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by Libero Monteforte and Gianluca Moretti

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REAL TIME FORECASTS OF INFLATION: THE ROLE OF FINANCIAL VARIABLES[#]

by Libero Monteforte* and Gianluca Moretti**

Abstract

We present a mixed-frequency model for daily forecasts of euro area inflation. The model combines a monthly index of core inflation with daily data from financial markets; estimates are carried out with the MIDAS regression approach. The forecasting ability of the model in real-time is compared with that of standard VARs and of daily quotes of economic derivatives on euro area inflation. We find that the inclusion of daily variables helps to reduce forecast errors with respect to models that consider only monthly variables. The mixed-frequency model also displays superior predictive performance with respect to forecasts solely based on economic derivatives.

JEL Classification: C13, C51, C53, E37, G19.

Keywords: forecasting inflation, real time forecasts, dynamic factor models, MIDAS regression, economic derivatives.

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1 Introduction

Forecasting inflation as frequently as possible has become significantly important for both institutional and private operators in recent years. On the one hand, a timely update of the macroeconomic projections is essential for conducting a modern monetary policy based on the market expectations (see Woodford (2003)); on the other hand, market participants tend to update their expectations continuously as new information is released, and to exploit this information to modify their investment strategies.¹ Since inflation data are available at monthly frequency, the common approach to forecasting inflation is to construct models based on monthly variables that are correlated with future inflation. Forecasts from these models can be quite accurate but not very timely, since by construction, they do not account for any important information that might become available within the month. One solution to this problem is to look at financial indicators, such as movements in the yield curve or interest rate spreads, that are available on a daily basis and that can provide some timely information about changes in inflation expectations. An alternative solution, which we present in this paper, is to construct an indicator of monthly inflation using both monthly and daily data. More precisely, we propose a mixed-frequency data model that combines a monthly core inflation index, constructed using a generalized dynamic factor model, with daily prices of commodities and financial assets.

Factor models have become in recent years a very popular approach to construct economic indicators since they allow us to handle the information contained in a large number of variables in a parsimonious way (see for instance Stock and Watson (2006)). In particular, the generalized dynamic factor (GDF) models, proposed by Forni et al. (2002), can explain most of the variability of the data at low and medium frequency by extracting a few common long-run components from a large set observable variables. Despite their popularity, large-scale factor models present a few drawbacks when they are used to forecast in a real time macroeconomic variables especially at short horizons. First, because they are designed to capture the slow-moving component of inflation, they have their best forecast accuracy at medium and long-term horizons (see Cristadoro et al. (2005, 2008)). Moreover, since economic data are released at different times, factor models are characterized

¹Bernanke and Kuttner (2005) study the reaction of asset prices to monetary policy shocks, Andersen et. al (2003) show that U.S. dollar exchange-rate quotations are linked to economic fundamentals.

by an unbalanced end of sample (ragged-edge). This problem, well known in the factor model literature, can have considerable effects on the forecasting properties of the models, especially in the short-term (see Marcellino and Schumacher (2010)).

In this paper, we propose to tackle this problem using a mixed frequency data models where a factor model indicator, estimated with a balanced dataset, is combined with relevant explanatory variables sampled at a higher frequency. For the case of euro area inflation we focus on daily prices of relevant commodities and financial assets. The choice of these variables lies in their ability to capture changes in market expectations as well as movements in the most volatile components on inflation, specifically energy and food, which are highly correlated with the short-run developments of the overall index. Furthermore, they might also anticipate the effects of changes in indirect taxes or other government measures on inflation that can not be easily captured in a pure backward-looking model. In this respect, our approach can be seen as an efficient way of exploiting the predictive content of financial data without altering the temporal structure of the data.

The class of mixed-frequency models we consider is the MIXed DATA Sampling regression models (MIDAS), proposed by Ghysels et al. (2002, 2006).² Most of the early applications of MIDAS models were on financial data but more recently there have been a few applications to macroeconomic variables. Clements and Galvão (2008) and Andreou, Ghysels and Kourtellis (2010) use a MIDAS model to forecast monthly US quarterly macro variables, Ghysels and Wright (2008) to track daily survey expectations of US macro variables and Marcellino and Schumacher (2010) to produce monthly estimate of German GDP. The use of asset prices to forecast macro variables is also not new in the literature. In an extensive review Stock and Watson (2003) show that financial variables have a statistically significant marginal predictive content for macroeconomic variables. However, this predictive content can not be exploited reliably and it is often very unstable over time. Our mixed-frequency approach can be an effective way to exploit the information coming from financial markets.

We run two real time forecasting exercises. In the first application we assess the accuracy of our mixed-frequency indicator in forecasting euro area

²Another class of mixed-frequency models, proposed by Mitnik and Zadrozny (2005) and more recently by Aruoba et al. (2009), is based on a state-space representation where they use the Kalman filter to construct high frequency unobserved indicators for the low-frequency variable.

inflation relative to standard monthly models and market expectations. We show that predictions from our mixed-frequency model outperform those of the standard benchmark models based only on monthly variables showing that the inclusion of the daily variables helps to reduce the forecasting errors. In the second exercise, we fully exploit the high-frequency structure of our models and run a daily forecasting exercise: we compare predictions of our model with market expectations, extracted from the quotes of euro area HICP future contracts. Daily forecasts of our models are not more accurate than those extracted from the daily quotes of euro area HICP future contracts but also less volatile.

The paper is organized as follows. Section 2 reviews the link between financial variables and inflation and describes the economic derivatives we used in our analysis. Section 3 describes our mixed-frequency models in details. In Section 4 we assess the forecasting ability of our models compared with VAR models and market daily expectations. Section 5 concludes.

2 Role of financial variables

If keeping track of persistent movements in inflation is crucial to the pursuit of price stability, it is also important for policy makers and financial operators to monitor the evolution of current inflation in real time. This is usually done by looking at the information embodied in high-frequency variables, such as the yield curve, bond yields and quotes on HICP economic derivatives. Not only are these variables forward looking and observed in real time, but also have potentially useful information about inflation expectations. Moreover, unlike economic data, they are not subject to any revisions. The modelling approach based on financial variables to predict inflation goes back to the quantity theory of money of the early nineteenth century.³ However, the empirical support for such approaches is still mixed and model dependent, as pointed out by Stock and Watson (2003) and Ang et al. (2007).⁴ One of the reasons for this puzzle could lie in the different frequencies at which inflation and financial variables are sampled. Specifically, even if daily financial data contain useful information about current and future movements of inflation,

³The intuitions that the money stock anticipates inflation is much older but the first model is in Fisher (1911).

⁴Using a factor model Forni et al. (2003) present some evidence for the euro area, Giannone et al. (2008) for the US.

the fact that inflation is sampled at a lower frequency makes it hard to exploit that predictive power. Solutions to this problem consist either in sampling daily data at a lower frequency choosing, for instance, the last observation of the month, or in prefiltering daily data to convert it to a monthly frequency. Both these approaches may discard useful information and corrupt the potential relation between the variables. As we show below, it is possible to overcome this problem with a mixed-frequency-data model. This approach allows us to combine monthly determinants of inflation with the daily information coming from financial markets in the same model. In this way, we can capture the medium to low frequencies of inflation using monthly regressors without discarding any useful information coming from financial data to predict short-term movements in inflation.

3 A two-step approach to model inflation

As key aspect of our approach is to model the low and high frequency variability of inflation separately. In this section we describe the two components that, in our view, should be used for this purpose: a core inflation index to model the medium-to-low frequencies of inflation, and daily financial variables to model the high-frequencies.

3.1 Modelling long-medium term component of inflation

In the last few years large-scale factor models have become increasingly important in the construction of reliable coincident and leading economic indicators.⁵ Factor models allow us to represent parsimoniously the information embodied in a large data set by assuming that there are a few common factors that drive the dynamics of data. In particular, in the generalized dynamic factor model (GDFM) these factors are chosen in order to explain most of the variability of the data at medium and low frequency. In this way, they disentangle the medium to long-run cyclical component from the short-term dynamics and minimize the effects of idiosyncratic and transient shocks.

⁵Factor models have been used to predict macroeconomic variables in the US (e.g. Stock and Watson (2002)) and in the euro area (e.g. Altissimo et al. (2006)) and to produce measures of core inflation for the euro area (Cristadoro et al. (2005)).

More specifically, if $x_{i,t}$, $i = 1, \dots, N$, is a panel of interest variables, the dynamic factor model assumes that they admit the following representation

$$x_{i,t} = \chi_{i,t} + \xi_{i,t} = \sum_{j=1}^p b_{i,j}(L) f_{j,t} + \xi_{i,t} \quad (1)$$

where $\chi_{i,t}$ and $\xi_{i,t}$ are respectively the common component and the idiosyncratic component of $x_{i,t}$. They are, by construction, unobserved, stationary and mutually orthogonal. The common component $\chi_{i,t}$ is driven by a few common factors $f_{j,t}$ which are possibly loaded with different coefficients and lags. An important feature of the GDFM is that under the assumption that the variables $x_{i,t}$ are stationary, the common component can be represented as the integral of waves of different frequency, so called spectral representation. In particular, by aggregating waves of different frequency we can decompose $\chi_{i,t}$ into the sum of a cyclical medium and long-run component $\chi_{i,t}^L$ and a non-cyclical, short-run component, $\chi_{i,t}^S$, i.e.

$$\chi_{i,t} = \chi_{i,t}^L + \chi_{i,t}^S$$

By construction $\chi_{i,t}^L$ is the (unobserved) component that drives persistent movements in $x_{i,t}$.⁶ A detailed description on the estimation of $\chi_{i,t}^L$ can be found in Forni et al. (2002). This approach was recently employed by Cristadoro et al. (2005, 2008) to construct a core inflation index for the euro area estimated using a large number of both national and sectorial prices together with monetary aggregates and other macroeconomic variables.⁷ In this paper we use the same core indicator since it presents various advantages. First, it is as accurate as the year-on-year inflation rate in capturing medium-long term components of inflation but, unlike the latter, it is not a lagging indicator of monthly inflation. In other words, there is no trade-off between smoothness and timing of the information provided. Moreover, it is constructed using data from a large panel of time series that includes sectorial and national prices as well as monetary and real variables. Finally, by construction it is cleaned of measurement and idiosyncratic errors caused by sector or country specific dynamics. The estimation of the GDFM requires

⁶In particular, for the core inflation index we focus on periodicity of at least one year.

⁷A complete list of the variable used in the construction of the euro area inflation index can be found in Cristadoro et. al (2005).

two conditions: all the variables of the dataset should be transformed into the same frequency; the dataset should have a balanced end of sample, i.e. no missing values in the most recent period.

In a real real-time forecasting framework this latter requirement is never met because of the different publication lags of many economic data, leading to the so called "ragged-edge data" problem. The presence of missing observation at the end of the sample, not only has important implication for the model estimation but it can also worsen the forecasting properties of the model especially in the very short-run. Several approaches have been proposed to tackle the issue of ragged-edge data. A good survey with an application to German data can be found in Marcellino and Schumacher (2010). The approach we propose is to model the medium-run component of inflation with a lagged core inflation index (from a balanced dataset) and the short-term component using high-frequency financial data that are available in real time and unaffected by revisions.

3.2 A mixed-frequency model for real-time forecasts of inflation

In this section we present the mixed-frequency model we use to forecast inflation in real time. We follow the mixed data sampling regression (MIDAS) approach proposed by Ghysels et al. (2002, 2006). The main feature of the MIDAS model is that it allows us to construct a regression model that combines both monthly and daily variables. The MIDAS approach assumes that the response to the high-frequency explanatory variables follow a distributed lag polynomial, in order to prevent overparameterization. For the sake of clarity we assume the presence of only one daily variable in the model. Specifically, if $x_{i,t}^d$ is a daily variables, \mathbf{z}_t a vector of monthly variables (that does not contain the core inflation index), and $B\left(L^{\frac{1}{d}}; \boldsymbol{\theta}_i\right)$ a daily lag polynomial, the mixed-frequency-data model we specify for inflation π_t is given by

$$\begin{aligned}
\pi_t &= \alpha_0 + \rho\pi_{t-1} + \sum_{i=1}^N \beta_i B \left(L^{\frac{1}{d}}; \boldsymbol{\theta}_i \right) x_{i,t}^d + \alpha \chi_{i,t-h}^L + \boldsymbol{\gamma}' \mathbf{z}_t + \varepsilon_t \\
&= \alpha_0 + \rho\pi_{t-1} + \sum_{i=1}^N \beta_i \sum_{k=1}^K b(k; \boldsymbol{\theta}_i) L^{\frac{k}{d}} x_{i,t}^d + \alpha \chi_{i,t-h}^L + \boldsymbol{\gamma}' \mathbf{z}_t + \varepsilon_t \quad (2)
\end{aligned}$$

where the daily lag coefficient $b(k; \boldsymbol{\theta}_i)$ are function of a small set of parameters $\boldsymbol{\theta}_i$, N is the number of daily variables and $\chi_{i,t-h}^L$ is the core inflation index, described in the previous section, lagged h periods. $L^{\frac{k}{d}}$ is the daily lag operator, which ranges from the last day of month t up to K days before. This means that $L^{\frac{1}{d}} x_t^d = x_{t-\frac{1}{d}}^d$ is the last observation of month t , $L^{\frac{2}{d}} x_t^d = x_{t-\frac{2}{d}}^d$ is the next to last observation, and in general $x_{t-\frac{k}{d}}^d$ is the $(d-k)th$ observation of the month. In order to avoid spurious seasonality in the model, the loading β_i is restricted to be

$$\beta_i = (1 - \rho L) \delta_i$$

The lag coefficient $b(k; \boldsymbol{\theta}_i)$ is assumed to follow a distributed lag function that depends on a small set of parameters $\boldsymbol{\theta}_i$, i.e.

$$b(k; \boldsymbol{\theta}_i) = \frac{f(k; \boldsymbol{\theta}_i)}{\sum_{k=1}^K f(k; \boldsymbol{\theta}_i)}$$

This allows us to reduce the number of parameters to be estimated in the model. In general, there are many ways of parameterizing $f(k; \boldsymbol{\theta}_i)$. Two common approaches are the exponential Almon polynomial, introduced by Almon (1965), and the Beta polynomials recently proposed by Ghysels et al. (2002, 2006). The first assumes that $f(k; b_i)$ has the following functional form:

$$f(k; \boldsymbol{\theta}_i) = e^{\theta_{i,1}k + \theta_{i,2}k^2}$$

The exponential Almon polynomials can generate different shapes including increasing, decreasing, single and multiple humped patterns. The second method of parameterization is based on the Beta density function defined as

$$f(x; b_1, b_2) = B(b_1, b_2)^{-1} x^{b_1-1} (1-x)^{b_2-1}$$

where $B(b_1, b_2) \equiv \Gamma(b_1)\Gamma(b_2)/\Gamma(b_1 + b_2)$ and $\Gamma(\cdot)$ is the gamma function. The Beta density is a very flexible distribution that allows many shaped weighting functions including uniform, humped and sharply decreasing (increasing) patterns. The model can be estimated using non-linear quasi maximum likelihood. In order to improve accuracy, we assume that the loadings of the daily variables and the parameters in the vector θ are uncorrelated and use a recursive two-stage estimation approach. We use the model to produce daily forecasts of inflation in the following way. First, we estimate the model on a daily basis and then we use the estimated parameters to make predictions on current and one-month-ahead inflation. More specifically, let's assume that we stand at the 15th day of the month t , say $t(15)$. The information set available on that day consists of past values of the inflation rate⁸ and the other monthly variables up to the previous month $t - 1$, and all the daily variables up to the 14th day of the current month, $t(14)$. Therefore, for the case of only one daily variable, the model we use to estimate the parameters is

$$\begin{aligned} \pi_{t-1} = & \alpha_0 + \rho\pi_{t-2} + b_1x_{t-1(14)}^d + b_2x_{t-1(13)}^d + b_3x_{t-1(12)}^d \\ & + \dots + b_{(K)}x_{t-1(14-K)}^d + \alpha\chi_{i,t-1}^L + \gamma z_{t-1} + \varepsilon_{t-1} \end{aligned} \quad (3)$$

where $x_{t-1(14)}^d$ is the daily variable available on the 14th day of the previous month $t - 1$. Notice that if K is greater the 14, then we are including in the model $K - 14$ daily observations of the previous month. Once the parameters have been estimated, predictions for current inflation $\tilde{\pi}_t$ are given by

$$\begin{aligned} \tilde{\pi}_t = & \hat{\alpha}_0 + \hat{\rho}\pi_{t-1} + \hat{b}_1x_{t(14)}^d + \hat{b}_2x_{t(13)}^d + \hat{b}_3x_{t(12)}^d \\ & + \dots + \hat{b}_Kx_{t(14-K)}^d + \hat{\alpha}_t\chi_{i,t-1}^L + \hat{\gamma}z_{t-1} \end{aligned} \quad (4)$$

while one-step-ahead predictions $\tilde{\pi}_{t+1}$ are obtained by replacing π_{t-1} with the current prediction $\tilde{\pi}_t$ and z_{t-1} with z_t if available. For instance, if we stand at the 15th of September and we want to forecast current inflation $\pi_{sept.}$, we would first estimate the model using monthly data until August and daily

⁸The flash estimate of the HICP for the euro area is usually released on the last business day of the current month.

data until the 14th of August, i.e.

$$\begin{aligned}\pi_{aug} = & \alpha z_{Jul} + \beta_1 x_{14aug}^d + \beta_2 x_{13aug}^d + \beta_3 x_{12aug}^d + \dots \\ & + \alpha_t \chi_{i,t-1}^L + \gamma z_{t-1} + \varepsilon_t\end{aligned}\quad (5)$$

and then forecast September inflation using the estimated coefficient and all the information available until the 15th of September, e.g.

$$\begin{aligned}\hat{\pi}_{sept} = & \hat{\alpha} z_{aug} + \hat{\beta}_1 x_{14sept}^d + \hat{\beta}_2 x_{13sept}^d + \hat{\beta}_3 x_{12sept}^d + \dots \\ & + \hat{\alpha}_t \chi_{i,t-1}^L + \hat{\gamma} z_{t-1}\end{aligned}\quad (6)$$

The following day we would update our information set by including the daily data of the previous day, re-estimate the model and obtain a new prediction for September inflation. One-step-ahead predictions are obtained in the same way by a direct approach. Specifically, we first estimate

$$\begin{aligned}\pi_{t-1} = & \alpha_0 + \rho \pi_{t-3} + b_1 x_{t-1(14)}^d + b_2 x_{t-1(13)}^d + b_3 x_{t-1(12)}^d \\ & + \dots + b_{(K)} x_{t-1(14-K)}^d + \alpha \chi_{i,t-1}^L + \gamma z_{t-1} + \varepsilon_{t-1}\end{aligned}$$

and then use the estimated parameters to make predictions for π_{t+1}

$$\begin{aligned}\tilde{\pi}_{t+1} = & \hat{\alpha}_0 + \hat{\rho} \pi_t + \hat{b}_1 x_{t(14)}^d + \hat{b}_2 x_{t(13)}^d + \hat{b}_3 x_{t(12)}^d \\ & + \dots + \hat{b}_K x_{t(14-K)}^d + \hat{\alpha}_t \chi_{i,t-1}^L + \hat{\gamma} z_{t-1}\end{aligned}$$

4 Two forecasting applications in real time

In this section we describe our three mixed-frequency models for the euro area HICP and assess their forecasting performance in two different exercises. In the first we evaluate the monthly forecast accuracy of the three models with respect to other standard models. Then we compare the models' daily predictions with the forecasts implied by the quotes of euro area HICP future contracts.

Each model, constructed as in Eq. 2, is constructed to capture different sources of shocks that, according to economic theory, should be related to movements in inflation. All the models are characterized by the same

monthly variables, chosen to model long-run developments in inflation, but different daily variables. The monthly variables are lagged inflation, the lagged yearly change of oil price and the fifth lag of the core inflation index defined in Section 3.1. We included the core index lagged five because we found it has its strongest predictive power at that horizon (this is also consistent with the results of Cristadoro et al. (2005)). At the same time, this choice has two important implications. First, it significantly reduces, in the real time exercise presented below, the distortion implied by the past data revision. Second, it eliminates the ragged-edge data issue mentioned in the introduction, which can have important implications in a nowcast exercise. Finally, the inclusion of the yearly rate of change in the oil price is aimed to capture possible second round effects of energy prices in consumer inflation. The daily variables include short and long term interest rates, interest rate spreads, commodity prices and exchange rates.⁹ The choice of these variables lies on their ability to capture changes in the market expectations (in particular interest rates and interest rate spreads) as well as movement in the most volatile components of inflation, specifically energy and food, which are highly correlated with the short-run changes of the overall index. Furthermore, market expectations might also anticipate changes in indirect taxes or other government measures that have an important impact on inflation but cannot be easily accounted for in a pure backward-looking model.

More specifically, in the first model (M1) we include the short-term rate and changes in interest rate spread and in oil future prices. These variables should reflect both changes in expectations and future expected movements in energy prices. The second model (M2) is designed to capture recent shocks coming from outside the euro area that are not yet embodied in lagged core inflation. For this reason we considered changes in the wheat price, in the oil futures quotes and in the exchange rate. Finally, in the third model (M3) we only focus on inflation expectations embodied in the interest rates and for this reason we include long-term rates and changes in the interest rate spreads and in the short term rate. The choice of three different models with

⁹The short-term rate is the 3-month Euro LIBOR rate while the long-term rate is the yield on the 10 year Bund. The interest rate spread is constructed as the difference between the 10-year German Bund and 3-month German interbank rate. The quotes of the future contracts and the spot oil prices refer to the Brent oil. The exchange rate is the effective rate (EER22). Daily data for the financial variables are taken from DATASTREAM; euro area HICP CME future quotes are extracted from Bloomberg, and monthly data for the HICP and interest rates from the ECB Statistical Data Warehouse (SDW).

a small number of daily variables is based on the need to keep the model parsimonious and, at the same time, to identify different sources that could partially explain short-run developments in euro area HICP.¹⁰

4.1 Real-time forecasts of monthly inflation

In this section we present two empirical exercises to assess in pseudo real time the forecasting ability of our models compared with monthly VAR models and market daily expectations. Even if we did not take into account the issue of data revision, the difference from a pure real-time application is negligible for two reasons. First, the use of the fifth lag of the monthly core inflation implies that we can estimate it with a balanced dataset and that the effects of data revision should be negligible. Second, the daily financial variables are available in real time and not subject to revisions.

In the first exercise we compute the root mean squared forecast error (RMSFE) of our mixed-frequency models and compare them with those from univariate and multivariate models. In particular, among the univariate models we consider a random walk, an AR model and an ARMA model whose order is chosen with the Schwarz criterion. In order to assess the contribution of the daily variables to improving the forecast accuracy of our three M-models, we consider two VARs: the first has the same monthly variables as our models (inflation, core inflation and the oil price); the second also includes the short-term interest rate.

Since these models produce monthly forecasts, the comparison has been done in the following way. For each day of each month we estimate our three M-models, make predictions for current and one-month-ahead inflation and finally take the monthly average of the daily forecasts. We use ten years of data as a burning period and then we run recursive forecasts for monthly inflation starting from May 2002 until September 2007. The RMSFE for all models are showed in Table 1. All the mixed-frequency data models outperform all the univariate models as well as the VAR models. The average reduction in the forecast errors is more than 20% for current and one-month-ahead inflation. In particular, the improvement toward the VAR models implies that the daily variables have significant predictive content for cur-

¹⁰In the early stage of our work we noticed that the inclusion of a large number of daily variables in the same model could lead to highly volatile parameter estimates. A possible solution that could be employed in a future extension of this work would be the construction of daily financial factors in line with Ghysels et al. (2009).

rent and one-month-ahead inflation. Although this result can be partially explained by the larger number of variables in the mixed frequency models, it must be noticed that our models impose much stronger restrictions on the data dynamics compared with the unrestricted VARs, which allows for important feedbacks among the variables. Finally, among the mixed-frequency models, M2 performs the best, showing that, in the sample period we considered, movements in commodities prices and exchange rates seem to be good predictors of the short-term developments in the EA HICP. This is not surprising if we consider the euro sharp depreciation in the first few years after its introduction.

4.2 Model forecasts vs market expectations

In the second application, we fully exploit the high-frequency structure of our models and run a daily forecasting exercise. Given the lack in the literature of benchmark models for daily forecasts of inflation, we decided to compare predictions of our model directly with market expectations, in particular with the inflation expectations extracted from the economic derivatives. Economic derivatives are securities whose payoff is dependent upon macroeconomic data releases. They were recently introduced and have become popular for their ability to mitigate some of the market risks found in standard instruments linked to inflation, such as the US TIPS bonds. Since their yields are tied to future data releases of a certain macroeconomic variable, they can be also considered as a good measure of the market beliefs about future realizations of the economy. A recent work by Wolfers and Gurkaynak (2006) shows in fact that market expectations extracted from economic derivatives are more accurate than survey data in predicting many US variables.

In this exercise we focus on the future contracts on the euro area inflation, defined as the yearly percentage change of the harmonized index of consumer price (HICP) excluding tobacco, released monthly by Eurostat around 15 days after the end of the month.¹¹ These future contracts were introduced in 2005 and are traded daily on the Chicago Mercantile Exchange (CME).¹²

¹¹The impact of tobacco on the overall index is negligible and estimated to be at most 2.5%. The correlation between the two indexes is 0.94.

¹²A detailed description of the contract can be found Grannan and Srinivasan (2007). To date there are more than 1.5 million contracts for the euro area HICP traded every day. The bid-ask spread for these contracts is reasonably tight, implying a low liquidity

In Figure 1 we show the expected inflation rates extracted from the quotes of the future for each reference month at maturity date. They can track quite accurately the annual growth rate of the euro area HICP. It has to be mentioned that since we are using contracts that are very close to maturity date, we should expect liquidity and risk premia to be negligible especially at such short term horizon (see Piazzesi and Swanson 2008).¹³

Another popular way in the literature to extract market expectations of inflation is to look at the so called break-even inflation rate. This is defined as the difference between yields of inflation-linked bonds and those of fixed rate bonds. For our empirical analysis we preferred to use the future contracts rather than the break-even inflation rate since they seem to be more accurate at predicting inflation at such short-term horizons. Furthermore, inflation-indexed bonds are influenced by microstructure and tax factors that are hard to quantify.

The empirical exercise is conducted as follows. For each day of the sample we estimate the model and generate current and one-month-ahead forecasts of inflation. In Figure 2 we show the boxplot for the daily forecast errors of the futures contracts and for those of the three mixed-frequency models. The left-hand panel refers to the distribution of the forecast errors for the current month, the right-hand panel for one month ahead. All the mixed-frequency models produce not only more accurate but also less volatile forecasts, especially for current inflation. The improvement in the forecast accuracy is on average around 30% for current inflation and somewhat smaller for one-month-ahead inflation, as shown in Table 2, where we report the RMSFE for the three models and the predictions of the futures contracts. In contrast with what we found in the previous exercise, M1 seems to perform slightly better than the other models. Since the forecast periods of the two exercises overlap only in the last two year, this could be interpreted as indicating an increased importance of interest rates in explaining inflation dynamics compared with the exchange rate. This is not surprising if we consider the relative stability of the exchange rate during this period compared with the significant depreciations of the euro that occurred from 2002 to 2005.

In Figure 1 we plot the evolution of the daily forecasts. The graph shows the daily forecasts of model one (M1), the inflation rates extracted from

premium.

¹³The risk premium is considered negligible for short term horizons as in Piazzesi and Swanson (2008).

the quotes of the futures contracts and the actual inflation rate (our target). Apart from a couple of episodes when our model could not capture a sudden drop in inflation, it seems they track inflation more closely than do market expectations. We computed the Diebold-Mariano (DM) test to assess whether this improvement in the forecasts is statistically significant. The DM statistics in Table 3, adjusted as in West (1996), show that model predictions for current inflation are significantly more accurate than those of the derivatives; however, there is no strong evidence for one month ahead. In order to assess the goodness of this result, we also computed a forecast encompassing regression to check whether our models encompass the information of the derivatives over future releases of inflation.¹⁴ Specifically, we construct a daily measure of inflation π_t^d by keeping monthly inflation π_t constant for each day of the month t and regress it over a constant, the daily future contracts expectations D_t^d and our daily model projections \widehat{M}_t^d :

$$\pi_t^d = \beta_0 + \beta_1 D_t^d + \beta_2 \widehat{M}_t^d \quad (7)$$

The results in Table 4 show a very different picture for the two forecasting horizons. For current inflation, the coefficient β_2 is much larger than β_1 , confirming that the model forecasts predicts inflation more accurately than future contracts do. However, both coefficients are significant, suggesting that future contracts still have a small but significant predictive content that is not captured by our models. This implies that we could further reduce the forecast error by combining the predictions from our models with those from the future contracts. The best approach to extract their forecast ability would be to use them directly in our mixed frequency models. However, since they have been quoted only since 2005, their sample length is too short for model estimation. Therefore, we preferred to resort to a forecast combination approach. In Table 5 we show the RMSFE for the combined predictions obtained with estimated weights and equal weights. Unsurprisingly, we find that combining the two forecasts brings a non negligible reduction in the RMSFE especially for the one-month-ahead predictions.

¹⁴As recently shown by Busetti et. al (2009), the Diebold-Mariano test can be characterized by low size compared to forecast encompassing tests.

5 Concluding remarks

In this paper we present a simple model to forecast euro area inflation in real time. It is based on a mixed-frequency model that combines two important components to forecast inflation at short-term horizons: a monthly core inflation index derived from a dynamic factor model that captures persistent changes in inflation, and daily financial variables that are used to extract timely information on the most recent shocks. Financial variables are useful in our context as they are forward looking, easy to observe in continuous time and not subject to revisions, unlike most of the hard data. We use the MIDAS approach, proposed by Ghysels et al. (2002, 2006), to keep the mixed-frequency model tractable and parsimonious. Our approach presents two main advantages. First, the mixed frequency structure of our model allows us to produce real-time forecasts of inflation that are updated with the latest market information. Second, it significantly reduces the unbalanced (ragged-edge) dataset problem typical of the dynamic factor models, which can produce considerable bias in short-term forecasts. Given the lack of daily models for inflation, we assess the forecasting ability of our models with respect to multivariate reduced form models and economic derivatives on euro area inflation. We find that the inclusion of the daily variables helps to reduce the forecasting errors relative to models with only monthly variables and forecasts extracted from daily economic derivatives. The predictive ability of daily asset and commodity prices for current inflation rate is consistent with forward-looking behaviour in the price setting mechanism of firms that could be interesting to study with a structural economic model.

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Table 1

Monthly forecasting accuracy
(RMSFE of recursive forecasts from 2002:5 to 2007:9)

	steps ahead	
	0	1
Compound models		
M1	0.158	0.226
M2	0.148	0.208
M3	0.163	0.216
Univariate models		
RW	0.185	0.261
AR(1)	0.181	0.250
ARMA(2,1)	0.184	0.248
Multivariate models		
VAR_MIDAS	0.169	0.234
VAR_ECON	0.173	0.244

Legend:

RW = random walk of inflation

VAR_MIDAS= VAR(2) with inflation, core inflation and oil prices

VAR_ECON= VAR(3) with inflation, core inflation, oil prices and interest rates.

Notes: in each entry Root Mean Square Forecast Error (RMSFE) is reported. Entries in bold indicate the lowest RMSFE. The first estimation period starts in may 1992 and ends in may 2002. Subsequent estimates follow the recursive scheme (keeping fixed the starting date). Daily forecasts for M1, M2 and M3 are aggregated to produce monthly predictions.

Table 2

RMSFE of daily predictions

	Econ deriv	M1	M2	M3
current month	0.166	0.123	0.132	0.140
one month ahead	0.233	0.219	0.224	0.211

Notes: Each entry reports the RMSFE of the different predictors. The model's prediction errors refer to the recursive unconditional out of sample forecast. Sample period: October 3, 2005 - September 30, 2007.

Table 3

Comparing predictive accuracy: Diebold Mariano forecasting test

	current month			one month ahead		
	M1	M2	M3	M1	M2	M3
MSE	0.012 (2.883)	0.010 (2.277)	0.008 (1.618)	0.006 (0.763)	0.004 (0.434)	0.010 (0.943)
MAE	0.044 (3.754)	0.037 (3.061)	0.035 (2.786)	0.015 (0.889)	0.028 (1.748)	0.032 (1.909)

Notes: the test is on the difference between derivative and model prediction errors. The null hypothesis is that the expected error of the competing forecast is equal to that of the futures market. In brackets the heteroskedasticity and autocorrelation consistent (Newey West) t-stat of the coefficients. Bold t-statistics imply significance at the 5 % level. Sample period: October 3, 2005 - September 30, 2007.

MSE: test on the squared residuals

MAE: test on the absolute residuals

Table 4

Forecast encompassing test : combination weights

	current month			one month ahead		
	M1	M2	M3	M1	M2	M3
Coefficients:						
constant	-0.136 (-1.366)	-0.188 (-2.113)	-0.228 (-2.262)	0.044 (0.296)	0.176 (1.277)	0.036 (0.241)
derivatives	0.297 (3.083)	0.351 (3.670)	0.414 (4.017)	0.389 (4.835)	0.388 (4.650)	0.384 (4.590)
model	0.769 (9.749)	0.634 (8.893)	0.691 (7.821)	0.609 (6.356)	0.517 (6.442)	0.588 (5.997)
Test a diagnostics:						
Wald F statistic	38.23	30.78	23.76	22.27	21.97	21.15
P value, %	0	0	0	0	0	0
Test b diagnostics:						
Wald F statistic	3.37	5.74	6.23	15.86	12.33	7.65
P value, %	1.8	0.0	0.2	0	0	0

- Notes: (1) Equation (7) forecast encompassing test on the daily forecasts
(2) Test a: the null hypothesis is that future forecasts encompass model forecasts
(3) Test b: the null hypothesis is that model forecasts encompass future forecasts
(4) In brackets: heteroskedasticity and autocorrelation consistent (Newey West) t-stat of the coefficients.

Table 5

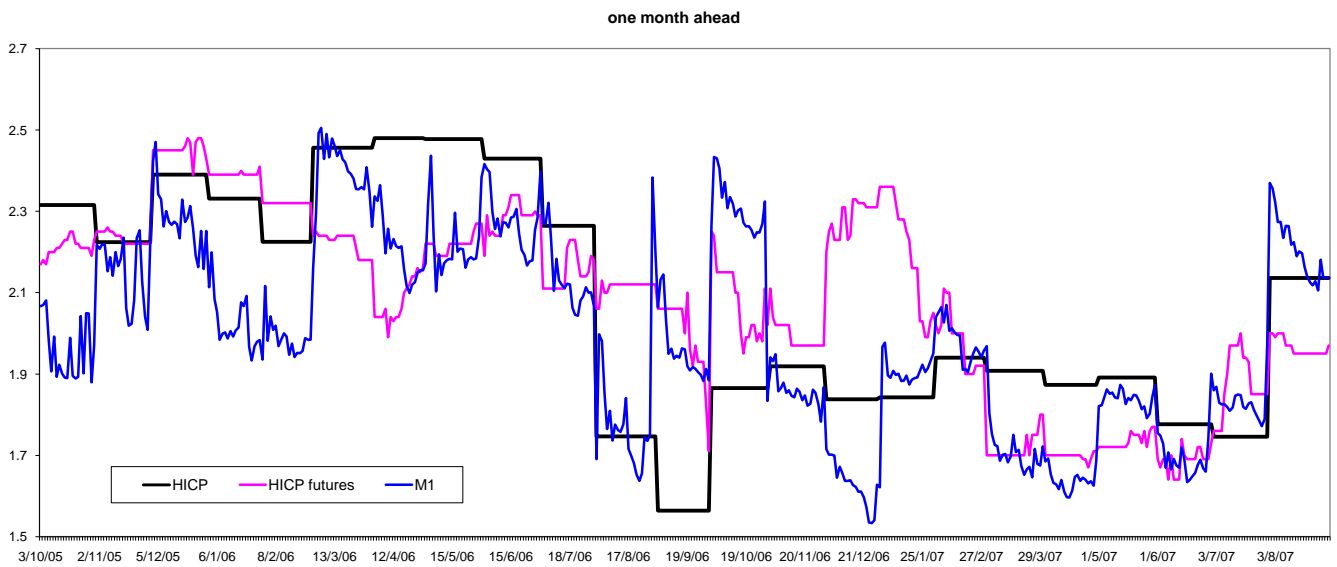
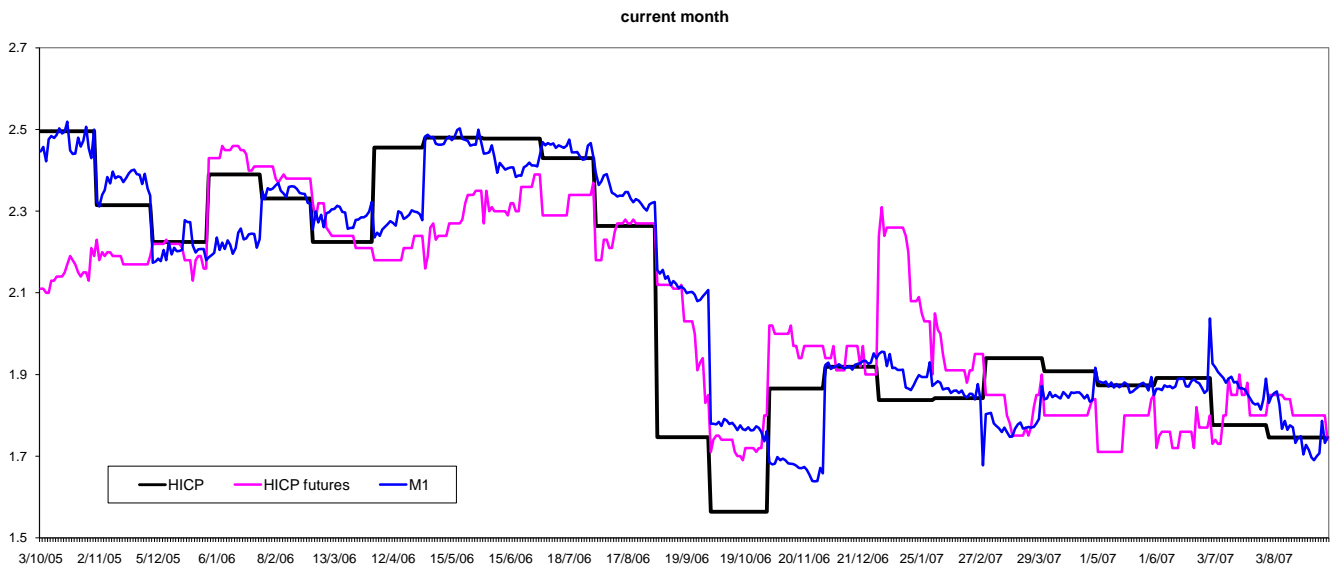
RMSFE of combined daily predictions

	Econ deriv	Combined predictions		
		M1	M2	M3
Equal weights				
current month	0.166	0.124	0.127	0.130
one month ahead	0.233	0.192	0.195	0.190
Estimated weights				
current month	0.166	0.117	0.123	0.128
one month ahead	0.233	0.191	0.195	0.189

Notes: Estimated weights are those of forecast encompassing regressions (Table 4).

Figure 1

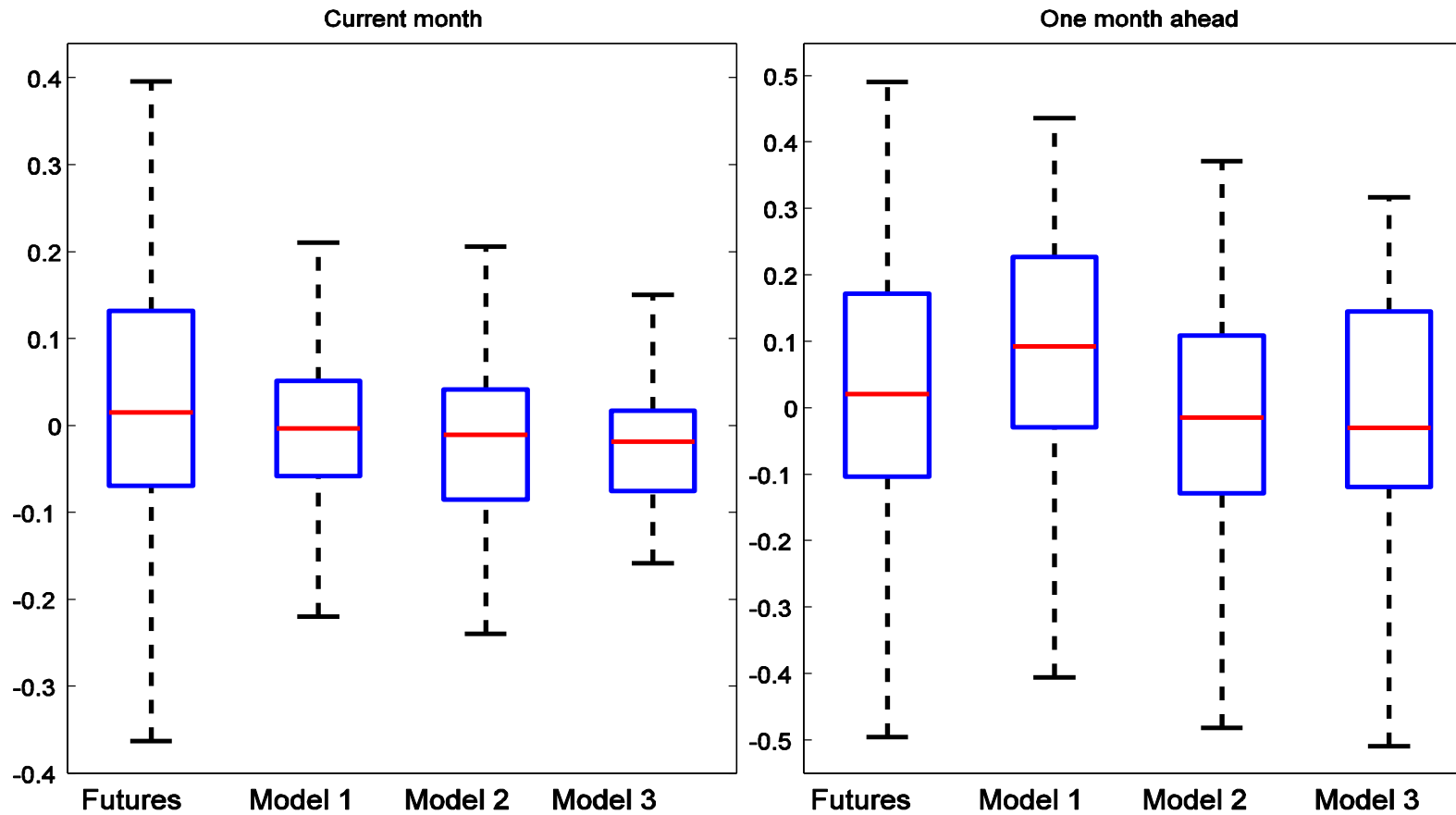
Daily forecasts



Legend:
HICP futures= Monthly inflation rate implied in the daily HICP future contracts (source: Bloomberg)
HICP = HICP inflation rate projected on daily data (source: Eurostat)
m1 = Daily inflation predictions of model 1

Figure 2

Box-Plots of daily forecast errors



Legend:
Futures = Forecast errors of the daily HICP future contracts (source: Bloomberg)
Model 1,2,3 = Forecast errors of the MIDAS models.
The blu box portion represents the first and third quartiles. The median is the red line through the center of the box. The staple is a black line drawn at the last data point within (or equal to) each of the inner fences.
Sample period: October 3, 2005 - September 30, 2007.

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