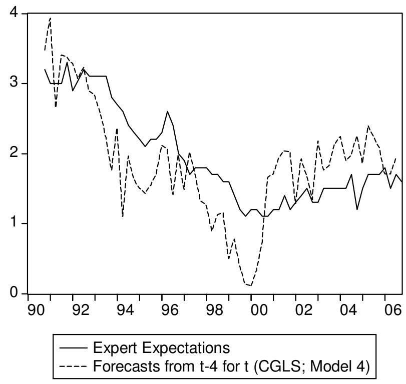

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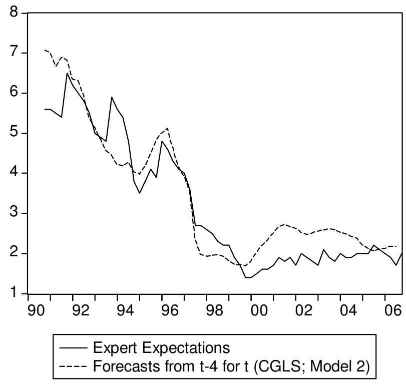

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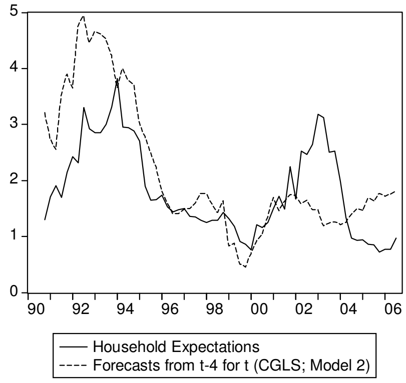
Figure 7: Household Expectations from t-4 for t and Generated Forecasts using the Best-Fitting Gain and Best-Fitting Model



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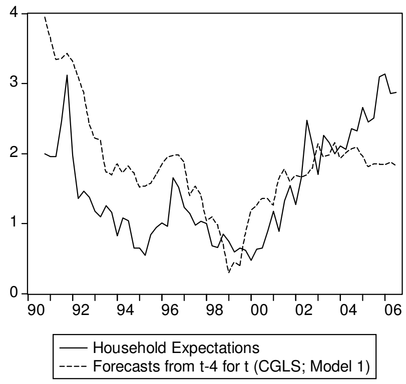

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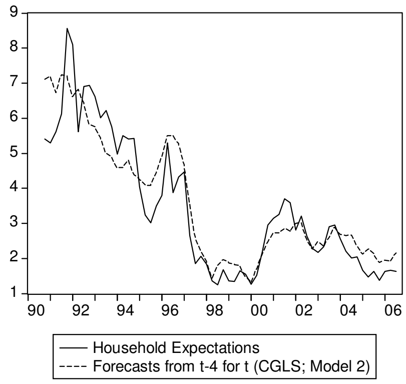

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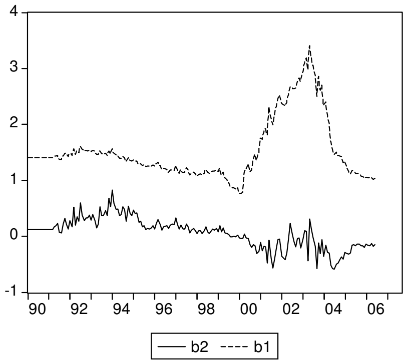
Figure 8: Smoothed State Estimates, Household Expectations



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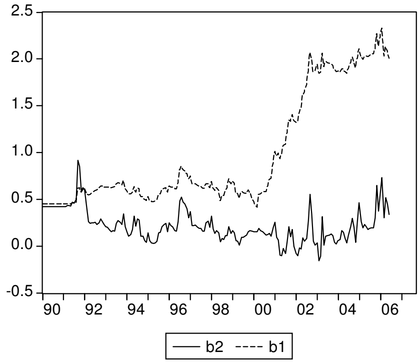

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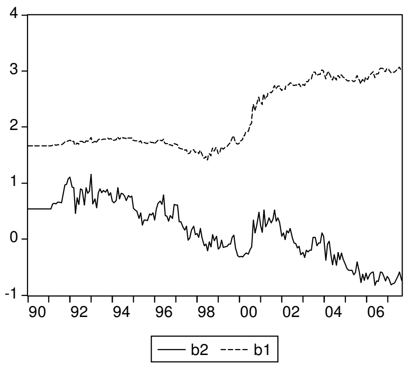

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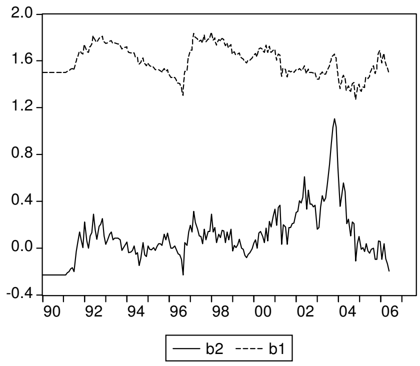

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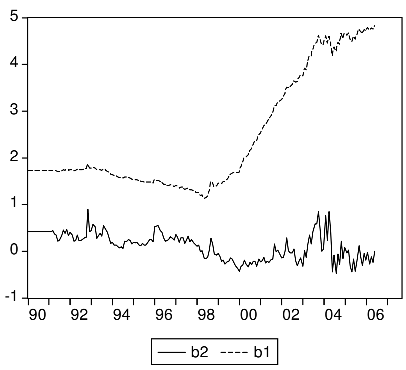

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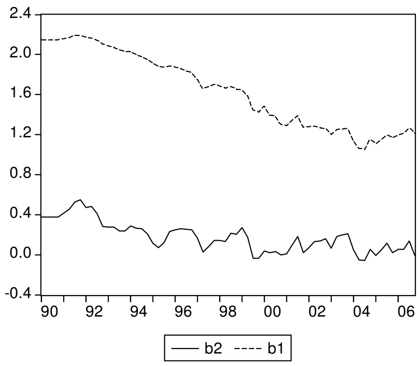
Figure 9: Smoothed State Estimates, Consensus Forecasts



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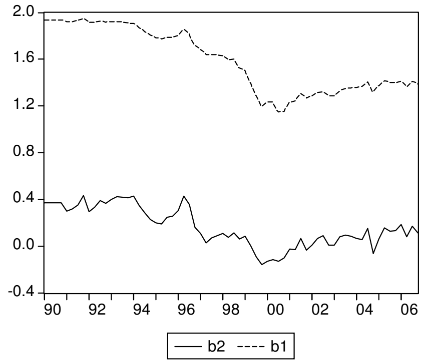

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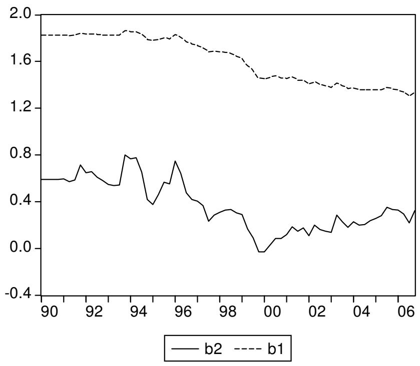

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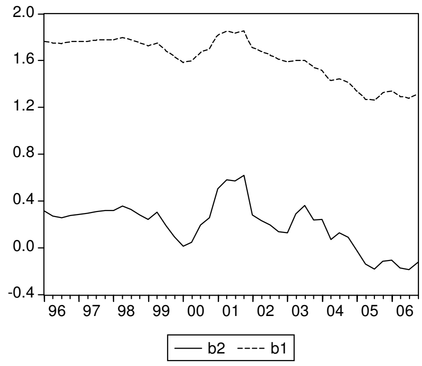

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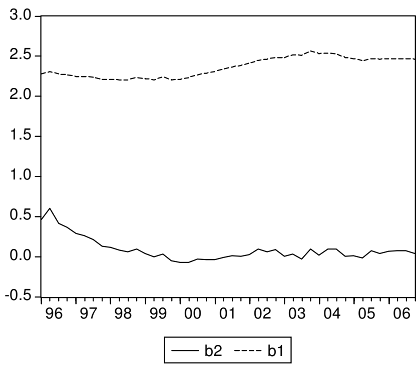

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9 Annex 2: The Data Set

Variable	Source	Frequency	Data period
Household Expectations for Inflation in $t + 12$	European Commission Consumer survey (DG ECFIN)	Monthly	1990M1-2006M9
Professional Experts Expectations for Inflation in $t + 4$	Consensus Economics	Quarterly	1990Q1-2006Q3
Consumer Price Index (HICP)	Eurostat-Indices of Consumer Prices	Monthly	1981M1-2006M9
Consumer Price Index-All Items	OECD-Main Economic Indicators	Quarterly	1961Q1-2006Q3
Industrial Production-All Items, Seasonally adjusted	Bank of International Settlements (BIS)	Monthly	1981M1-2006M9
GPP in real terms, Seasonally adjusted	Bank of International Settlements (BIS)	Quarterly	1961Q1-2006Q3
3-month interest rate	Bank of International Settlements and ECB	Monthly	1981M1-2006M9
3-month interest rate	Bank of International Settlements (BIS) and ECB	Quarterly	1961Q1-2006Q3

Table 18: Data Sources

The following Discussion Papers have been published since 2006:

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1	2006	The dynamic relationship between the Euro overnight rate, the ECB's policy rate and the term spread	Dieter Nautz Christian J. Offermanns
2	2006	Sticky prices in the euro area: a summary of new micro evidence	Álvarez, Dhyne, Hoeberichts Kwapil, Le Bihan, Lünnemann Martins, Sabbatini, Stahl Vermeulen, Vilmunen
3	2006	Going multinational: What are the effects on home market performance?	Robert Jäckle
4	2006	Exports versus FDI in German manufacturing: firm performance and participation in international markets	Jens Matthias Arnold Katrin Hussinger
5	2006	A disaggregated framework for the analysis of structural developments in public finances	Kremer, Braz, Brosens Langenus, Momigliano Spolander
6	2006	Bond pricing when the short term interest rate follows a threshold process	Wolfgang Lemke Theofanis Archontakis
7	2006	Has the impact of key determinants of German exports changed? Results from estimations of Germany's intra euro-area and extra euro-area exports	Kerstin Stahn
8	2006	The coordination channel of foreign exchange intervention: a nonlinear microstructural analysis	Stefan Reitz Mark P. Taylor
9	2006	Capital, labour and productivity: What role do they play in the potential GDP weakness of France, Germany and Italy?	Antonio Bassanetti Jörg Döpke, Roberto Torrini Roberta Zizza

10	2006	Real-time macroeconomic data and ex ante predictability of stock returns	J. Döpke, D. Hartmann C. Pierdzioch
11	2006	The role of real wage rigidity and labor market frictions for unemployment and inflation dynamics	Kai Christoffel Tobias Linzert
12	2006	Forecasting the price of crude oil via convenience yield predictions	Thomas A. Knetsch
13	2006	Foreign direct investment in the enlarged EU: do taxes matter and to what extent?	Guntram B. Wolff
14	2006	Inflation and relative price variability in the euro area: evidence from a panel threshold model	Dieter Nautz Juliane Scharff
15	2006	Internalization and internationalization under competing real options	Jan Hendrik Fisch
16	2006	Consumer price adjustment under the microscope: Germany in a period of low inflation	Johannes Hoffmann Jeong-Ryeol Kurz-Kim
17	2006	Identifying the role of labor markets for monetary policy in an estimated DSGE model	Kai Christoffel Keith Küster Tobias Linzert
18	2006	Do monetary indicators (still) predict euro area inflation?	Boris Hofmann
19	2006	Fool the markets? Creative accounting, fiscal transparency and sovereign risk premia	Kerstin Bernoth Guntram B. Wolff
20	2006	How would formula apportionment in the EU affect the distribution and the size of the corporate tax base? An analysis based on German multinationals	Clemens Fuest Thomas Hemmelgarn Fred Ramb

21	2006	Monetary and fiscal policy interactions in a New Keynesian model with capital accumulation and non-Ricardian consumers	Campbell Leith Leopold von Thadden
22	2006	Real-time forecasting and political stock market anomalies: evidence for the U.S.	Martin Bohl, Jörg Döpke Christian Pierdzioch
23	2006	A reappraisal of the evidence on PPP: a systematic investigation into MA roots in panel unit root tests and their implications	Christoph Fischer Daniel Porath
24	2006	Margins of multinational labor substitution	Sascha O. Becker Marc-Andreas Mündler
25	2006	Forecasting with panel data	Badi H. Baltagi
26	2006	Do actions speak louder than words? Household expectations of inflation based on micro consumption data	Atsushi Inoue Lutz Kilian Fatma Burcu Kiraz
27	2006	Learning, structural instability and present value calculations	H. Pesaran, D. Pettenuzzo A. Timmermann
28	2006	Empirical Bayesian density forecasting in Iowa and shrinkage for the Monte Carlo era	Kurt F. Lewis Charles H. Whiteman
29	2006	The within-distribution business cycle dynamics of German firms	Jörg Döpke Sebastian Weber
30	2006	Dependence on external finance: an inherent industry characteristic?	George M. von Furstenberg Ulf von Kalckreuth
31	2006	Comovements and heterogeneity in the euro area analyzed in a non-stationary dynamic factor model	Sandra Eickmeier

32	2006	Forecasting using a large number of predictors: is Bayesian regression a valid alternative to principal components?	Christine De Mol Domenico Giannone Lucrezia Reichlin
33	2006	Real-time forecasting of GDP based on a large factor model with monthly and quarterly data	Christian Schumacher Jörg Breitung
34	2006	Macroeconomic fluctuations and bank lending: evidence for Germany and the euro area	S. Eickmeier B. Hofmann, A. Worms
35	2006	Fiscal institutions, fiscal policy and sovereign risk premia	Mark Hallerberg Guntram B. Wolff
36	2006	Political risk and export promotion: evidence from Germany	C. Moser T. Nestmann, M. Wedow
37	2006	Has the export pricing behaviour of German enterprises changed? Empirical evidence from German sectoral export prices	Kerstin Stahn
38	2006	How to treat benchmark revisions? The case of German production and orders statistics	Thomas A. Knetsch Hans-Eggert Reimers
39	2006	How strong is the impact of exports and other demand components on German import demand? Evidence from euro-area and non-euro-area imports	Claudia Stirböck
40	2006	Does trade openness increase firm-level volatility?	C. M. Buch, J. Döpke H. Strotmann
41	2006	The macroeconomic effects of exogenous fiscal policy shocks in Germany: a disaggregated SVAR analysis	Kirsten H. Heppke-Falk Jörn Tenhofen Guntram B. Wolff

42	2006	How good are dynamic factor models at forecasting output and inflation? A meta-analytic approach	Sandra Eickmeier Christina Ziegler
43	2006	Regionalwährungen in Deutschland – Lokale Konkurrenz für den Euro?	Gerhard Rösl
44	2006	Precautionary saving and income uncertainty in Germany – new evidence from microdata	Nikolaus Bartzsch
45	2006	The role of technology in M&As: a firm-level comparison of cross-border and domestic deals	Rainer Frey Katrin Hussinger
46	2006	Price adjustment in German manufacturing: evidence from two merged surveys	Harald Stahl
47	2006	A new mixed multiplicative-additive model for seasonal adjustment	Stephanus Arz
48	2006	Industries and the bank lending effects of bank credit demand and monetary policy in Germany	Ivo J.M. Arnold Clemens J.M. Kool Katharina Raabe
01	2007	The effect of FDI on job separation	Sascha O. Becker Marc-Andreas Mündler
02	2007	Threshold dynamics of short-term interest rates: empirical evidence and implications for the term structure	Theofanis Archontakis Wolfgang Lemke
03	2007	Price setting in the euro area: some stylised facts from individual producer price data	Dias, Dossche, Gautier Hernando, Sabbatini Stahl, Vermeulen
04	2007	Unemployment and employment protection in a unionized economy with search frictions	Nikolai Stähler

05	2007	End-user order flow and exchange rate dynamics	S. Reitz, M. A. Schmidt M. P. Taylor
06	2007	Money-based interest rate rules: lessons from German data	C. Gerberding F. Seitz, A. Worms
07	2007	Moral hazard and bail-out in fiscal federations: evidence for the German Länder	Kirsten H. Heppke-Falk Guntram B. Wolff
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