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Abstract

We evaluate the out-of-sample forecasting performance of six competing models at horizons of up to three quarters ahead in a pseudo-real time setup. All the models use information in monthly indicators released ahead of quarterly GDP. We estimate two models – averaged vector autoregressions and bridge equations – relying on just a few monthly indicators. The remaining four models condition the forecast on a large set of monthly series. These models comprise two standard principal components models, a dynamic factor model based on the Kalman smoother and a generalized dynamic factor model. We benchmark our results to the performance of a naïve model and the historical near-term forecasts of the Czech National Bank's staff. The findings are also compared with a related study conducted by ECB staff (Barhoumi et al., 2008). In the Czech case, standard principal components is the most precise model overall up to three quarters ahead. However, the CNB staff's historical forecasts were the most accurate one quarter ahead.

JEL Codes: C22, C32, C38, C52, C53, E23, E27.

Keywords: Bridge models, dynamic factor models, GDP forecasting, principal components, real-time evaluation.

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Nontechnical Summary

Short-term forecasting of quarterly GDP using monthly indicators is well motivated by the substantial delay in the publication of National Accounts statistics. This delay is ten weeks after the end of the quarter in the case of the Czech Republic. However, weeks before the appearance of the latest GDP figure, several monthly indicators gradually become available for the full quarter. The availability of early information in monthly series therefore offers potential for improving the accuracy of GDP forecasts. Accordingly, GDP forecast accuracy is of key importance for monetary policy in particular, as well as in the general context of macroeconomic forecasting.

In the present study we evaluate the out-of-sample forecast accuracies of six competing models at horizons of up to three quarters ahead. Two of these models rely on only a few key monthly indicators to forecast GDP. The remaining four models are able to condition the forecast on a large number of monthly series. In the latter group we estimate two static and two dynamic factor models. The results of the above models are also contrasted with those of a simple univariate model and the historical forecasts made by the Czech National Bank's staff.

We evaluate the competing quarterly GDP growth forecasts in a pseudo-real time setup. This means using initially just a fraction of the time interval of the available data to generate a forecast. In further steps we gradually add observations and generate new forecasts. Here, we reflect the uneven data availability patterns across the monthly series in every period. The average GDP forecast errors are then computed based on comparisons with actual GDP figures. Our methodology closely follows Barhouni et al. (2008), which is a study conducted by ECB staff using data for nine EU countries and the euro area as a whole.

We find that at the shortest horizon of one quarter ahead, the historical forecasts of the CNB's staff were the most accurate. Overall, looking at all the horizons, the best performing model was principal components, which is one of the static factor models. Second place was taken by the CNB's historical forecasts and third place by a dynamic factor model. These outcomes are roughly comparable to the results of the ECB study, especially concerning euro area countries. To sum up, we recommend that the CNB include the models tested in this paper in its near-term model portfolio for GDP forecasting. We also find, quite surprisingly, that the average forecast computed from the five main models that we focus on is relatively poor compared to the performance of the individual models used in the averaging. Another finding relates to the number of indicators included in the large-scale factor models. Specifically, the factor models estimated on the full set of 98 monthly indicators available did worse compared to both the case of a narrowed set of 27 series and the nave model. The differences in forecasting performance between the various models in our study were found to be statistically significant in most cases.

1. Introduction

Short-term forecasting of quarterly GDP using monthly indicators is well motivated by the substantial delay in the publication of National Accounts statistics. This delay is ten weeks after the end of the quarter in the case of the Czech Republic. However, weeks before the appearance of the latest GDP figure, several monthly indicators gradually become available for the full quarter. These indicators are usually closely related to real economic activity in the broad sense and include industrial production, construction output, domestic or foreign sales and labour market data. Other, alternative monthly indicators that provide timely information on recent developments on the aggregate level, such as price statistics, financial variables and survey data, can also be considered. The availability of early information in monthly series therefore offers potential for improving the accuracy of GDP forecasts. Accordingly, GDP forecast accuracy is of key importance for monetary policy in particular, as well as in the general context of macroeconomic forecasting.

Using Czech data, we compare the out-of-sample GDP forecasting performance of six models relying on information from monthly statistics. Out of the six models using monthly indicators, averaged bivariate VARs and bridge equations consider just a few important monthly series. The two models differ mainly how they bridge the monthly data to quarterly GDP. The remaining four models rely on a relatively large number of indicators (up to 98), which are summarized using recent techniques, such as static and dynamic factor models. In the latter group we include two static factor models estimated by principal components. One dynamic factor model is estimated based on the Kalman smoother and the other one by generalized principal components in the frequency domain. In most of the six approaches outlined we closely follow a related study carried out by ECB staff and described in Barhoumi et al. (2008).¹ In addition, we test the performance of the average forecast obtained from the above models. This is motivated by studies (for example Kapetanios et al., 2007) that have found pooled forecasts outperform individually well-performing but differently mis-specified models.

What we do slightly differently from the aforementioned ECB study is to narrow down the large set of 98 monthly indicators. We apply a simple rule of thumb so as to include only those variables which are “well correlated” with GDP and to exclude those indicators which are mutually “too correlated”. By doing this we aim to reduce variable-specific noise within the panel of monthly series by excluding somewhat irrelevant indicators. The described variable pre-selection results in better performance, especially in the case of the large-scale factor models.

We benchmark the above results to the performance of a naïve univariate model of GDP and the historical near-term forecasts of the Czech National Bank’s staff. The bank’s near-term forecasting framework is multivariate, although it does not explicitly rely on monthly data. In addition, the bank incorporates a considerable amount of expert judgment into its near-term forecast. To summarize, the current project enables us to assess, in the context of Czech data, the forecasting abilities of monthly indicators, various ways of bridging monthly data to quarterly GDP, different versions of factor models, and the role of expert judgement.

¹ The ECB study considers the euro area as whole, six countries from the euro area (Belgium, Germany, France, Italy, the Netherlands and Portugal) and three new EU member states (Hungary, Poland and Lithuania).

We evaluate the competing GDP forecasts in a pseudo-real time setup with monthly updating of the forecasts. The availability of the different monthly indicators at the end of every month is therefore reflected in the evaluation. This results in an unbalanced monthly panel with ragged edges around the latest observations, given the variable-specific delays in data releases. Accordingly, the ragged edges are dealt with in various ways by the models considered. Regarding the described real-time setup we follow the ECB study of Barhoumi et al. (2009). We are also aware of an improved approach to real-time simulations by Camacho and Perez-Quiros (2008, 2009) for the euro area and Spain. The authors use real-time data vintages for their evaluation of a dynamic factor model, which means unrevised versions of both GDP and the monthly indicators exactly as they were available in every period. We have left this possible extension of our application for future research.

The paper is organized in the following way. First, we describe the competing models in detail, grouping them as non-factor models and factor models. Second, we provide some details on our dataset, consisting of 98 monthly indicators. Third, we evaluate our models in terms of out-of-sample root-mean-squared errors and compare the results to the aforementioned ECB study. In the same part we also provide an illustrative example of monthly updates of a forecast as new data becomes available. The last section concludes.

2. Competing Models

We evaluate the out-of-sample forecast accuracies of the eight competing models.² The list can be divided into two groups, namely four non-factor models and four factor models. The first four include the naïve model of four-quarter moving averages of GDP, the core near-term forecasting (NTF) framework used at the bank, the averaged bivariate VAR models (VAR) and bridge equations (BEQ). The naïve model is univariate and the NTF approach does not explicitly rely on information from monthly indicators. The VAR and BEQ models directly link GDP to selected monthly series that are considered good predictors.

The second group is composed of four factor models which link GDP growth to a set of a few estimated factors that are common to a larger set of monthly indicators. Here we include two versions of standard principal components³, where quarterly GDP is bridged with static factors. The first version of the principal components model (PC) follows the ECB's cross-country study by Barhoumi et al. (2008). We include a second, slightly different version (PC-Q) as a reference to an earlier work with leading indicators by Benda and Ruřička (2007) at the Czech National Bank.

The group of factor models under our evaluation further includes two models with an explicitly dynamic structure of factors. In the dynamic factor model of Doz et al. (2007), dynamic factors are estimated by Kalman filtering (DFM). The approach of Forni et al. (2000, 2005), referred to as the generalized dynamic factor model (GDFM), estimates dynamic factors in the frequency domain.

² We replicate the majority of the models listed below from the cross-country study of EU member states conducted by ECB staff in Barhoumi et al. (2008).

³ For a seminal work on forecasting with factors obtained from principal components, see Stock and Watson (2002)

As an additional benchmark we test the out-of-sample forecasting performance of the average forecast coming from the five main models listed above (VAR, BEQ, PC, DFM and GDFM). This approach is motivated by evidence in the literature that pooling forecasts from individually well-performing but differently mis-specified models can improve forecast accuracy. For theoretical studies with related findings see, for example, Fischer and Harvey (1999) and Hendry (2004), while Kapetanios et al. (2007) provide empirical evidence in favour of forecast combination in the context of UK GDP and inflation.

2.1 Non-Factor Models

As a benchmark for the out-of-sample forecast precisions of our models we use the naïve forecasts from the four-quarter moving averages of GDP.⁴ We selected four quarters as the averaging interval based on a rule of thumb. The out-of-sample RMSEs of this model, however, were not very sensitive to slightly altering the averaging window. This result was also robust to changing the start and the end of the evaluation interval. The h-quarters-ahead forecast of the naïve model can be expressed as:

$$\hat{y}_{t+h} = \frac{1}{4} \sum_{i=1}^4 y_{t+h-i}, \text{ where for } h>i \text{ the forecasted values of } y_{t+h-i} \text{ are used.}$$

Next, we test the accuracy of the historical near-term forecasts (NTF) produced at the CNB. The bank's core NTF method can be characterized as a set of linear regression equations describing most of the expenditure components and deflators of GDP. Based on the situation and a subjective evaluation of the quality of the various equations, the forecasts were complemented with expert judgement. The year-on-year GDP growth forecast was computed as the weighted average of the growth rates of the expenditure components using the nominal weights from the same period of the preceding year. When compiling the GDP figure, further expert judgement was applied in order to produce a sensible and sufficiently smooth trajectory for GDP. The aforementioned equations were estimated at a quarterly frequency and the information in the monthly indicators was not reflected explicitly. However, the evolution of the most important leading indicators was usually reflected in the form of expert judgement. Since the set of the aforementioned equations and the amount of expert judgement in the historical forecasts have been changing over time, we will not specify the equations in further detail.

The remaining two non-factor models – averaged bivariate VARs (VAR) and bridge equations (BEQ) – already use the information in the monthly indicators explicitly. Hence, in these two cases we encounter the problem of mixed frequency data. The VAR and BEQ approaches differ mainly in how they bridge the monthly variables to quarterly GDP, including how incomplete quarters, i.e. the ragged edges of the panel of indicators, are treated.

⁴ In the related ECB study by Barhoumi et al. (2007) a simple AR(1) model and the full-sample historical average growth are used as a benchmark. We use the four-quarter average growth instead, as its out-of-sample forecasts turned out to be more precise in the Czech case compared to the naïve models used in the aforementioned study.

In the case of the averaged VAR models,⁵ the N monthly indicators $x_{i,\tau}$ are first aggregated to quarterly frequency (1), where τ indexes time at the monthly frequency and t denotes quarterly time periods. Incomplete quarters are simply omitted. Next, pairs of the GDP series (y_t^Q) and each of the quarterly aggregate indicators $x_{i,t}^Q$ are formed (2). For each of the N pairs a VAR(2, p_i) model is estimated (3), where the lag length p_i is set on the basis of the Akaike information criterion (AIC). Finally, we get the GDP forecast as the average of the forecasts from all the pairwise models (4).

VAR:

$$x_{i,t}^Q = \frac{1}{3} \sum_{s=0}^2 x_{i,\tau-s} \quad (1)$$

$$z_{i,t}^Q = \{y_t^Q, x_{i,t}^Q\} \quad (2)$$

$$z_{i,t}^Q = \mu_i + \sum_{s=1}^{p_i} A_s z_{i,t-s}^Q + \varepsilon_{i,t}^Q \quad (3)$$

$$\hat{y}_{t+h|t}^Q = N^{-1} \sum_{i=1}^N \hat{y}_{i,t+h|t}^Q \quad (4)$$

In the case of the bridge equations⁶ model (BEQ), the monthly indicators are first forecasted at the horizon of interest, which is $H=3h$ months ahead of the latest available GDP figure. The forecast is performed individually for each monthly series based on an AR(q_i) process. The lag length is again selected on the basis of the AIC. Next, each monthly series and its forecast are aggregated to quarterly frequency (5). In the following step, similarly to the VAR(2, p_i) approach above, pairs of GDP and each of the indicators are formed (6). For every pair i bridge equation (7) is estimated by OLS, where the lag length of the indicator series is set on the basis of the AIC. The final GDP forecast is obtained as the arithmetic average of the forecasts from the pairwise models (8).

BEQ:

$$x_{i,t+h}^Q = \frac{1}{3} \sum_{s=0}^2 x_{i,\tau+H-s} \quad (5)$$

$$\{y_t^Q, x_{i,t}^Q\} \quad (6)$$

⁵ The averaged VAR approach has been also applied to data from the United Kingdom by Camba-Mendez et al. (2001). For a general treatment of vector autoregressions, see, for example, Hamilton (1994).

⁶ The outlined bridge equations procedure closely follows the features of Baffigi et al. (2004), Kitchen and Monaco (2003) and Mariano and Murasawa (2003).

$$y_t^Q = \mu_i + \sum_{s=0}^{q_i} \beta_{i,s} x_{i,t-s}^Q + \varepsilon_{i,t} \quad (7)$$

$$\hat{y}_{t+h|t}^Q = N^{-1} \sum_{i=1}^N \hat{y}_{i,t+h|t}^Q \quad (8)$$

2.2 Factor Models

In the second group, containing factor models, we consider two versions of static principal components (PC and PC-Q) similar to the approach of Stock and Watson (2002) and two models assuming dynamic factors (DFM and GDFM). The PC model is estimated as follows. To get a balanced panel of the monthly indicators, incomplete quarters are filled in by forecasts from an autoregressive model (lag lengths set via AIC). Factors are estimated by principal components from the panel of N monthly series x_t . The number of static factors, $r \ll N$ to be included in the model are determined by the Bai and Ng (2002) information criterion.⁷ Every monthly series can thus be decomposed into a linear combination of r factors common to all series and an idiosyncratic term specific to the particular series (9). Next, the estimated factors are aggregated to quarterly frequency (10) and bridged with GDP. The h -quarters-ahead forecast of GDP then follows from the OLS-estimated bridge equation (11). The outlined procedure is thus very standard in estimating principal components, as in Stock and Watson (2002), and bridging the quarterly aggregates of factors with GDP, as in Giannone, Reichlin and Sala (2004) and Giannone, Reichlin and Small (2005).

PC:

$$x_{i,\tau} = \sum_{j=1}^r \lambda_{i,j} F_{j,\tau} + u_{i,\tau} \quad (9)$$

$$F_{j,t}^Q = \frac{1}{3} \sum_{s=0}^2 F_{j,t-s} \quad (10)$$

$$y_{t+h|t}^Q = \rho y_t^Q + \beta F_t^Q + \varepsilon_t \quad (11)$$

Notice that similarly to Stock and Watson (2002), Barhoumi et al. (2007) and others, the h -periods-ahead forecasts are obtained using the projection of GDP growth y_{t+h} on y_t and F_t in (11). As an alternative we could have considered vector autoregression of the (y_t, F_t) pair and acquired h -steps-ahead forecasts by iterating forward by one period h times. However, as Stock and Watson (2002) argue, this alternative may imply estimating more parameters than necessary and therefore worse forecast performance.

⁷ In our data, the Bai and Ng (2002) criterion usually suggested only one static factor to be included in the model.

We also evaluate an alternative version of the model based on static principal components, namely PC-Q. PC-Q differs from PC in three ways. First, in PC-Q the principal components are estimated on the quarterly aggregates of monthly indicators (12). Although quarterly aggregation cuts the number of observations for estimating principal components, this approach was followed by Benda and Ruřička (2007) in order to allow for potential leading indicators that are available only at quarterly frequency. However, in our evaluation exercise we estimate PC-Q on the same set of monthly indicators as PC. Second, the number of static factors is set by the Kaiser criterion.⁸ The last aspect in which PC-Q differs from PC is the treatment of ragged edges in the monthly series. PC-Q uses a balanced panel of indicators by simply omitting incomplete quarters. To sum up, by comparing PC-Q to PC we mainly try to assess whether the information in timely monthly data matters for forecast precision. The h-quarters-ahead forecast of PC-Q (13) is estimated by OLS.

PC-Q:

$$x_{i,t}^Q = \sum_{j=1}^r \lambda_{i,j} F_{j,t}^Q + v_{i,t} \quad (12)$$

$$y_{t+h|t}^Q = \rho y_t^Q + \beta F_t^Q + \varepsilon_t \quad (13)$$

The dynamic factor model (DFM) due to Doz et al. (2007) is estimated in the steps described below. First, static factors are retrieved by the same procedure as in PC above, which includes balancing the panel of monthly indicators and estimating principal components. Next, we assume a VAR(q,p) process (14) driving the dynamics of factors, where q and p are set based on the information criterion developed by Bai and Ng(2007).⁹ The coefficients in A_k and B are estimated by OLS using static factors obtained by principal components. In the next step, dynamic factors are estimated by the Kalman smoother taking the OLS estimates of the coefficients from above as given. Then, forecasts of the dynamic factors at the relevant horizons are produced by the Kalman filter.¹⁰ The ragged edges in the panel of indicators are automatically taken care of by the Kalman filter, which uses all the available information in the monthly series. In the final stage, the factors are aggregated to quarterly frequency (15) and bridged with GDP via the OLS equation (16). For more details on the estimator and the estimation procedure, see Doz et al. (2007).

DFM:

$$f_{\tau} = \sum_{k=1}^p A_k f_{\tau-k} + B \omega_{i,\tau} \quad (14)$$

where f_{τ} is a $[q \times 1]$ vector of dynamic factors, p is the lag length and $\omega_{i,\tau}$ is a vector of innovations $[q \times 1]$.

⁸ According to the Kaiser criterion, principal components with eigenvalues greater than 1 are included in the model. In our data, the Kaiser criterion usually suggested about ten static factors.

⁹ In our data, the Bai and Ng (2007) criterion usually suggested both q and p to be equal to 1.

¹⁰ For a general treatment of Kalman filtering and smoothing in the context of time series analysis, see, for example, Hamilton (1994).

$$f_{j,t+h}^Q = \frac{1}{3} \sum_{s=0}^2 f_{j,\tau+H-s} \quad (15)$$

$$y_{t+h|t}^Q = \mu + \beta' f_{t+h|t}^Q + \varepsilon_{i,t} \quad (16)$$

The last, generalized dynamic factor model (**GDFM**) is based on Forni et al. (2000, 2005). This method allows both dynamic impacts of factors on particular indicators and some degree of cross-sectional and intertemporal correlation among the idiosyncratic shocks of the indicators. The model is estimated by generalized principal components in the frequency domain instead of the time domain, as suggested by the authors. In this approach, individual factors are not estimated directly, therefore the GDP forecast can be obtained only by including GDP in the set of indicators. The GDP forecast is then represented by the forecast of the common components of GDP and the indicators. We follow the ECB study by Barhoumi et al. (2008) and estimate GDFM at quarterly frequency. For more details on the estimation procedure, see also Nieuwenhuyze (2006). Ragged edges of the monthly indicators are equalized by forecasts from autoregressive models, similarly to PC. The number of dynamic factors q and the lag length p are selected based on information criteria.

3. Data

The full database of our monthly indicators consists of 98 time series describing the development of the main areas of Czech economy and the external environment (see also Appendix A). The supply side is represented by indicators depicting the development of industry (29 series), construction (5 series) and the main branches of services (9 series). Several indicators represent the labour market (5). The list contains also foreign trade indicators (4), real and nominal exchange rates (5), monetary aggregates (2) and interest rates (12). We add also surveyed confidence indicators (6) and consumer and producer prices (11). The development of foreign demand is captured by leading indicators for Germany and Europe (10), such as the IFO business climate indicators, the composite leading indicators compiled by the OECD, and new car registrations in both Germany and the eurozone. The beginning of the time period examined was set at January 2001, as longer time series are not available for many of the indicators listed above.

The indicators under consideration were pre-adjusted in the following way. The first step is seasonal adjustment, which is followed by calculating the logarithm and differencing individual time series to make them stationary. Next, the three-month ($xt - xt-3$) growth rates are calculated. Finally, missing values and outliers were identified in the transformed time series and were replaced by the largest admissible values. As for aggregate output, we considered quarterly growth rates of GDP at constant prices of 2000 seasonally adjusted by the Czech Statistical Office and published on 9 June 2010. The series in levels was observed from Q1 1996 until Q1 2010.

To make sure that only the most relevant monthly indicators are considered when estimating the models, we narrowed down the full list of 98 series by a simple rule of thumb. We aggregated the series to quarterly frequency and computed the quarterly growth rates. Next, we calculated the correlation coefficient for every series and the quarterly growth rate of GDP. All variables with a

correlation coefficient of less than 0.5 in absolute terms were excluded. In the next step we eliminated further series if the absolute value of their correlation with any other series was above 0.9. From such a pair, the one more correlated with GDP was kept in each case. The final set of indicators consists of 27 series, as indicated in Appendix A, including correlation coefficients with GDP growth. We are aware that some properties of the estimators we consider in our factor models are based on the assumption of a “large” number of indicators. Motivated by the resulting improvement in the forecasting performance of the factor models, we still opted for reducing the initial set of monthly series for estimating those models.

4. Evaluation

In what follows, the evaluation of forecast accuracies is described. First, the out-of-sample root-mean-squared errors (RMSEs) of the forecasts for the set of methods are compared both in absolute terms and relative to the naïve model. Next, an example of the forecast for Q4 2009 is presented based on all the examined methods. This is aimed at illustrating how forecasts are updated and accuracies improve as additional information becomes available. Finally, the outcomes are compared to an ECB study that covers other countries of the European Union.

The monthly dataset used was available for the period Q1 2001–Q4 2009. The pseudo-real time forecast simulation was carried out for the evaluation period of Q1 2005–Q4 2009. The RMSEs of the out-of-sample forecasts were computed compared to the actual quarterly growth rates of GDP as observed at the time of the exercise (with GDP available up to Q1 2010). Within the simulation the time series are cut to the beginning of the evaluation period, also reflecting the publication lags of the monthly variables. As subsequent months of observations are gradually added, the models are re-estimated and the forecasts are updated on a monthly basis. The exercise continues this way until the end of the evaluation interval.

4.1 Out-of-Sample Forecast Errors

Table 1 below¹¹ presents the out-of-sample RMSEs 1Q to 3Q ahead, where the six models in the upper part of the table are the main focus of our study and the ones below the line are included as benchmarks. In the second part of the table, the forecast errors of the PC, DFM and GDFM factor models in their full panel versions are presented. Here, all 98 monthly indicators were used for the estimation.¹² In addition, we report the performance of the average forecast, which is the simple average of the forecasts from the five main models, namely VAR, BEQ, PC, DFM and GDFM. Finally we report the performances of three simple univariate models – AR(1), historical average and four-quarter average. The first two were also evaluated in the ECB study by Barhoumi et al. (2007), where the second one was taken as the naïve model. We henceforth refer to the four-quarter average as our naïve model.

¹¹ We have omitted the CNB’s NTF framework from the table, as the results are not comparable with the rest of the models. This is because the NTF forecasts were performed on unrevised data.

¹² As we described in the Data section, we reduced the initial panel of 98 monthly indicators considered for estimating the PC, DFM and GDFM factor models to a narrower set of 27 series by a simple rule of thumb in order to improve the forecast accuracy. For a list of the full and narrow sets of monthly series, see Appendix A.

In Table 1, the forecast errors tend to widen with longer horizons. Overall, the best performance is shown by standard principal components (PC). DFM and BEQ are quite close to the top ranked model. The remaining positions are taken by GDFM, PC-Q and VAR. We can argue that the 1Q-ahead horizon is in most cases a nowcast or a backcast, which makes the availability of monthly indicators for the same period most promising for forecasting GDP. We find some evidence in favour of this argument in our results, as the RMSEs for nearly all the models tend to worsen substantially from 2Q onwards. Note that the RMSEs of the NTF model are not comparable to the rest of the data, as the CNB's historical forecasts were made on unrevised data while our model evaluation is performed on the latest data vintage.

Table 1: Out-of-Sample RMSEs (in Terms of Quarterly GDP growth)

RMSE	+1Q	+2Q	+3Q	Average
<i>NTF</i>	0,99	1,43	1,69	1,37
VAR	1,15	1,45	1,63	1,41
BEQ	0,82	1,20	1,46	1,16
PC	0,82	0,89	1,24	0,98
PC-Q	0,94	1,42	1,75	1,37
DFM	0,89	1,03	1,36	1,09
GDFM	1,23	1,21	1,35	1,26
Average forecast	0,97	1,12	1,30	1,13
PC - full panel	1,09	1,07	1,31	1,15
DFM - full panel	1,26	1,43	1,43	1,37
GDFM - full panel	1,29	1,28	1,39	1,32
AR(1)	1,31	1,49	1,50	1,43
historical mean	1,33	1,33	1,33	1,33
4Q averages	1,19	1,31	1,38	1,29

Note: The forecast errors for NTF were computed on unrevised GDP data, so the RMSEs of NTF are not comparable with the rest.

Our results in Table 1 further suggest that the average forecast is by far not the most precise forecasting tool in our case. This is not what one would expect given the experience of previous studies, such as Kapetanios et al. (2007). Moreover, we find that the full panel versions of the PC, DFM and GDFM factor models do much worse than those estimated on the narrower set of indicators, as seen in Table 1. This suggests that smaller models containing only the most relevant indicators make more precise forecasts, in line with the conclusions of Camacho and Perez-Quiros (2008). Finally, we find that, overall up to three quarters ahead, the four-quarter average is the best performing naïve model compared to AR(1) and the historical mean. Therefore, our naïve benchmark is somewhat stricter than that of Barhoumi et al. (2007).

All the methods considered were estimated and evaluated on revised GDP data as available at the time of the evaluation exercise (GDP observed until Q1 2010). This is not the case for the NTF approach, since the historical forecasts had been performed on unrevised time series. Moreover, the evaluation interval of the NTF approach was somewhat shorter than in the rest of the models, as it started from Q3 2006 instead of Q1 2005 owing to the limited availability of historical records of the CNB's short-term forecasts. As a result, the absolute RMSEs are not comparable between the NTF approach and the rest of the models. Therefore, we computed the RMSEs for the naïve model of four-quarter average quarterly GDP growth both on revised and unrevised

GDP vintages. Next, we used the unrevised version to compute the relative RMSEs of the NTF and the revised version for the relative RMSEs of the remaining models, as shown in Table 2.

Table 2: RMSEs Relative to the Naïve Model of Four Quarter Averages

Relat. RMSE	+1Q	+2Q	+3Q	Average
NTF	0,67	0,80	0,91	0,81
VAR	0,97	1,11	1,18	1,09
BEQ	0,69	0,92	1,06	0,90
PC	0,69	0,68	0,90	0,76
PC-Q	0,80	1,09	1,27	1,06
DFM	0,75	0,79	0,99	0,85
GDFM	1,04	0,93	0,98	0,98
Average forecast	0,81	0,86	0,95	0,88
PC - full panel	0,92	0,82	0,95	0,89
DFM - full panel	1,06	1,10	1,04	1,07
GDFM - full panel	1,09	0,98	1,01	1,02
AR(1)	1,10	1,14	1,09	1,11
historical mean	1,13	1,02	0,97	1,03
4Q averages	1,00	1,00	1,00	1,00

Note: RMSEs are presented relative to the naïve model of 4Q averages. The RMSEs of NTF are expressed relative to the naïve model run on unrevised GDP data.

Apparently, the NTF framework does well compared to models using monthly data, and at the shortest horizon of 1Q ahead the NTF performs best. We can hypothesize that the relative success of the NTF comes first from expert judgement, which is likely to take into account developments in the monthly indicators. The second possible explanation stems from the consistency of the NTF forecasts in the structure of the expenditure components of GDP. The structural consistency perhaps better captures turning points in GDP. However, the top ranking of principal components is maintained when all horizons are considered, where the NTF proves to be the second best.

Not all the models, however, are able to beat the naïve model in terms of forecast precision. At all the horizons considered, VAR and PC-Q do worse than the naïve model. In addition, GDFM does not outperform the naïve model at the shortest horizon of 1Q ahead.

To test whether the differences between the forecasting performances of the reported models are statistically significant, we computed pairwise Diebold-Mariano test statistics¹³ on squared errors. This statistic tests the zero hypothesis of equal forecast errors and has a t-distribution with H-1 degrees of freedom, where H is the number of forecast errors observed. Since our forecasts were updated on a monthly basis up to eight months before every quarter of GDP growth observation and the evaluation interval consists of 20 quarters, we have 160 forecast errors available for every model. In Table 3 below we report the test statistics for all horizons together. The listed pairwise test statistics consider the five main models and the naïve forecast. Negative numbers indicate smaller forecast errors for the model in the row. One and two stars denote significance at 95% and 99% respectively. According to Table 3, most of the pairwise tests reject the hypothesis of equal forecast errors. The tests performed at particular horizons provide a slightly smaller number of statistically significant outcomes, though at substantially smaller degrees of freedom.

¹³ The test was developed in Diebold and Mariano (1995). For an applied treatment in the context of ARIMA models, see, for example, Enders (2004).

Table 3: Diebold-Mariano Test Statistics for the H_0 of Equal Squared Forecast Errors.

	VAR	BEQ	PC	DFM	GDFM	4Q average
VAR		2.01*	3.81**	3.28**	1.87*	2.05*
BEQ	-2.01*		2.95**	1.44	-0.41	-0.41
PC	-3.81**	-2.95**		-2.63**	-3.25**	-3.21**
DFM	-3.28**	-1.44	2.63**		-3.17**	-3.03**
GDFM	-1.87*	0.41	3.25*	3.17*		-0.02
4Q average	-2.05*	0.41	3.21**	3.03**	0.02	

Note: Negative statistics indicate smaller forecast errors for the model in the row. * and ** denote significance at the 95% and 99% levels respectively. Degrees of freedom equal 159.

4.2 An Example: Monthly Updates of the Forecast for Q4 2009

The forecast for Q4 2009 is shown in the next figures in order to illustrate the updating of the forecasts and their standard errors on a monthly basis. The forecast for q-o-q GDP growth depending on the number of months remaining to the actual GDP data release is shown together with the standard deviations. The first estimate is evaluated eight months before the GDP data release (the 3Q-ahead forecast), and it continues until the forecast made shortly before the official figures are published (the 1Q-ahead forecast). The last value in point 0 represents the actual GDP growth rate.

Figure 1: VAR (q-o-q, in %, ± 1 std. dev.)

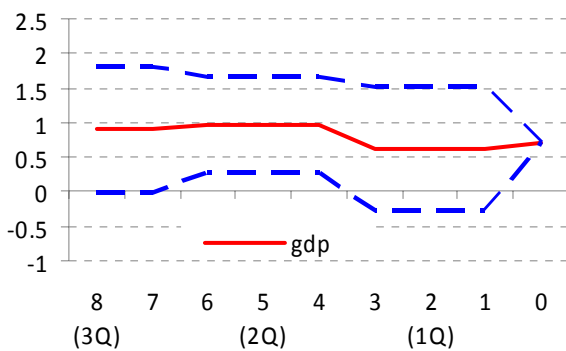


Figure 2: BEQ (q-o-q, in %, ± 1 std. dev.)

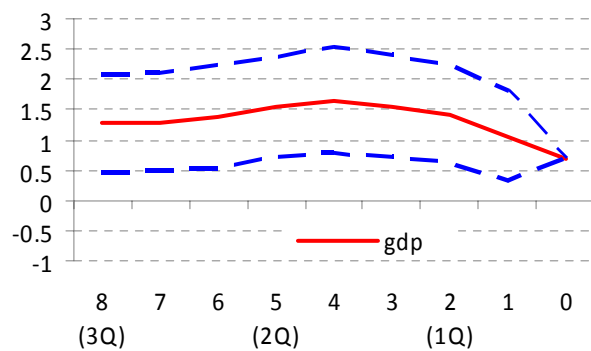
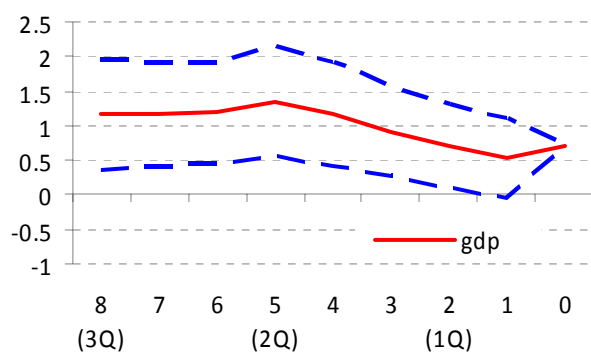
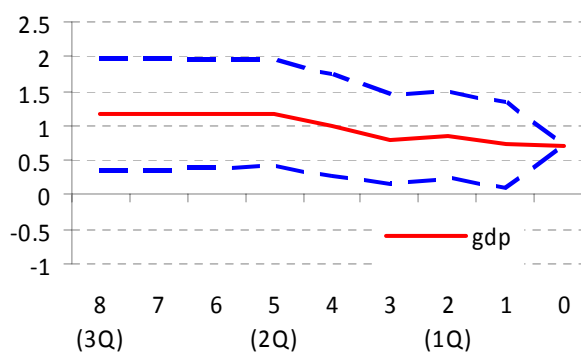
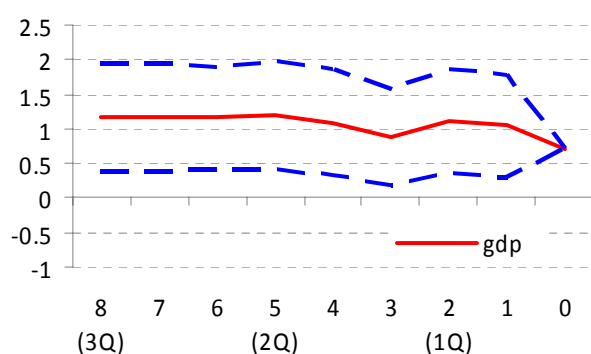


Figure 3: PC ($q-o-q$, in %, ± 1 std. dev.)Figure 4: DFM ($q-o-q$, in %, ± 1 std. dev.)Figure 5: GDFM ($q-o-q$, in %, ± 1 std. dev.)

Note: The *gdp* line represents the evolution of the GDP forecast depending on the number of months remaining to the actual data release.

4.3 Comparable Results from Other EU Countries

A similar comparison of the methods discussed was carried out by the ECB (Barhoumi et al., 2008) for EU countries. The list of countries included the euro area as a whole and six members of the euro area – Belgium, Germany, France, Italy, the Netherlands and Portugal. In addition, three new EU member states were considered, namely Hungary, Poland and Lithuania. This study yields different conclusions for the euro area members on the one hand and for the new EU members on the other hand in terms of the forecast errors of quarterly GDP growth. A fundamental difference emerges right at the beginning and is related to the quantity and quality of the available data. For the euro area countries the methods could be applied to a wide database from Q1 1991 to Q3 2005, whereas in the case of the new member states the time interval started only in Q1 1995. At the same time, the number of monthly indicators, ranging from 76 to 393, was often larger than in the case of the new member states (80 to 103 series). The individual methods therefore in general show better forecasting precision for the euro area countries than for the new EU members. The following table reports the average RMSEs of the evaluated methods for six countries of the euro area and the euro area aggregate relative to the naïve model of the historical mean.

Table 4: RMSEs for Eurozone Countries Relative to the Naïve Model of the Historical Mean

Relat. RMSE	+1Q	+2Q	+3Q	Average
AR	0,99	0,99	1,00	0,99
VAR	0,97	0,99	1,01	0,99
BEQ	0,93	0,96	1,00	0,97
PC	0,86	0,92	0,94	0,91
DFM	0,83	0,90	0,95	0,89
GDFM	0,91	0,92	0,98	0,94

Note: Simple averages across different countries were computed based on the detailed tables of Barhoumi et al. (2007).

The models using additional information from monthly indicators apparently surpass the naïve forecast. At the same time, the approaches using a large set of monthly indicators (PC, DFM and GDFM) show a better forecasting ability than the simpler AR¹⁴, VAR and BEQ methods, some of which use only a limited amount of monthly information.

From the new EU member states, Lithuania, Hungary and Poland were considered. As the following table shows, their average RMSEs relative to the naïve model are considerably worse for some models compared to the euro area results. This is true especially for the approaches that use all the monthly indicators at once, namely PC and DFM (but not GDFM), which perform worse than the simpler AR, VAR and BEQ methods. At the same time their RMSEs are higher in comparison to the naïve forecast (with the exception of GDFM).

Table 5: RMSEs for New EU Member-States Relative to the Naïve Model of the Historical Mean

Relat. RMSE	+1Q	+2Q	+3Q	Average
AR	0,91	0,95	0,99	0,95
VAR	0,95	0,94	0,95	0,90
BEQ	0,94	0,98	0,98	0,96
PC	1,24	1,06	1,07	1,09
DFM	1,14	1,06	1,01	1,05
GDFM	0,90	0,94	0,99	0,94

Note: Simple averages across different countries were computed based on the detailed tables of Barhoumi et al. (2007).

5. Conclusion

We evaluated the out-of-sample GDP forecasting performance of six models based on monthly indicators. We compared those results to the average forecast, various naïve univariate models and the historical near-term forecasts made by the Czech National Bank's staff. The CNB staff forecasts do not explicitly rely on monthly data, but incorporate a significant amount of expert judgement. Our results suggest that at all the horizons considered (up to three quarters ahead),

¹⁴ AR stands for the standard autoregressive model of GDP.

most of the competing models did better than the naïve univariate model of four quarter averages. This is not the case for averaged bivariate VARs, which could only beat the naïve model one quarter ahead. A version of principal components where incomplete quarters of monthly indicators were not taken into account also did worse than the naïve benchmark on average.

Overall, at all the horizons considered, the best performing model was standard principal components, which conditions the forecast on a large number of monthly indicators. The next positions were taken by the following models: the Czech National Bank's historical near-term forecasts, the dynamic factor model using the Kalman smoother, bridge equations, the generalized dynamic factor model, the alternative version of principal components (PC-Q) and averaged bivariate VARs. The top ranking of principal components was maintained for the horizons of two and three quarters ahead. At the shortest horizon, however, the CNB's historical forecasts provided the best results. Quite surprisingly, the average forecast combining the forecasts from the five main models that we focus on was rather poor compared to the individual models. Finally, the three large-scale factor models (PC, DFM and GDFM) did worse than the naïve benchmark when estimated on the full set of 98 monthly indicators instead of a narrowed set of 27. This finding is in line with some other studies suggesting that smaller factor models tend to have better forecasting performance. Our model rankings based on forecast precision were found to be statistically significant in most cases according to pairwise Diebold-Mariano tests of the equality of the squared forecast errors.

In comparison to the ECB study, we got similar results to the euro area countries. Principal components and the dynamic factor model based on the Kalman smoother did well on data from both the Czech Republic and the euro area countries. However, we obtained quite different results in terms of model rankings compared to the new EU member states (Hungary, Poland and Lithuania). At this stage, therefore, it is difficult to draw general conclusions from our results. Nevertheless, we need to interpret such comparisons with substantial care, as the forecast errors are relatively sensitive to the selection of the evaluation interval and the set of monthly indicators. Both these parameters of our evaluation design are difficult to relax. This is first because the sample size of the Czech data is relatively small and therefore we used the longest possible time interval for the evaluation, and second because the set of available indicators differs substantially across countries too.

Concerning the implications for GDP forecasting practices at the Czech National Bank, we recommend using all the models evaluated in the present study. The average forecast of the above models could serve as a good benchmark for the bank's core near-term forecasting framework, at least at the one-quarter horizon. For further quarters ahead, greater weight could be given to the principal components model, which ranked as clearly the best in our evaluation.

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Appendix A: Monthly Indicators Considered for Estimation

Series No.	Name	Correlation with GDP*	Included in factor models?	Number of log differences**
1	Industrial Production Index (IPI)	0.57	N	1
2	IPI mining	-0.03	N	1
3	IPI manufacturing	0.57	Y	1
4	IPI electricity, gas, water	-0.09	N	1
5	IPI food processing	-0.18	N	1
6	IPI beverages	0.47	N	1
7	IPI textile	0.29	N	1
8	IPI clothing	0.08	N	1
9	IPI leather	0.51	Y	1
10	IPI wood	0.00	N	1
11	IPI paper	0.03	N	2
12	IPI printing	0.49	N	1
13	IPI coke, oil refinery products	0.08	N	1
14	IPI chemicals	0.01	N	1
15	IPI pharmaceuticals	0.34	N	1
16	IPI plastics	0.31	N	1
17	IPI non-metal mineral products	0.41	N	2
18	IPI metals	0.22	N	1
19	IPI fabricated metal products	0.49	N	1
20	IPI computers, electronic and optical devices	0.32	N	1
21	IPI electric devices	0.08	N	1
22	IPI machinery	0.63	Y	2
23	IPI motor vehicles excl. motorcycles	0.51	Y	1
24	IPI other vehicles	0.01	N	1
25	IPI furniture	0.15	N	2
26	IPI other manufacturing	0.34	N	1
27	IPI service and maintenance of machines	-0.29	N	1
28	Industry sales	0.55	Y	1
29	New orders in industry	0.32	N	1
30	Construction output	0.20	N	1
31	Building construction	0.28	N	2
32	Civil engineering	-0.16	N	1
33	Building permits issued	-0.08	N	1
34	Approximate value of permitted constructions	-0.06	N	1
35	Sales - wholes., retail, service and maint. of motor vehicles	0.63	Y	2
36	Sales - retail (incl. fuels)	0.42	N	2
37	Sales - services total	0.86	Y	2
38	Sales - transport and warehousing	0.65	N	2
39	Sales - accommodation, catering and hospitality	0.52	Y	2
40	Sales - information and communication services	0.51	Y	2
41	Sales - real estate services	0.29	N	2
42	Sales - professional, scientific and technical services	0.58	Y	2
43	Sales - administrative and complementary activities	0.63	Y	2
44	Number of unemployed	-0.66	N	2
45	Free vacancies	0.73	Y	1
46	Newly registered unemployed (inflows)	-0.77	Y	2
47	Unemployed removed from the register (outflows)	0.02	N	2
48	Unemployment rate (total)	-0.72	Y	2
49	CPI total	0.02	N	2
50	CPI net (excl. regulated prices and indirect taxes)	0.21	N	2
51	CPI adjusted (CPI net, excl. food and fuels)	0.21	N	1
52	Export (current prices)	0.53	Y	1
53	Import (current prices)	0.57	Y	1
54	Export price index	-0.11	N	1
55	Import price index	0.15	N	1
56	Oil price (Brent)	0.32	N	1
57	Earth gas price (Russian, price in Germany)	0.41	N	1
58	Gasoline price (ARA exchange)	0.23	N	1
59	Eurozone PPI (effective)	0.64	Y	1
60	PPI minerals	0.13	N	1
61	PPI manufacturing	0.57	Y	1
62	PPI electricity, gas, steam	-0.30	N	1
63	CZK/EUR	-0.44	N	1
64	CZK/USD	-0.28	N	1
65	NEER	0.31	N	1
66	REER (def. by CPI)	0.33	N	1
67	REER (def. by PPI)	0.27	N	1
68	M1	0.03	N	2
69	M2	-0.05	N	2
70	3M PRIBOR	0.52	Y	2
71	1Y PRIBOR	0.44	N	2
72	ECB 3M rate	0.75	N	2
73	ECB 1Y rate	0.75	Y	1
74	PX stock index (Prague)	0.35	N	2
75	Czech government bond yield (5Y)	0.11	N	1
76	Czech government bond yield (10Y)	-0.01	N	1
77	FRA 3*6 (forward rate)	0.49	N	2
78	FRA 3*9 (forward rate)	0.46	N	2
79	FRA 6*9 (forward rate)	0.43	N	2
80	FRA 6*12 (forward rate)	0.41	N	2
81	FRA 9*12 (forward rate)	0.38	N	2
82	Confidence indicator index (entrepreneurs)	0.61	Y	1
83	Confidence indicator index (consumers)	0.32	N	1
84	Confidence indicator index (total)	0.60	N	1
85	Industry survey - overall economic situation	0.71	Y	2
86	Industry survey - demand	0.60	Y	1
87	Industry survey - expected economic situation in 3 months	0.28	N	1
88	The Ifo Business Climate for Germany - Business Climate	0.38	N	1
89	The Ifo Business Climate for Germany - Business Situation	0.67	Y	2
90	The Ifo Business Climate for Germany - Business Expectations	0.00	N	1
91	OECD Composite Leading Indicator - Czech Republic	0.46	N	1
92	OECD Composite Leading Indicator - Germany	0.81	Y	1
93	OECD Composite Leading Indicator - Europe	0.76	N	1
94	OECD Composite Leading Indicator - Total	0.75	N	1
95	New car registrations - EU	-0.12	N	1
96	New car registrations - Germany	-0.54	Y	1
97	Euro area Business Climate Indicator	0.52	Y	1
98	Electricity consumption in the Cz. Rep. (adj. for temperatures)	0.37	N	1

Notes: * Correlation coefficients were calculated from q-o-q growth rates of the quarterly aggregates

** Monthly indicators were log-differenced before estimation to achieve stationarity

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