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Forecasting Inflation via Electronic Markets Results from a Prototype Experiment

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Summary. Forecasts of macroeconomic variables as the inflation rate serve as important guidelines for the private as well as the public sector. At least central banks that adopted an inflation targeting regime are in urgent need of high quality inflation forecasts. Accurate inflation forecasts are also needed within private sector wage negotiations. In this paper we present a new method to predict future inflation via conducting electronic markets. We show at the example of a prototype market how the market data of such an experimental market can be used to generate predictions of the future inflation rate. We also show that the market data provide important evidence on the distribution of inflation expectations.

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Introduction

Electronic market research started to evolve in the aftermath of a market experiment set up by a group of researchers from the University of Iowa. On the occasion of the 1988 presidential election in the United States they organized an electronic market where shares on the candidates for presidentship were traded. This first political stock market proved to be highly successful in predicting the outcome of the presidential election.[1] Motivated by the good results the Iowa Electronic Markets (IEM) were founded to organize electronic markets regularly. Since 1988 IEM organized a large number of markets, most of them on the occasion of political elections.[2] Altogether the markets were quite successful in predicting the electoral outcome.[3] Initiated and strongly supported by members of IEM, political stock markets were also organized outside the U.S., for instance in Austria, Canada, Denmark, Germany, Italy, the Netherlands and Turkey. Though the electoral systems and the political landscapes in these countries are somewhat more complex than in the U.S. the most of these markets provided well forecasting results. A recent meta study by *Berlemann and Schmidt* (2001) for 28 German political stock markets showed that on average the markets proved to be even more successful in predicting the electoral outcome than the polls of public opinion research institutes.

Political stock markets' success in predicting political events made us believe that it could be fruitful to think about transferring the idea of using electronic markets as a forecasting device to genuine economic events. We argue that a well-designed electronic market should also be able to provide some reasonable forecast of macroeconomic variables. In this paper we focus on the question, how electronic markets can be used to forecast future inflation. Using binary options, we develop a prototype-market for forecasting inflation. We also present empirical results from a recent pilot experiment with an inflation forecasting market and show how the market reveals worthy information on future inflation and the probability of different inflation scenarios.

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[1] For a description of the 1988 presidential stock market compare *Forsythe et al*. (1992).

[2] For an overview on the political stock markets organized by IEM compare *Berg et al*. (1997). More information on IEM is provided on the *IEM-Homepage*: http://www.biz.uiowa.edu/iem.

[3] It should be noted that the main objective of electronic market research was to 'produce' market data in an at least somewhat controlled environment to analyze aspects like individual market behavior, information aggregation within markets or informational efficiency of markets. In the beginning of electronic market research forecasts were only some kind of by-product of conducting markets. Even if the data from the markets we propose can be used study market behavior, too, we will solely focus on the forecasting aspect in this paper.

The paper is organized as follows: In the second section we deal with the question why forecasting inflation is an important issue. The third section briefly reviews conventional methods of forecasting inflation. In section Four the basic design of an inflation forecast market is developed. We also show why we expect this market to produce some high quality inflation forecast in this section. Section Five presents empirical results from a recent pilot experiment with an inflation forecasting market. In section Six we show some further evaluations of the market data under the assumption of normally distributed expectations. In section Seven we compare the electronic markets system with conventional forecasting methods and discuss unresolved questions and possible further extensions. Section Eight summarizes the main results and gives a short outlook on future research ideas.

Why Bother with Future Inflation?

The starting point of the following expositions is the question, why people care about future inflation or – at least – why they should care about it. Inflation, defined as permanent increases of the aggregate price level, is typically supposed to cause several effects that might positively or negatively influence personal and social welfare. The reason why the goal of a stable price level is a major objective of economic policy all around the world is that the negative distributional and allocative effects of (expected and unexpected) inflation are typically supposed to dominate the positive ones.[4]

Nowadays, in the most countries the central banks are concerned with the goal of guaranteeing stable prices. In order to so, an increasing number of central banks have adopted a so-called 'inflation targeting regime' during the last decade. Inflation targeting is a framework for monetary policy that is characterized by announcing an explicit official target or at least a target range for the inflation rate for some predefined period of time. In an inflation targeting framework there is a strong commitment of the monetary authority to concentrate on holding inflation within the target range as the primary goal of monetary policy. An important element of such a strategy is a high degree of transparency with respect to the central bank's objectives as well as to the undertaken actions to fulfill them. Since monetary policy affects the inflation rate with a lag of some 18 – 24 months, monetary policy has to be forward looking. *Svensson* (1997) showed that the implementation of an inflation targeting regime for monetary policy implies to use the inflation fore-

[4] *Sill* (1999), p. 5.

cast as intermediate target in a way that monetary policy should be tightened when actual inflation expectations exceed the target level and the other way round. Even if a monetary authority follows a different monetary policy strategy but still primarily tries to guarantee stable prices it often uses inflation expectations as an important indicator, at least with respect to the credibility of its monetary policy strategy. Whenever a central bank that is committed to low inflation observes high inflation expectations, the actual monetary strategy seems not to be highly credible. A central bank might take this as a signal to think over the actual policy strategy.

Even if central banks in industrial countries were quite successful in fighting inflation within the last decade, inflation was not eliminated at all. There is even no guarantee that the actually low levels of inflation will last within the future. Thus also private institutions are interested in future inflation to anticipate expected changes in the aggregate price level in order to prevent negative distributional effects of unexpected inflation. Banks carry an interest in anticipating future inflation in credit contracts. Labor unions try to anticipate future inflation during the wage negotiations to prevent their members from suffering unexpected losses in real wages *etc.*

Last but not least researchers are interested in the way how people make individual forecasts on macroeconomic variables like inflation. Empirical data on this aspect are worthy to test different hypotheses on the formation of expectations, thereby providing evidence how to model the private sector in macroeconomic models.

Altogether we may conclude that governmental as well as private institutions are in urgent need of forecasts of future inflation. In fact, by far the most central banks care very much about future inflation and often invest a lot of resources into forecasting activities. The same is true for private banks and firms.

Conventional Forecasting Methods

There are two basic concepts of dealing with the problem of forecasting future inflation. The first concept, we will call it the 'econometric approach' in the following, tries to generate forecasts on the basis of actual and historical empirical data using econometric techniques. The basic idea of this approach is that there is some theoretical model explaining by which factors inflation is determined. Whenever we believe to know, which is the correct model and we have the necessary data at hand we should be able to produce some reasonable forecast of future inflation. The second concept of forecasting inflation, we will call it 'expectations approach,' does not care about the question which is the appropriate theory allowing to predict future inflation. The expectations approach simply suggests that a certain subgroup of people, caring about future inflation, knows enough about the true determinants of price level changes to be able to predict future inflation well on average. Thus it is sufficient to measure the inflation expectations of an informed subgroup without knowing which methods are used for the individual forecasts.

It is easy to imagine that both, the econometric and the approaches of measuring inflation expectations are themselves quite heterogeneous. In the following we will give a brief overview on the typically used methods.

The Econometric Approach

When using econometric methods for forecasting purposes we typically start out from some theoretical model how the economy works. It is out of the question that an economy is an extremely complex and highly dynamic system. On the one hand the model should capture as many important relationships between the relevant macroeconomic variables as possible to be successful in forecasting. On the other hand a growing complexity of the model typically increases the problems to handle it and to use econometric forecasting methods. In the end the problem to solve typically is to determine which econometric model allows to reach a given average forecasting success by the lowest effort.

As it was argued earlier in this paper, most central banks are in urgent need of precise inflation forecasts. Thus it is no surprise that central banks typically invest a lot of resources into forecasting activities. Most central banks use highly complex macroeconometric core-models that sometimes consist of more than a hundred of equations. While the basic inflation forecasting concepts of the central banks are typically well documented,[5] it is often hard to get detailed information on how the forecasts are done.[6] In any case the models are far too complex to be reviewed at length in this paper.

The basic problem with purely econometric models is that they try to estimate future inflation via past observations of inflation itself and other realizations of macroeconomic variables. These models are backward-looking

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[5] Compare e.g. *Poloz, Rose and Tetlow* (1994) for the Bank of Canada's, *Goodhart* (2001) for the Bank of England's, *Cassino et al.* (1997) and *Drew and Hunt* (1998) for the Bank of New Zealand's, *Jansson and Vredin* (2001) for the Swedish Riksbank's and *Brayton et al.* (1997) for the Federal Reserve Bank's forecasting system.

[6] An exception is the detailed report on the Bank of England's forecasting system (Bank of England, 1999).

thereby neglecting the Lucas-Critique. It is easy to understand that such models will hardly be able to predict changes in inflation expectations that have to do with news like announcements of future policy changes, at least in the long run.[7] It is also hard to say something about the probability of different inflation scenarios on the basis of these models.

Even if the used forecasting models differ quite heavily from case to case, some regularities can be observed. Most central banks do not rely on a single econometric inflation forecasting model. Often the core-model is supplemented by less complex models to generate forecasts for exogenous variables, to adjust the core model for short-term disequilibria or to simply control for the plausibility of the core-model's predictions. The Bank of England as well as the Federal Reserve Bank use – among others – Phillips curve models for this purpose.[8] Even if central banks invest a lot of resources into econometric forecasting models they often do not completely rely on these models' forecasts. *George* (1999, p. V), the Bank of England's Governor, states in this respect:

> "The Bank's use of economic models is pragmatic and pluralist. In an ever-changing economy, no single model can possibly assimilate in a comprehensive way all the factors that matter for policy. Forming judgements about those factors, and their implications for policy, is the job of the Committee, not something that can be abdicated to models or even to modelers. But economic models are indispensable tools in that process."

Thus individual beliefs and judgments often play an important role even in inflation forecasts that are based upon econometric models.

Since the inflation forecasts from econometric models of central banks are often not published,[9] it is hard to judge the quality of this type of forecasts. Even if the forecasts are publicly announced, often the time series are too short to assess the forecast's quality empirically. In a recent study *Atkeson and Ohanian* (2001) analyzed in how far different types of Phillips

[7] *Ragan* (1995), p. 4.

[8] Compare Bank of England (1999), p. 77-92 or *Stock and Watson* (1999) for a description of *Phillips* curve models.

[9] The Bank of England publishes its inflation forecasts within the regular inflation reports. Nevertheless, the mean inflation forecast is somewhat hard to assess because the forecasts are presented in the form of so-called fan-charts. Somewhat surprising neither the empirical data underlying this fan-chart nor the mean inflation forecast is provided numerically. The Federal Reserve Bank treats its own inflation forecasts as confidential and therefore publishes them with a lag of five (!) years in the so-called *Greenbook*.

curve models, as they are used by the Federal Reserve Bank or the Bank of England, are useful for forecasting inflation. Using US data they show that the predictions of these models were worse than simply assuming that inflation will be the same over the next year as it has been over the last year. Interestingly enough, *Atkeson and Ohanian* (2001) also found that even the Federal Reserve Bank's inflation forecasts, published in the Greenbook, proved not to be better than the naive forecast that everything stays the same in the future.

The Expectations Approach

As it was described earlier, the expectations approach does not care about the question which is the appropriate model of the economy. The basic idea of the expectations approach is that many people care – or at least should care – about inflation. Since inflation directly decreases purchasing power of all monetary assets, people owning or intending to buy these assets will make individual predictions on future inflation. The individual beliefs on future changes in the price level might differ heavily because of heterogenous information sets and different ways of interpreting them (i.e. individuals might use different theoretical 'models' for their forecasts). If individual expectations are formed rationally they should be a good predictor for future inflation. Thus the basic question to be answered is how to measure inflation expectations.

Again there are two basic concepts how to solve the problem of measuring inflation expectations: conducting inflation expectation surveys or deriving inflation expectations from financial market data. In the following we will briefly describe both approaches.

Inflation Expectation Surveys

The most direct way to assess inflation expectations is to conduct qualitative or quantitative inflation expectation surveys.

The most commonly applied qualitative survey method is the so-called 'net balance statistic'. In these surveys the respondents have to guess whether inflation will 'go up', 'stay the same' or 'go down' within a certain period of time. In its simplest form the net balance value is then obtained by simply subtracting the proportion of respondents that supposed the inflation rate to decrease from the one that predicted increasing inflation.[10]

[10] For a more detailed discussion of the net balance statistics compare *Batchelor* (1986) and *Foster and Gregory* (1977).

In direct quantitative surveys the respondents have to state numerical values for expected inflation.[11] The results then have to be aggregated by some procedure. Typically the answers of the respondents are weighted equally to calculate the mean inflation expectation. Often quantitative surveys are conducted separately for different groups in society, e.g. households, manufacturers or professional forecasters.[12]

In a expert's report on the measurement of inflation expectations, made out on the occasion of the recent adoption of an inflation targeting regime in South Africa, *Laubscher and Schombee* (1999) evaluated experiences of 6 inflation targeting countries and the United States with different inflation expectations surveys. Their main results can be summarized as follows:

- Direct quantitative inflation expectation surveys typically perform better than qualitative surveys. The net balance statistics creates somewhat erratic forecasts correlating poorly with real inflation. In addition to that net balance statistics turned out to be biased downwards in times of high inflation and high uncertainty and *vice versa*.
- The best results with respect to predicting core inflation and future nominal wage growth can be obtained by household and consumer surveys while the results of surveys of professional forecasters and economists perform better in predicting future interest rate movements.

Nevertheless there are various unresolved problems with quantitative inflation expectation surveys due to the typical survey errors:

- There is an urgent need of having a representative sample to reduce sampling errors. It is a long known fact that such a sample is hard to obtain. As *Laubscher and Schombee* (1999, p. 16) report, the response rates in inflation expectation surveys are generally low (25 up to 35%). This makes it nearly impossible to obtain a representative sample.

[11] Prominent examples for quantitative inflation expectations surveys are the Livingston Survey and the Survey of Professional Forecasters, conducted by the Federal Reserve Bank of Philadelphia.

[12] In an analysis for US data *Gramlich* (1986) found the surprising result that the quantitative expectation surveys of consumers, namely the University of Michigan ISR consumer survey, performed significantly better than the Livingston survey of professional forecasters in forecasting future inflation. Similar results were found by *Roberts* (1998). In addition to that the lower educated and poorer consumers performed better in forecasting inflation than those of the higher educated and richer consumers on average. Thus different groups in society seem to have different levels of information or at least do react differently on certain types of information.

- The questions the respondents have to answer within the survey have to be formulated very carefully to avoid answering biases. The same is true for the used questioning technique. Especially the often used telephone surveys are prone to different sorts of biases.
- The timing of inflation expectation surveys is extremely important. All respondents should be asked within a short period of time to ascertain that the basic information set is the same.
- One of the most important problems is that the respondent typically have no incentive to reveal their true expectations. Often the respondents are rewarded financially for answering and thus have a strong incentive to take part in the survey even if they have no information on future inflation at all or do not care about the topic. In addition to that the interviewers might motivate uninformed respondents to answer nevertheless because they are paid per interview and typically are interested in minimizing their transaction costs.
- Given that the survey typically includes a good number of very poor informed respondents it seems to be somewhat questionable to attach the same weight to each individual interview. This aggregation problem can hardly be solved because the level of information of a respondent can not be measured objectively.

Thus there are several theoretical arguments explaining why inflation expectation surveys do not predict future inflation very accurately.

Gauging Inflation Expectations from Financial Market Data

Two major problems of the direct approach of measuring inflation expectations are, as pointed out earlier, that the interviewed people have no incentive to reveal their true expectations and the aggregation problem. Both problems can be solved by means of gauging inflation expectations from financial market data. According to the Fisher relation (compare *Fisher* (1930))

$$i_t^m = E_t[\pi_t^m] + r_t^m \qquad (1)$$

inflation expectations at time t with respect to time m, denoted by $E_t[\pi_t^m]$, affect nominal interest rates i. The basic problem to solve when using the Fisher equation to extract inflation expectations from financial market data is how to get information on the corresponding real interest rate r.

Inflation expectations are easy to extract from market data when there is a well-functioning market for real (indexed) bonds. In that case we can sim-

[13] Compare *Deacon and Derry* (1994) or *Svensson* (1994).

ply subtract the real interest rate from the nominal interest rate of equal-maturity bonds to obtain inflation expectations.[13] Since there are only a few countries with markets for indexed bonds this method can rarely be used.

If there is no market for indexed bonds it is possible to gauge inflation expectations from the term structure of (nominal) interest rates on government bonds[14] under certain circumstances. Ex-post inflation within the period from t to m can be described by

$$\pi_t^m = E_t[\pi_t^m] + \varepsilon_t^m \tag{2}$$

with ε being the forecast error. Combining equation (2) and (1) we obtain

$$\pi_t^m = i_t^m + r_t^m + \varepsilon_t^m \tag{3}$$

Using equation (3) for bonds with two different maturities m and n with $m > n$ leads to

$$\pi_t^m - \pi_t^n = (i_t^m - i_t^n) - (r_t^m - r_t^n) + (\varepsilon_t^m - \varepsilon_t^n) \tag{4}$$

Under the assumption of rationally formed expectations the expectation errors are zero on average. If we further assume that the real interest rate is not changing between time n and m or we at least know on how much it is assumed to change within this period, we are able to calculate the financial market's inflation forecast.[15]

Altogether the empirical results on the predictive quality of the above described method are not very promising. While *Mishkin* (1990,1991) and *Estrella and Mishkin* (1997) found at least long term forecasts to be somewhat reliable, *Jochum and Kirchgassner (*1999) show that even these results do not hold when taking non-stationarity of at least some of the data into account.

Conclusions

It was shown that all described methods of forecasting inflation have their advantages and their drawbacks. Thus it is not surprising that none of them dominates in the practice of forecasting. Most central banks rely on a mixture of the concepts and often decide somewhat discretionary on the appropriate forecast. We might interpret this as some kind of distrust in conventional forecasting methods. Thus further research in methods of measuring future inflation seems to be useful and necessary.

[14] Governmental bonds are used because they are assumed to have the lowest degree of default risk, thereby assuring that the nominal interest rates contain no risk premium.

[15] For an overview on more advanced methods to extract inflation forecasts from financial instruments compare e.g. *Soderlind and Svensson* (1997).

The Design of an Electronic Inflation Forecasting Market

In the face of the fact that conventional methods of forecasting did not prove to be highly reliable in predicting future inflation, yet, it might be useful to think about alternative forecasting methods. Our proposal is to use well-designed electronic markets for this purpose. The forecasting system we propose is some kind of combination of the two expectation approaches (expectation surveys, use of market data) we already discussed.

Principally, electronic market research belongs to the field of experimental economics. An electronic market is a virtual market where shares on certain events are traded. Typically electronic markets are organized via internet and on the basis of real-money transactions. In the following we will show how an electronic market can be designed to forecast future inflation at the example of a recently conducted prototype market.

Market Admittance

Electronic markets are fully computerized markets. To be able to take part in such a market, participants have to register for admittance via internet, first. Besides providing some personal data during the process of registration, participants have to decide on their personal initial investments. Typically investments are somewhat restricted due to legislative restrictions. In the prototype market the minimum investment was 10 euro and the maximum investment was 500 euro. The initial investments have to be covered by the traders. All transactions in the market are based on real money. Each participant can win or loose money in the market, depending on his or her success in trading.

As soon as the initial investment has been transferred to the market organizer (typically this is done via cash or bank transfer to a market account) the participant gets a trader-ID and a password to login the market. In addition to that a trader account for the participant is created and his initial investment is transferred to the account.

Technical precondition for taking part in an electronic market is an internet connection. Even if there were no formal restrictions for participation in the prototype market the most traders were students of economics and business administration at Dresden University of Technology. The market was presented within two university courses on monetary economics[16] and

[16] The students in these two courses got an extra endowment of 5 euro when investing at least ten euro on their own as an additional incentive to take part in the market. It should also be

was announced in some other university courses.

Market Setup

Within the prototype market certain types of future contracts were traded. The complete set of contracts that was traded in the market and the contracts' payoff structure are shown in Table 1.

Table 1

TRADED CONTRACTS

Contract name	Pays off 1 euro, if
I_0.0-	I<0,0
I_0.0-1.5	0.0 ≤ I<1.5
I_1.5-2.0	1.5 ≤ I<2.0
I_2.0-2.5	2.0 ≤ I<2.5
I_2.5-3.0	2.5 ≤ I<3.0
I_3.0-3.5	3.0 ≤ I<3.5
I_3.5-4.0	3.5 ≤ I<4.0
I_4.0+	4.0 ≤ I

Initially there were eight types of contracts in the market. The ultimate value of these contracts depended on the realization of the German year-to-year inflation rate in February 2001 (I), as announced by *Statisches Bundesamt Wiesbaden* on 10 March 2001. The payoff, a certain type of contract generated on the liquidation day, was 1 euro if the German inflation rate for February 2001 turned out to fall into the interval, the contract was denominated to, and 0 euro otherwise. Thus we deal with so-called 'simplex options'. To illustrate the liquidation procedure assume that the inflation rate turns out to be 1.8%. In this case all 'I_1.5-2.0'-contracts are worth 1 euro and all other contracts are worth nothing. Markets where simplex options are traded are called 'winner-takes-all-markets'.

On 22 November the contract 'I_2.0-2.5' was split into two contracts: 'I_2.0- 2.25' and 'I_2.25-2.5'. Therefore, each participant who held former 'I_2.0-2.5'-contracts in his portfolio was endowed with the same number of the two new contracts. Thus the expected worth of the participants' portfolios was not changed by the contract split. The contract split was done be-

noted that the students had to answer some questions on electronic markets in their final examination. This surely increased their interest in taking part.

cause it was observed that the former ‘I_2.0-2.5’-contract had been traded for quite high prices, thus indicating that the participants attached a high probability to the event that the inflation rate would have been in between 2 and 2.5%. To be able to forecast the inflation rate more accurately, the former contract ‘I_2.0-2.5’ was divided into two new contracts covering the same interval.

Market Liquidation

The prototype market was liquidated soon after the German inflation rate for February 2001 was announced on 10 March. This was done by the following two-step procedure:

1. Each participant got back the money he held on his market account in the end of the market.
2. Each participant got the liquidation value of the portfolio of contracts, he held in the end of the market.

To illustrate the liquidation procedure we shall give an example of an imaginary participant X.

Therefore we assume that the inflation rate turned out to be 1.8%. The second column in Table 2 shows the individual portfolio of participant X and the third column the liquidation values of the contracts. The total value of X’s portfolio of contracts is 13 euro. Adding the 3 euro X is assumed to hold on his market account he gets a total payoff of 16 euro.

Table 2

PORTFOLIO LIQUIDATION FOR AN IMAGINARY PARTICIPANT X UNDER THE ASSUMPTION THAT THE INFLATION RATE TURNED OUT TO BE 1.8%

Contract/asset	Number of contracts in portfolio of participant X	Liquidation value per contract unit	Total value in euro
I_0.0-	76	0	0
I_0.0-1.5	4	0	0
I_1.5-2.0	13	1	13
I_2.0-2.5	2	0	0
I_2.5-3.0	5	0	0
I_3.0-3.5	9	0	0
I_3.5-4.0	5	0	0
I_4.0+	0	0	0
Cash on account	3	-	3
Total payoff	-	-	16

Trading within the Inflation Market

The prototype market was open for transactions at any time during the market period, i.e. from 9 October 2000 up to 15 March 2001. Upon entering the market and any time thereafter until the market closed a participant could buy unit portfolios (so-called ‘bundles’) from the market organizer for the price of 1 euro. Each unit portfolio consisted of one of each type of contracts. Thus a bundle in the inflation market included 8 contracts initially and 9 contracts after the contract split. Complete unit portfolios could also be sold back to the market organizer during the market period for the price of 1 euro each. Selling and buying unit portfolios from or to the market organizer are primary market transactions.

Together with the already described market-liquidation procedure the pricing of the unit portfolios guaranteed that the market is a zero-sum-game for the market organizer. All initial investments were paid back to the participants. The market was typically no zero sum game for the individual participant since he could win or loose money, depending on his success in trading within the market.

To be able to realize profits in the market, a participant had to trade within the secondary market, i.e. he had to buy or sell contracts from or to other participants.[17] The secondary market was organized as a so-called ‘double-auction-market’. The participants could issue offers to buy (bids) or offers to sell (asks) contracts. When using the first type of transactions, the so-called ‘limit orders’, the traders had to choose the order type (bid or ask), the contract type (e.g. ‘I_0.0- 1.5’), the number of contracts he wants to trade, the transaction price and finally the expiration date of the order. Limit orders were maintained in separate bid and ask queues ordered first by offer price and then by the time of issuance. Whenever an offer entered one of the queues it remained there until the offer turned out to be unfeasible (e.g. because of a lack of liquidity to realize a buying transaction), was withdrawn by the trader, reached its expiration date or was carried out. Orders were carried out whenever bid- and ask-prices overlapped.

The market software provided several facilities for the traders to obtain information on the market. On the one hand, the trader got personal information about his market account, current portfolio and the orders he submitted. On the other hand, there was information about the highest bids to buy and lowest asks to sell for each traded contract type. Similar to real stock markets

[17] For a more detailed description of the trading system of the Iowa Electronic Markets-software compare *Forsythe et al.* (1991), pp. 74 – 78.

the trader obtained no information on how much contracts he would have been able to buy or sell at actual prices. He could only be sure to be able to sell or buy at least one contract at actual prices. To do so the traders could use the second type of transaction, the so-called 'market orders'. Market orders were always carried out immediately at current prices. Thus the trader had only to specify the contract type, the order type (bid or ask) and the number of contracts he wants to trade in this case.

Finally we should note that, different from real stock markets, short sales and purchases on margin were disallowed to secure the zero sum-game character of the market.

Before we turn to the results of the inflation market, we will discuss which basic trading strategies are possible. Principally we might think of the following four types of possible strategies that might be combined in several ways:

1. the arbitrage strategy,
2. the expectations strategy,
3. the risk-adjusted expectations strategy and
4. the speculative strategy.

The arbitrage strategy focuses on realizing risk-free profits. Arbitrage operations are possible in the inflation market whenever the sum of all actual bids to buy is above 1 euro or the sum of all asks to sell is below 1 euro. In the first case a trader can buy a unit portfolio from the market organizer at the price of 1 euro and sell it immediately at current prices within the secondary market. In the latter case a trader can buy a unit portfolio at current prices on the secondary market and sell it on the primary market at the price of 1 euro. In both cases he earns a risk-free profit.[18]

The second strategy, the expectations strategy, requires to build some expectation on the realization of the event that is determining the final liquidation values of the contracts. In its simplest form the trader starts out from the assumption that his expectation will coincide with the realization of the event. In this case he will buy only those contracts, he assesses to be undervalued by the market, and sell all contracts he supposes to be overvalued.

A third strategy is some kind of variation of the simple expectations strategy. Following the risk adjusted expectations strategy requires to take into

[18] If we take a closer look at the situation, the described arbitrage strategy is not totally risk-free because of the risk that during the arbitrage transactions someone may withdraw his order. If we take into account that realizing arbitrage transactions do take only a few seconds of time, this risk is very small and thus can be neglected.

account that the subjective expectations on the realization of the event might be wrong or at least somewhat distorted. Similar to a trader following the simple expectations strategy he will buy contracts he supposes to be heavily undervalued. But different from the simple strategy he will weigh up the possible profits if his expectations proof to be correct against the risk that they are wrong. Therefore *ceteris paribus* a trader following the risk adjusted expectations strategy will sell a contract earlier when prices rise than a trader following the simple expectations strategy.

Under the speculative strategy there is no need to know very much about the 'true' realization of the event determining the liquidation values of the traded contracts. Traders that are keen on speculative profits are trying to make use of short- or middle-term trends. Thus a speculative trader will hold a contract even if he suggests that is already overvalued as long as he expects that prices will go on rising. This strategy is quite risky because there is no guarantee for the trader to be able to sell the contracts before the speculative bubble bursts.

Results from the Prototype Market

Basic Market Data and Properties of the Prototype Market

Initial Investments and Final Payoffs

Before we present the forecasting results of the prototype market we should summarize some basic market data and properties. The total number of participants was 44 and most of them were students at Dresden University of Technology. The total amount of money invested was 1021.62 euro. Thus the average initial investment was some 23.22 euro. In comparison to so-called 'vote-share-markets'[19] the chances to win or loose money are quite high in winner-takes-all-markets because only one type of contract has a positive liquidation value. Thus the distribution of payoffs typically differs quite heavily from the one of initial investments. In Figure 1 the Lorenz-curve for both, initial investments and final payoffs, is shown.

[19] Vote-share-markets are often used in forecasting political events like elections. In such markets the liquidation value of a contract depends on the percentage of votes, the party, the contract is denominated to, got in an election. Thus typically each contract has a positive liquidation value in a vote-share-market.

Figure 1

REAL LOCATION OF INITIAL INVESTMENTS

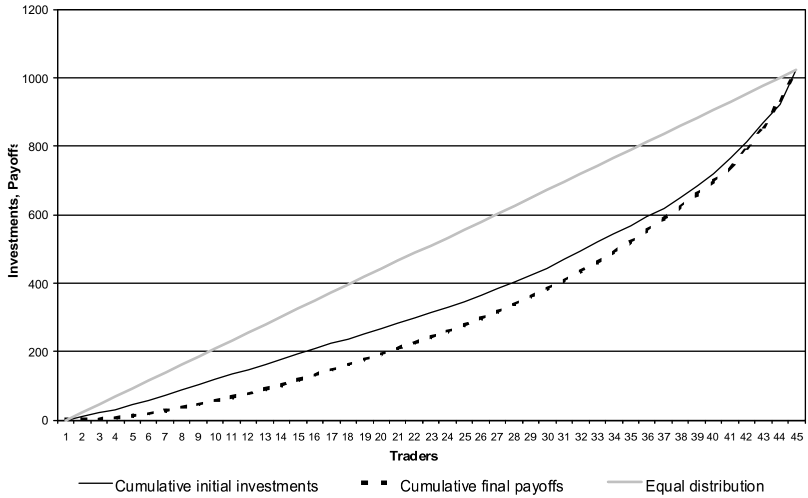
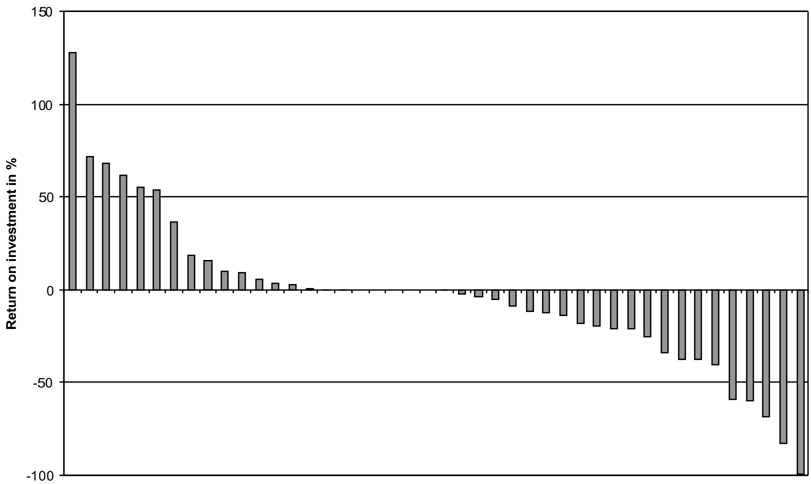


Figure 2

DISTRIBUTION OF INDIVIDUAL RETURNS ON INVESTMENT



We see that initial investments differed quite heavily from trader to trader, resulting in a Gini-coefficient of 0.29.[20] After the market was closed, the inequality of the traders' wealth increased heavily to a Gini-coefficient of 0.57. Thus the traders' success in trading was somewhat different. The distribution of the rates of return on investment, the traders realized, is shown in Figure 2.

It might be suggested that the traders with high degrees of information realize higher returns on investment than the low informed traders. Because it is hard to measure the degree of individual information we can not test this hypothesis directly. We do not find supporting evidence in favor of the hypothesis that traders investing more money (what might be a signal of high information) are earning higher profits. The very low positive correlation between initial investments and returns ($r = 0.112$) is highly insignificant ($p = 0.471$).

From Figure 2 it is easy to see that the number of traders that realized positive returns on investment was somewhat smaller than the one that realized losses within the market. Altogether we might suppose that individual information on the future inflation rate was at least somewhat dispersed among the traders.

Market Activity

The first transactions in the prototype market were done on 25 October 2000, i.e. about two weeks after opening up the market. This is due to the fact that the university courses and market advertising started in mid of October. That is why we will focus on the period from 25 October up to 12 March 2001 in the following expositions.

There was activity in the market during the whole market period with only two short periods of very low activity. The first period of low activity (20 December 2000 up to 8 January 2001) was due to Christmas holidays. The second one (the week from 9 February up to 16 February 2001) started in the end of the winter term at Dresden University of Technology.

Market activity can be measured in terms of the daily traded contract volume as well as the daily turnover in the inflation market. In Figure 3 the daily traded contract volume is shown. It is easy to see that market activity was significantly higher in the period from 25 October up to 20 December 2000 as in the period after Christmas holidays. The same is true for the daily turnover in the inflation market (compare Figure 4).

[20] The Gini-coefficient can be calculated as $G = \frac{2.\sum_{i=1}^{n} i.x_i - (n+1).\sum_{i=1}^{n} x_i}{n.\sum_{i=1}^{n} x_i}$, where n is the number of observations and x_i is the value of observation i.

Figure 3

MARKET ACTIVITY

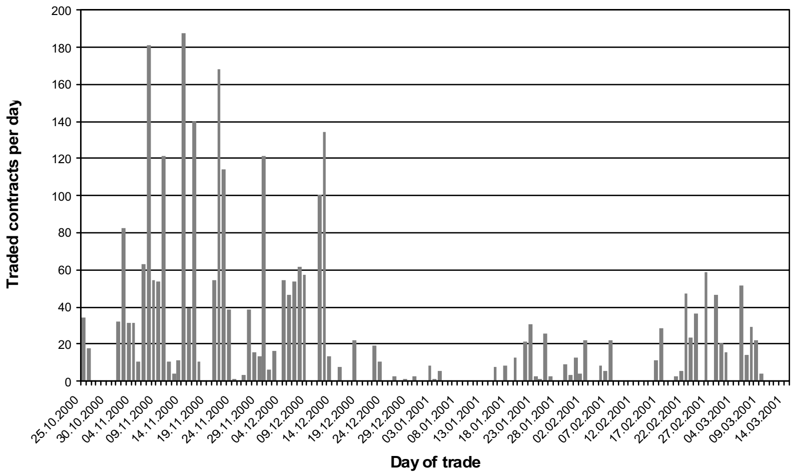
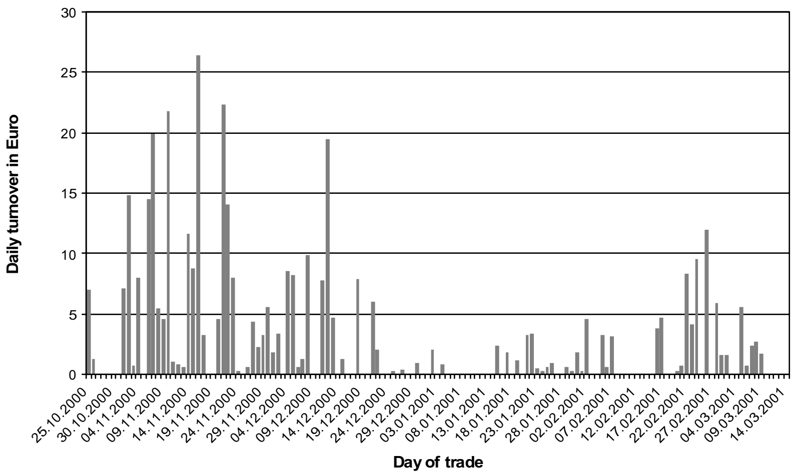


Figure 4

MARKET TURNOVER



We suppose that the observed pattern is somewhat typical since – as the event to be forecasted is getting closer – the degree of dispersion in the individual forecasts should diminish. Thus, the possibilities to organize profitable trades slightly decrease in the course of time.[21]

The Mean Market Inflation Forecast

As it was already pointed out earlier, the main objective of conducting the inflation market was to produce some high quality inflation forecast at low costs. The basic idea is to use the market prices, we observed in the inflation market, to forecast inflation. Before turning to the concrete results we shall first discuss why and how the market data can be used to forecast inflation.

To understand why the market should be able to produce some good inflation forecast we can use the fiction of a highly informed trader. Let us assume that this trader knows the 'fundamental inflation rate' that would be realized if no shocks occur. *Ex ante* he can not observe inflation shocks perfectly but he has perfect information on the distribution of the shocks. For simplicity let us assume the following concrete situation: the trader knows that the fundamental inflation rate is 1.8% and that there is a shock that might push inflation up to 2.3% with probability 0.2 or up to 2.6% with probability 0.1%. The fair prices for the contracts are shown in Table 3.

Table 3

EXAMPLE FOR FAIR PRICED CONTRACTS IN THE INFLATION MARKET

Contract	Fair price
I_0.0-	0
I_0.0-1.5	0
I_1.5-2.0	0.7
I_2.0-2.5	0.2
I_2.5-3.0	0.1
I_3.0-3.5	0
I_3.5-4.0	0
I_4.0+	0

[21] There are several additional reasons that might have contributed to the decreasing market activity. An additional explanation for the observed pattern might be that it was initially intended to close the market in late December. The decision to prolong the market was made only a short time before, as well as the announcement to do so. A second explanation might be that at least some of the traders lost interest in trading in the market because the novelty effect of

Such a trader would buy all 'I_1.5-2.0'-contracts at prices below 0.7 euro and sell these contracts at prices above 0.7 euro, thereby fixing the market price to 0.7 euro. Similarly he would fix the prices of the other contracts to their fair prices.

In reality we have to take into account that there might be no highly informed traders. Nevertheless we should expect that all relevant information within the market is revealed by the market prices in the course of time. We should also expect that the quality of the market forecast depends on the traders' strategies. Forecast quality can be supposed to increase with an increasing number of traders making use of the earlier described arbitrage strategy[22] and the expectations strategy. Principally, it is somewhat unclear how forecast quality should be correlated to the number of speculative transactions. On the one hand, speculative transactions that are motivated by 'normal backwardation' or informational asymmetries are likely to increase market efficiency. On the other hand, speculative behavior might cause so-called 'speculative bubbles' that are characterized by nonfundamental prices. Such bubbles can occur when prices depend implicitly on expected prices.[23]

The daily mean inflation forecast was calculated by a normalization of each days' last traded prices as shown in Table 4 at the example of data from 3 December 2000. The normalized prices can be interpreted as the market's valuation of the probability that the inflation rate is going to fall into the referring interval. Multiplying this probability with class middles (respective the bounds of the lowest and the highest interval) and adding up for all traded contracts gives the daily mean inflation forecast (in this case 2.26%).

trading within the market (compare *Forsythe et al.* (1991), p. 78) diminished in the course of time. A possible third explanation is that activity decreased because an increasing number of traders went out of cash but were neither willing to sell contracts at current market prices nor to increase their investment in the market. The fact that the winter term at Dresden University of Technology ended in the beginning of February and the students had to prepare for their final examinations could also have been a factor for the decreasing market activity in the second half of the market period.

[22] The argument is somewhat similar to the so-called 'marginal-trader-hypothesis' discussed in *Forsythe et al*. (1992), p. 1157 and *Bruggelambert* (1996).

[23] Compare *Blanchard and Watson* (1982) and *Flood and Hodrick* (1990).

Table 4

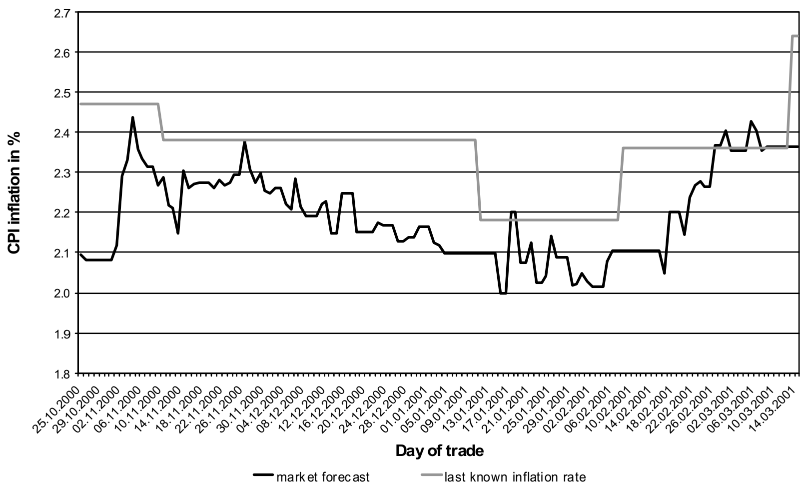
CALCULATION OF THE MEAN INFLATION FORECAST AT THE EXAMPLE OF DATA FOR 3 DECEMBER 2000

Contract name	Last traded price (p_t)	Normalized price (p_t^n)	Class middle resp. bound (m)	$p_t^n \cdot m$
I_0.0-	0.001	0.001	0.000	0.00000
I_0.0-1.5	0.025	0.025	0.750	0.01875
I_1.5-2.0	0.130	0.129	1.750	0.22575
I_2.0-2.25	0.340	0.338	2.125	0.71825
I_2.25-2.5	0.308	0.306	2.375	0.72675
I_2.5-3.0	0.171	0.170	2.750	0.46750
I_3.0-3.5	0.030	0.030	3.250	0.09750
I_3.5-4.0	0.001	0.001	3.750	0.00375
I_4.0+	0.001	0.001	4.000	0.00400
Σ	1.007	1.000	-	2.26

Different from conventional inflation surveys we can obtain an actual inflation forecast at any point in time during the market period. In Figure 5 the daily mean inflation forecast based on last traded prices is shown.

Figure 5

MEAN INFLATION FORECAST FOR FEBRUARY 2001 AND LAST KNOWN INFLATION RATE



The mean inflation forecast was in between 2.0 and 2.5% within the whole market period. Thus inflation expectations were relatively robust. One question that is of major interest is, whether the market was able to forecast the February 2001 inflation rate for Germany in a satisfactory manner. To be able to answer this question we calculated the absolute errors of the daily forecasts. From Figure 6 it is easy to see that the market systematically underestimated the true inflation rate that turned out to be 2.64% in February 2001. On average the mean inflation forecast was some 0.45% below the true inflation rate. Principally, it should be expected that the accuracy of the inflation forecast is increasing in the course of time since the relevant event is getting closer, thereby lowering uncertainty about the realization of the inflation rate. A look at Figure 7 reveals that this hypothesis seems to be true for at least the last three months of the market. We will discuss the prototype's mean inflation forecast in section 7 in more detail.

Another interesting question is which kind of information was used to generate the traders' personal forecasts. Since by far the most of the traders in the inflation market were students it might be supposed that professional forecasting methods have hardly been applied. It seems to be reasonable to suppose that primarily information supplied by newspapers and news services were used and especially the current inflation rate, as announced by *Statistisches Bundesamt* played a decisive role in expectations formation. If the traders believe that the actual inflation rate is a proxy for future inflation we should observe that the market forecast shows a tendency towards the last announced inflation rate.

In Figure 5 we also plotted the market forecast against the last announced inflation rate. On average, the market forecast was some 0.16% below the last announced inflation rate. A t-test reveals that this difference is highly significant. Thus the traders did not only reproduce the observed inflation pattern. As it is easy to see, the market forecast converged against the last announced inflation rate during the last two weeks of the market period.

Figure 6

ABSOLUTE PREDICTION ERRORS OF DAILY MEAN INFLATION FORECASTS

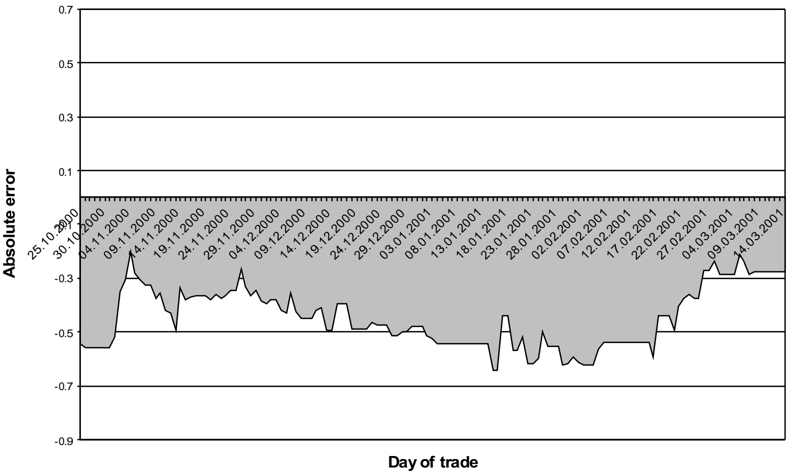
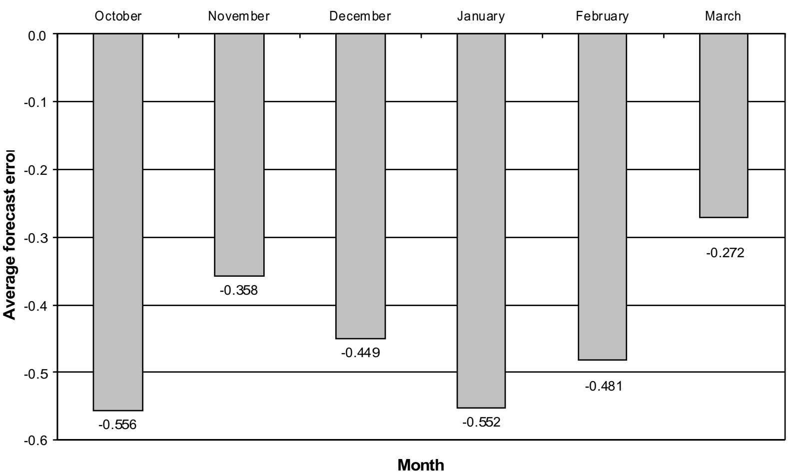


Figure 7

AVERAGE MONTHLY PREDICTION ERRORS



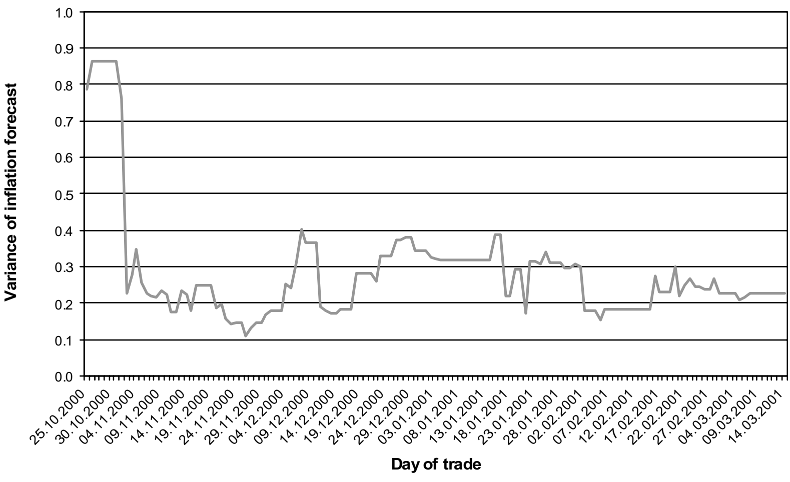
Measuring Uncertainty of the Mean Inflation Forecast

By far the most published inflation forecasts are mean forecasts. Typically these forecasts do not provide any information on the underlying probabilities of different inflation scenarios that generated a certain forecast. Since a certain mean inflation forecast can result from different distributions of individual predictions, information on the distribution of the forecast is helpful in assessing the mean inflation forecast's uncertainty.

In inflation expectation surveys, often the variance across the individual forecasts is used as a proxy for the uncertainty surrounding a mean inflation forecast. This is somewhat problematic since a high degree of dispersion in individual forecasts might also be due to forecasters' heterogeneous sets of information. Thus using the variance as a proxy for the mean inflation forecast might be misleading.[24]

Figure 8

VARIANCE OF DAILY MEAN INFLATION FORECAST



[24] *Bomberger* (1996) showed at the example of U.S.-data for the period of 1946 up to 1994 that disagreement in the Livingston inflation expectation survey is correlated with uncertainty derived by ARCH-models. Nevertheless it is at least controversial whether disagreement in inflation expectation surveys is a useful proxy for uncertainty.

Our prototype market allows to assess the mean inflation forecast's uncertainty directly. Since the normalized market prices $p^n_{t,j}$ can be interpreted as the market's aggregated evaluation of the probabilities of different inflation scenarios, these probabilities can be used to calculate the variance of the daily mean inflation forecast as

$$\sigma_t^2 = \sum_{j=1}^{J} t^n_{t,j} . (m_j - \mu_t)^2$$

where J is the number of traded contract types, m_j are the class middles (respective bounds), μ is the mean inflation forecast and t is an index representing time. The results are presented in Figure 8. We observe that the variance of the daily mean inflation forecast in the prototype market decreased sharply after a few days of trade and fluctuated around 0.25 thereafter. Within the last three months the variance showed a somewhat decreasing tendency thereby indicating a slightly diminishing degree of uncertainty.

Normally Distributed Forecasts and Further Applications

For each point in time during the market was open we can visualize the market's actual evaluation of the probability of different inflation realizations in a histogram. In Figure 9 we show the empirical distribution of the inflation forecast of 12 December 2000 (last traded prices). We have one observation for each contract that is represented by its class middle (respective the class bound).

A first inspection of the histogram suggests that inflation expectations might be normally distributed. When extending the inspection to a larger number of days at different points in time during the market period this suggestion is substantiated. Because of the relatively low number of observations we are not able to test this hypothesis formally.

If in fact the market forecast is normally distributed – and that is what we will assume in the following – we are able to make more precise statements about the probability of different inflation scenarios. Since we know the mean and the standard deviation of the forecast we can calculate and graph the cumulative probability function (compare the example of 12 December 2000 that is shown in Figure 10). We can also calculate and graph the referring density function. In Figure 11 we show the density functions on different days during the market period.[25]

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[25] Recently authors like *Blix and Sellin* (1999) and *Wallis* (1999) supposed inflation scenarios often to be distributed asymmetrically. It should be noted that the market data also allow to calculate the moments of asymmetric distributions as e.g. the two-piece normal distribution.

Figure 9

DISTRIBUTION OF INFLATION FORECAST ON 12 DECEMBER 2000

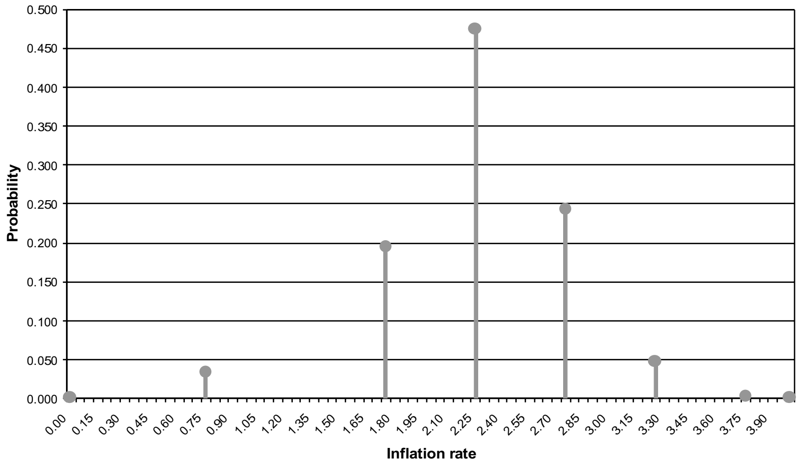


Figure 10

CUMULATIVE PROBABILITY FUNCTION OF THE MARKET INFLATION FORECAST ON 12 DECEMBER 2000

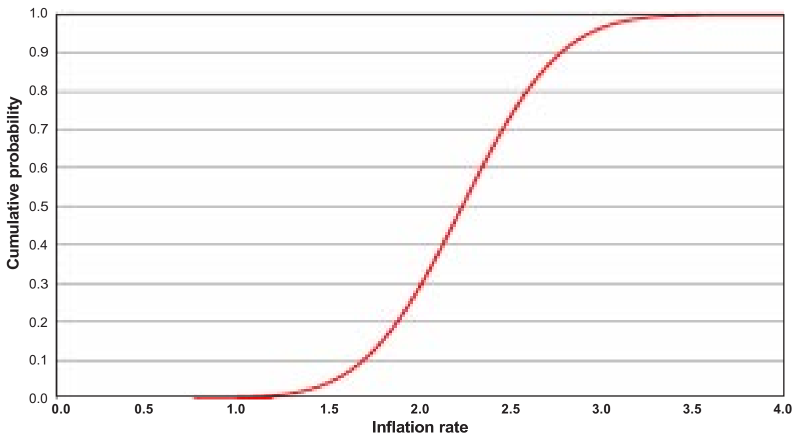
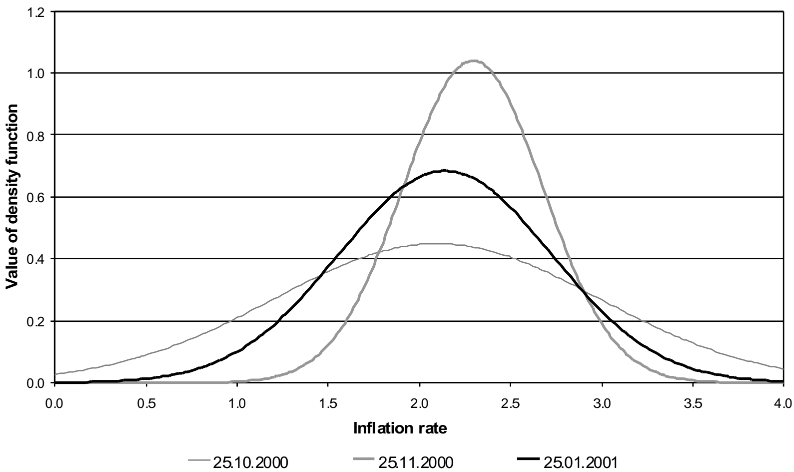


Figure 11

DENSITY FUNCTIONS FOR MARKET INFLATION FORECAST ON SELECTED DATES



Application I: Calculation of the Probability of Inflation Scenarios, No Contract Is Traded for

The knowledge about the density functions enables us to calculate the probability for every inflation scenario that might be of interest, even if no contract in the market was traded for the referring interval. To show this we use the data of 12 December 2000 that correspond to the histogram in Figure 9. Let us assume that we would like to know on 12 December 2000 the probability for the scenario that the inflation rate in February 2001 falls into the interval of 1.25% and 2.25%. Since there is no contract for this scenario we can not assess this probability directly from the market prices – even not by simply summing up the probabilities for two or more intervals.[26] The mean of inflation expectations on 12 December 2000 was 2.229% and the standard deviation of inflation expectations turned out to be 0.42265. Let $f(I \mid \mu; \sigma^2)$ be the density function of inflation expectations I with mean μ and variance σ^2. Thus we can calculate the probability for the specified scenario as

[26] Note that the probability of inflation scenarios, a contract is traded for, is already known and that we need no assumption on the empirical distribution of the forecast to assess this probability.

$$p(1.25 \le I \le 2.25 = \int_{1.25}^{2.25} f(I \mid \mu;\sigma^2) =$$

$$= \int_{1.25}^{2.25} \frac{1}{\sigma\sqrt{2.\pi}}.e^{-\frac{1}{2}.(\frac{I-\mu}{\sigma})^2} dI \approx 0.5198 - 0.0103 = 0.5095$$

Application II: Calculation of Confidence Intervals and Modified Fan Charts

One might also be interested to calculate a confidence-interval for the February inflation rate. Since we assumed a symmetric distribution, the confidence interval has to be symmetric around the mean of the distribution and can be calculated quite easily. Let α be the confidence level we are interested in. We know that the lower bound I_l of the confidence interval is the inflation rate for which

$$\int_{I_l}^{\mu} f(I)\,dI = 0.5 - \frac{\alpha}{2}$$

is fulfilled. Similarly the upper bound of the confidence interval I_u has to fulfill the condition

$$\int_{\mu}^{I_u} f(I)\,dI = 0.5 - \frac{\alpha}{2}\cdot$$

Again we shall illustrate the argument by giving an example. We will therefore assume that we are interested in the 95%-confidence interval for the February inflation rate on the basis of the market data of 12 December 2000. The upper bound is the 97.5%-quantile of the specified normal distribution:

$I_u = 3.057\%$.

Since the distribution is symmetric the lower bound can easily be calculated as

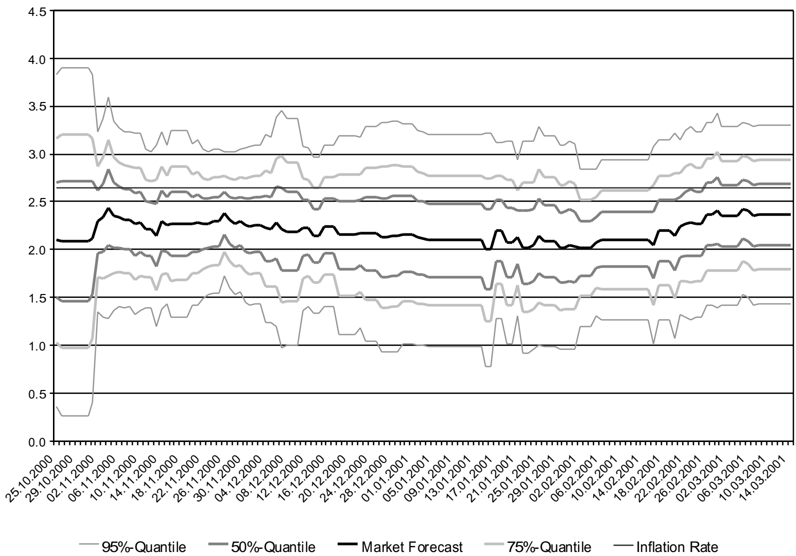
$\mu - (I_u - \mu) = 2\,.\,\mu - I_u = 1.401\%$.

Thus, the market judged the probability that the February inflation rate will be in between 1.401% and 3.057% to be 0.95.

The Bank of England uses fan charts to present their inflation forecasts. These fan charts include a graphical representation of confidence intervals for inflation at different times in the future. Since our prototype market generates a time series of forecasts for one certain future date only, we would need several markets to reproduce such a fan chart. To produce a modified version of a fan chart we calculate the confidence intervals for different α

Figure 12

FAN CHART FOR THE FEBRUARY 2001 INFLATION RATE



levels and for different forecasting dates (compare Figure 12). Thus we receive some graphical representation of how different confidence intervals developed in the course of time.

Discussion of the Prototype Market's Design and Its Results

After presenting some basic results from the prototype market we will turn to a discussion of the market's results and its design.

It seems to be reasonable to start out with a discussion of the market's mean inflation forecast quality. Even if the market proved to work well from a technical point of view the mean inflation forecast of the market was not highly accurate. As it was shown earlier, the traders underestimated the February inflation rate systematically, a phenomenon that was often observed within inflation expectation surveys during times of rising inflation.[27] This result is obviously violating the unbiasedness property of rational expectations which requires the expectation errors to have zero means. Thus a series of forecasts can be called 'rational' whenever the expectation errors fluctuate

[27] *Croushore* (1996).

around the true inflation rate. Even if it is desirable to have forecasts fulfilling the properties of rational expectations we should note that most time series of inflation forecasts are not satisfying these conditions.[28] Thus the failure to exhibit a 'rational' forecast pattern does not necessarily mean that an inflation market produces worse forecasting results than conventional forecasting methods. To be able to judge whether electronic markets are a useful method of forecasting macroeconomic variables more forecasting markets have to be organized.

Nevertheless it seems to be reasonable to think about how to improve the forecasting quality of future inflation forecasting markets. As it was pointed out earlier it is very important that all important information on future inflation is present at least somewhere in the market. The fact that our prototype market included a relatively low number of 44 traders might be an explaining factor for the low degree of accuracy of the market forecast. Possibly even more important is the fact that nearly all traders were students from two university courses. Since taking part in the market increased the probability of passing the courses' final examinations (that also included questions on the functioning of electronic markets) at least some of the traders might have had somewhat disturbed incentives to take part. Therefore, the basic advantage of electronic markets to have traders only, who suppose to have superior information on the event to be forecasted, was obviously not given in the prototype market. Thus it might be supposed that inflation market's forecasting quality can be increased by advertising the market to a broader public audience and especially not to run such a market as a mandatory part of an university course.

An important and still unresolved question is what is the optimal number of contract types that should be traded in the market. On the one hand, the accuracy of the market forecast obviously increases with an increasing number of contract types traded. This is due to the fact that we use the class middles to calculate the mean inflation forecast, thereby assuming that all possible outcomes in the interval are equally likely. The forecasting errors caused by using this procedure can be supposed to decrease when using smaller intervals for the contracts. On the other hand, the traders' problem of determining the fair prices for the contracts can be supposed to be positively correlated to the number of traded contracts. Up to now there is little evidence which number of contracts solves this trade-off in an optimal way. A good strategy might be to start out with a relatively low number of contracts and then to

[28] Compare e.g. *Gramlich* (1983), *Pearce* (1979) and *Laubscher and Schombee* (1999), p. 10.

split those contracts which turn out to be traded for the highest prices to increase the forecast's quality.

As it was pointed out earlier, electronic markets can be used to predict any future event that is measurable objectively. Nevertheless we should underline that electronic markets are better suited to short-run forecasts than to long-run predictions. This is due to the fact that the markets cannot be liquidated before the event, the market is conducted on, has taken place. Technically it is no problem to run a long-term forecast market. Such a forecast can be obtained from a market that is run several years before the event of interest takes place. But it is obvious that it will be hard to get traders for such a market because there is a long period of time between trading and the liquidation of the market.

With respect to political stock markets critics often argue that electronic markets are no independent instruments because the traders in the markets would simply reproduce the latest polls' results. Even if some studies found a significant influence of polls on contract prices in political stock markets (compare e.g. *Bruggelambert* (1997) or *Beckmann and Werding* (1996)), recent results indicate that traders in electronic markets do not simply reproduce poll results (compare *Berlemann and Schmidt* (2001)). Nevertheless it is hard to judge whether the results of political stock markets would have been as accurate as they have been when no polling information would have been at hand. This is due to the fact that typically a large number of polls is conducted on the occasion of political elections. It is somewhat easier to conduct electronic forecasting markets on macroeconomic variables, no adequate forecast is available for. Doing so might help to answer the question whether electronic markets are an independent forecasting instrument.

Summary and Outlook

In this paper we presented a new method to generate inflation forecasts via electronic markets. At the example of results from a class room experiment we demonstrated how the market data of a well-defined electronic market can be used to forecast mean inflation as well as the probability of different inflation scenarios at low costs. The promising results from the prototype market make us believe that the electronic market instrument is a useful forecasting device.

To learn more about the accuracy of electronic market forecasts a large number of markets has to be conducted. To get well informed traders and to obtain a high quality forecast it could be useful to advertise the markets via media partners as it often has been done in political stock markets (note that it is not necessary to have a somewhat representative sample of traders). Electronic markets could also be used as an instrument to aggregate professional forecasters' individual predictions in a more reasonable and objective manner than it is often done within conventional consensus forecasts.

Up to now most electronic markets were conducted in environments where other forecasts on the market event were available. Thus it might be interesting to set up markets in countries where no reliable forecasts of macroeconomic variables exist. Currently first attempts are being undertaken to install a regular forecasting system for inflation, unemployment and the exchange rate in Bulgaria.

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