Tracking the Course of the Economy

Nowcasting of basic macroeconomic indicators of Slovakia

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Nowcasting of basic macroeconomic indicators of Slovakia

Miroslav Klucik[1]

ABSTRACT

Real GDP and its structure are available within 70 days after the end of the reference quarter. By using leading indicators of higher frequency, it is possible to nowcast GDP in real-time. With an assumption of unobserved factor driving the business cycle we estimate dynamic factor models for real GDP, its demand components, inflation, wages and employment using statistically significant domestic and foreign indicators. To ensure the consistency of out-of-sample forecasts for GDP and its components, past forecast deviations and correlation coefficients are used to adjust the forecast, which helps to reduce the bias of individual models. Forecasts using real-time database are carried out since the 1st January of 2017 using daily data vintages. Real-time forecasts display a reduction of forecasting error with the arrival of new data in the last month of the quarter until the official publication.

The main role of nowcasting in CBR is to track the actual positive and negative macroeconomic risks of the Slovak economy in relation to the latest official national macroeconomic forecast by the Macroeconomic Forecasting Committee. Additionally, the nowcast models help to improve precision of estimates of initial conditions of the economy by bridging the short-term forecast and mid-term forecast.

Keywords: Nowcasting, dynamic factor model, business cycle, Kalman filter, Slovak economy, demand components, short-term forecasting

JEL classification: C22, C32, C53, E32, E37

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1 Introduction

The first release of real gross domestic product (GDP), the so-called flash estimate, is available within 47 days after the end of the reference quarter. The structure of GDP and its components is revealed within 70 days. Nowcasting refers to estimation of macroeconomic variables before their official release during the ongoing reference quarter.

Using an assumption of unobserved latent factor driving macroeconomic variables representing the state of the economy or economic sector we estimate dynamic factor models (DFM) for GDP and its demand components based on domestic and foreign leading indicators. A comprehensive picture of the economy is completed by additional models for consumer prices, nominal wages and employment.

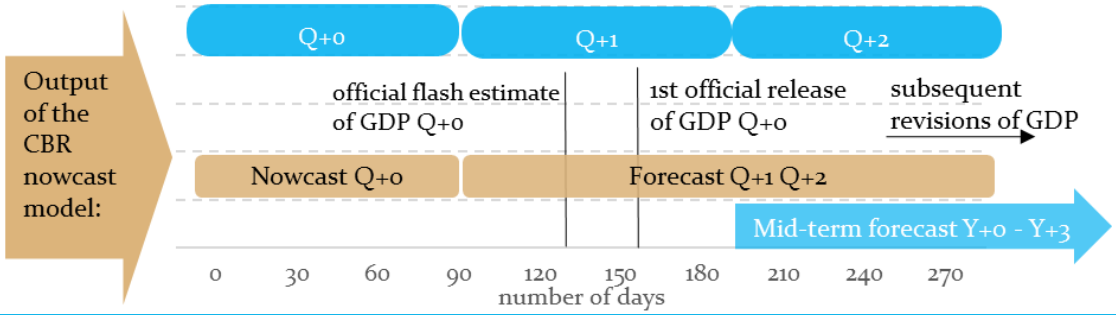
The main role of nowcasting in CBR is to track the actual positive and negative macroeconomic risks of the Slovak economy in relation to the latest official national macroeconomic forecast by the Macroeconomic Forecasting Committee (MFC). Additionally, the nowcast models help to improve precision of estimates of initial conditions of the economy by bridging the short-term forecast and mid-term forecast.

The methodology of nowcasting is based on the application of Cuevas, Perez-Quiros and Quillis (2015) with the proposed methodology of Camacho and Perez Quiros (2010)[2]. In Slovakia several models are currently used in practice, a small dynamic factor model for short-term outlook of economic activity at Institute for Financial Policy at Ministry of finance (Tóth, 2014 or Šilan, 2015 for private consumption) and estimates of GDP and other aggregates by analysts of the National Bank of Slovakia with an approximate factor model (Huček et al., 2015 or Feldkircher et. al, 2015).

The CBR uses simultaneous estimation of several DFMs for GDP and main demand components, extended persistent dynamics of the unobserved factor as well as of the idiosyncratic specific factors. The estimation allows mixing different frequencies of data as well as ragged-end data. The forecasting exercises include back-casting, which coincides with flash estimation of GDP, nowcasting, as well as prediction behind the horizon of the current quarter (**Figure 1**).

Up-to-date macroeconomic information is crucial for fiscal planning. Unrealistic and outdated macroeconomic forecasts can serious hamper budgetary objectives. More precise short-term forecasts of macroeconomic variables can ensure more accurate subsequent mid-term forecast for fiscal planning. These are taken into account in CBR's evaluation reports.

Figure 1. Forecasting time-line



Source: author

[2] An extended parsimonious specification of Stock and Watson (1991).

2 Data

The database is compiled from National Accounts indicators and relevant data of monthly and quarterly frequency selected according to their economic relevance as potential explanatory variables (subjective criterion). Shortlisted database contains real, financial and sentiment indicators from domestic and foreign sources, reflecting the high openness of Slovak economy (Appendix A[3]). The narrow selection of indicators is carried out according to objective criteria in two steps. Firstly, the suitable time series are filtered according to the cross-correlation relationship, secondly, indicators from the shortlisted set compete directly in estimation of the model according to explained variance of the forecasted variable.

All data are seasonally adjusted, deflated and/or in unit values. The estimation period starts in 1st quarter of 2000 until the latest available observation. The chosen econometric approach allows also ragged-end time-series. All variables are transformed to growth rates (for variables in levels), changes (rates), or left in their original form such as sentiment balances, which are understood as deviations from previous year's level. All variables are subsequently demeaned and transformed to have unit standard deviation (Stock and Watson, 2016).

While each model can benefit from the timely publication of indicators vis-a-vis the forecasted national accounts aggregate, they can have additionally a leading relationship. The economic rationale of the lead can be traced towards the early phase of production (e.g. orders), high responsiveness of variables to the development of economy (e.g. working hours v. employment), or forward-looking character of the time series, such as sentiment indicators (Gyomai, Guidetti, 2012). Possible time lead is tested directly during the estimation of the models.

Additional data properties important for forecasting are connected to volatility and revisions of the forecasted variables. Sharp fluctuations in growth rates imply lower likelihood of precise forecast, size and frequency of revisions may give the forecaster additional information about movement of the variable after its first release.

Fixed investment, exports and imports show the largest fluctuation around their mean. On the contrary, private consumption, public consumption and labour market indicators show low volatility[4] (Figure 2). We observe different volatility of variables before and after crisis, especially for real GDP. According to the data of Eurostat, Slovakia's GDP growth rate has the lowest standard deviation in EU since 2010, while it is near median when considering the full sample (Figure 3). This may imply different data generating process of official statistics in the two periods (DGP)[5], possibly more stable economic conditions after the adoption of euro. Very low standard deviations may indicate preference of naive forecasting models relatively to more sophisticated models.

[3] Domestic data sources: Statistical Office of Slovak Republic, National Bank of Slovakia, Ministry of Finance, Central Office of Labour, Social Affairs and Family, The Bratislava Stock Exchange. Foreign data sources: International Monetary Fund, Federal Reserve Bank of St. Louis, CPB Netherlands Bureau for Economic Policy Analysis.

[4] Similarly, stable growth rates of private and public consumption compared to exports, imports and investments are observed in almost in all EU countries. According to the data of Eurostat, largest economies and eurozone, show higher standard deviations of imports and exports relative to investments.

[5] Here, the DGP refers to procedures behind the creation of time series. This procedure can be dependent on used estimation methods, organizational, institutional and other factors used in a particular country.

Figure 2: Standard deviation of quarterly growth rates, forecasted variables

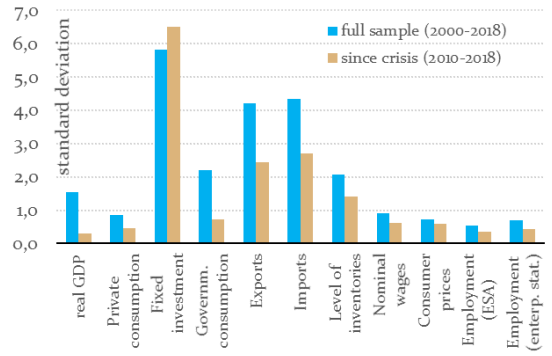
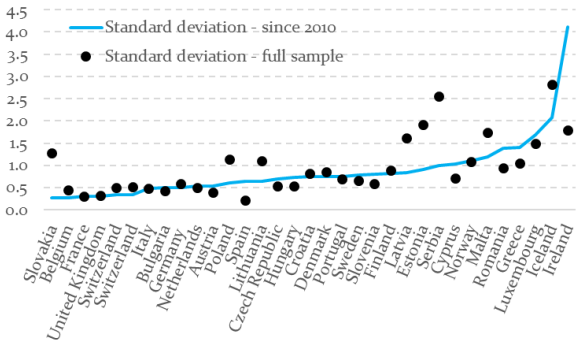


Figure 3: Standard deviation of GDP quarterly growth rates in EU



Source: Eurostat, SO SR, NBS, author

Revision analysis provides information about the likely direction, size and frequency of additional movements of the forecasted variable subsequently after the first preliminary estimate. Starting from the data available at the OECD Revisions Analysis Dataset the basic revision statistics are summarized in Table 1 based on Casey and Smyth (2016)[6]. Large revisions relate to the most volatile time series of exports, imports, and investment reaching over two percentage points year over year (mean absolute revision, MAR). The statistics based on Root Mean Squared Revision (RMSR), which additionally penalizes large outliers, shows more extreme revisions in case of exports and imports relatively to investment.

We can expect the revisions to be roughly balanced in view of the positive and negative revisions. When comparing the actual nowcast from the model to the first preliminary estimate we can expect that in average roughly 1/5th of the GDP quarterly growth rate will be revised (RMAR), based on the sample after the crisis. More revision uncertainty is connected to government consumption and investment where we can expect an average 50% revision of the original quarterly growth rates. In case of government consumption large revisions are partly related to relocation of companies between the private and public sector.

[6] Root Mean Squared Revision (RMSR) measures the average distance of latest estimates (l_l) from preliminary estimates (p_t) in percentage points over the sample n, penalizing large outliers. Mean Absolute Revision (MAR) is a simple mean of revisions without considering their direction. Relative Mean Absolute Revision (RMAR) measures the average size of revision over some period in terms of the initial estimate (p_l).

$$RMSR = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(l_l - p_t)^2}$$

$$MAR = \frac{1}{n}\sum_{t=1}^{n}|l_t - p_t|$$

$$RMAR = \frac{\sum_{t=1}^{n}|l_t - p_t|}{\sum_{t=1}^{n}|p_t|}$$

Tab 1: Revision statistics of quarterly statistics

QoQ growth rates 2001-2018 (2010-2018)						
	GDP	C	G	I	X	M
Mean Average Rev. (MAR)	0.5 (0.1)	0.4 (0.1)	1.7 (0.4)	2.1 (1.7)	1.3 (0.5)	1.4 (0.5)
Root Mean Sq. Rev. (RMSE)	1.2 (0.2)	1 (0.3)	4.4 (1)	4 (3.3)	2.3 (0.8)	2.6 (0.8)
Relative Mean Abs. R. (RMAR)	0.3 (0.2)	0.3 (0.3)	0.7 (0.5)	0.6 (0.5)	0.4 (0.2)	0.4 (0.2)
Maximum range of revision	9.3 (0.7)	10 (1.9)	40.4 (4.6)	27.8 (17.4)	17.6 (3.7)	21 (4.2)
Ratio of upwards revisions	0.52 (0.51)	0.5 (0.49)	0.5 (0.53)	0.51 (0.52)	0.52 (0.52)	0.49 (0.51)
YoY growth rates 2001-2018 (2010-2018)						
Mean Average Rev. (MAR)	0.5 (0.2)	0.6 (0.2)	1.6 (0.6)	2.4 (1.7)	2.3 (0.5)	2.7 (0.7)
Root Mean Sq. Rev. (RMSE)	0.7 (0.4)	1 (0.4)	2.5 (1.2)	3.7 (3.2)	4.2 (0.9)	4.9 (1.4)
Relative Mean Abs. R. (RMAR)	0.1 (0.1)	0.1 (0.1)	0.4 (0.3)	0.3 (0.2)	0.2 (0.1)	0.2 (0.1)
Maximum range of revision	3.8 (1.8)	5.5 (2.7)	11.1 (6.4)	16.3 (16.3)	18.1 (4.9)	20.2 (7.2)
Ratio of upwards revisions	0.52 (0.53)	0.51 (0.49)	0.5 (0.5)	0.5 (0.52)	0.51 (0.53)	0.5 (0.5)

GDP – real gross domestic product, C – real private consumption, G – real government consumption, I – real fixed investments, X – real exports, M – real imports *Source: author*

For real GDP we can expect frequent and higher average revisions during the first 18 months after the preliminary estimate, later large revisions are possible but less often (Figure 4). Most of the revisions in first years relate to seasonal adjustment with median of revisions near zero, while later revisions relate to change of dynamics of the economy (Figure 5).

Figure 4: Average revisions of GDP in terms of YoY growth rates*

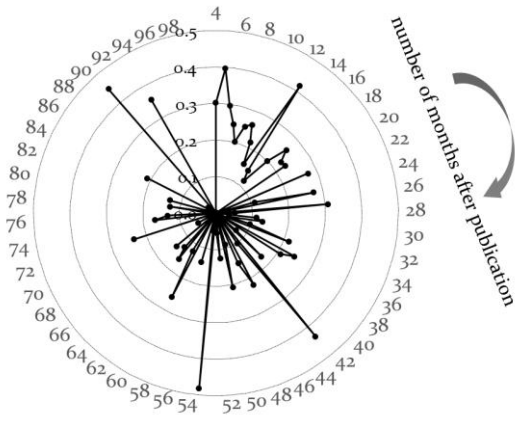
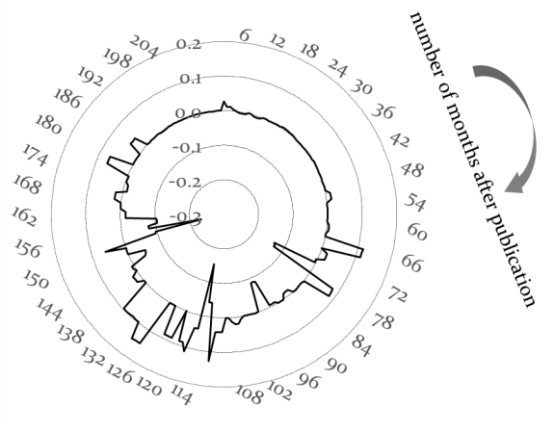


Figure 5: Median of revisions of GDP in terms of YoY growth rates



** Based on the sample 2010-2018.* *Source: OECD, author*

3 Econometric methodology

The aim of the model is to estimate the unobserved state of the economy and its sectors in the form of a monthly common unobserved factor, specific idiosyncratic factors for each sector/variable and estimated uncorrelated errors. Observed variables, such as GDP and monthly explanatory variables, are assumed to have a significant relationship with such common unobserved factor. The estimated factors can help to explain a predominant part of the variation of growth of each macroeconomic aggregate.

The DFM estimation follows the procedure of Camacho and Perez-Quiros (2010), or more recently of Cuevas et al. (2015). The development of macroeconomic variables is determined by the unobserved monthly factor f_t (t is time in months), called economic activity tracker or signal detector. The detector is estimated by means of evolution of a set of indicators in vector $\boldsymbol{x_{it}}$, where the index i refers to number of indicators selected for the model. The relationship between the indicators and the unobserved factor is captured by estimated parameters in $\boldsymbol{\lambda_i}$ (measurement equation – equation 1.1).

$$x_{it} = \lambda_i f_t + e_{it} \tag{1.1}$$

The factor captures only the common movement of all indicators, while the unexplained part – the idiosyncratic component – $\boldsymbol{e_t}$ – represents individual specific movement of economic sectors of the i^{th} time series. Its dynamics is approximated by second-order AR process with estimated parameter in vectors $\boldsymbol{\phi_{1i}}$ and $\boldsymbol{\phi_{2i}}$, independent from the dynamics of the common factor (1.2). The main unobserved factor has a dynamic specification in the state equation (or transition equation – 1.3), with AR(2) process and estimated parameters in vectors $\boldsymbol{\psi_{1i}}$ and $\boldsymbol{\psi_{2i}}$. The movement of common and idiosyncratic component is estimated with identically and independent normally distributed error terms in vectors $\boldsymbol{u_{it}}$, $\boldsymbol{\eta_t}$, with zero mean and constant variance (1.4a, 1.4b).

$$e_{it} = \phi_{1i} e_{t-1} + \phi_{2i} e_{t-2} + u_{it} \tag{1.2}$$

$$f_t = \psi_1 f_{t-1} + \psi_2 f_{t-2} + \eta_t \tag{1.3}$$

$$u_{it} \sim iid\ N(0, \sigma_{i1}) \text{ a } \eta_t \sim iid\ N(0, \sigma_f) \tag{1.4a) (1.4b}$$

The structure of parameters in $\boldsymbol{\lambda_i}$ is related to the specific frequency of indicators in x_{it}. We relate the quarterly growth rate of GDP (and other q quarterly series $\boldsymbol{y_{qt}}$) to monthly rates as a geometric average approximation of monthly growth rates of unobserved monthly factor (1.5)[7].

$$\boldsymbol{y_{qt}} = \boldsymbol{\lambda_i}\left(\frac{1}{3}f_t + \frac{2}{3}f_{t-1} + f_{t-2} + \frac{2}{3}f_{t-3} + \frac{1}{3}f_{t-4}\right) + \frac{1}{3}e_{qt} + \frac{2}{3}e_{qt-1} + e_{qt-2} + \frac{2}{3}e_{qt-3} + \frac{1}{3}e_{qt-4} \tag{1.5}$$

[7] The procedure is set according to Mariano and Musawa (2003). Alternatively, Proietti, Moauro (2006) use non-linear weights, and Tóth (2014) uses geometric average of 3 months. Currently available sample suggests high cross-correlation of GDP growth with four lags of monthly indicators.

Similarly, as in Cuevas et al. (2015), the sentiment indicators (with the notation $\boldsymbol{s_{it}}$) are related to the annual growth rate of unobserved factor due to the year-to-year character of sentiment balances (1.6), as stated by the European Commission (2006). Unlike Cuevas et al. (2015), we set the lead of each indicator separately, according to their ability to improve the fit of the model and we shift time series accordingly.

$$\boldsymbol{s_{it}} = \boldsymbol{\lambda_i}(f_t + f_{t-1} + f_{t-2} + f_{t-3} + f_{t-4} + f_{t-5} + f_{t-6} + f_{t-7} + f_{t-8} + f_{t-9} + f_{t-10} + f_{t-11}) + \boldsymbol{e_{it}} \qquad (1.6)$$

Missing monthly observations in case of quarterly time series and unbalanced data set are dealt with the same way as in Mariano and Murasawa (2003). In case of quarterly data, we assume that the growth rate is observable only in the 3rd month of the quarter. The missing observations are filled with random growth rates from normal distribution (unit standard deviation). After the error is estimated the observation is put back as an unobservable. The same procedure is applied when dealing with unbalanced data set with different start- or end-point of time series.

Given the available system in state-space form (1.7 to 2.0), the estimation via Kalman filter and maximum likelihood optimization requires starting point values of parameters in matrix **H** with elasticity of $\boldsymbol{k}$ explanatory variables to changes in monthly factor stacked in vector $\boldsymbol{h_t}$ (1.8). In the transition equation, the matrix $\boldsymbol{F}$ contains estimated parameters of lagged dynamics and additionally, the variances of all the variables in diagonal of matrix **Q**, which is the variance-covariance matrix of white noise vector $\boldsymbol{U_t}$.

$$Z_t = Hh_t \qquad (1.7)$$

$$\boldsymbol{h_t} = [f_t \dots f_{t-4}, e_{qt} \dots e_{qt-4}, e_{it}, e_{it-1} \dots \boldsymbol{e_{kt}}, \boldsymbol{e_{kt-1}}]' \qquad (1.8)$$

$$h_t = Fh_{t-1} + U_t \qquad (1.9)$$

$$Q = E[U_t U_t'] \qquad (2.0)$$

4 Estimation of the model

The starting values are estimated using principal component analysis (PCA). The monthly unobserved factor is approximated as the first component of PCA explaining the prevailing part of the variance in time series (Figure 6).

The elasticities of explanatory variables to changes in the proxy-factor are estimated by simple regression (starting value for $\mathbf{h_t}$ in 1.7), as well as the lagged parameters of the common and idiosyncratic components (starting values for **F** in 1.9), which are computed as the error of regression. Finally, the variances of errors are taken from the regression as input into matrix **Q**. For each forecasted variable the first principal component is estimated on a subset of time series with no missing observations.

Figure 6: Estimated principal components

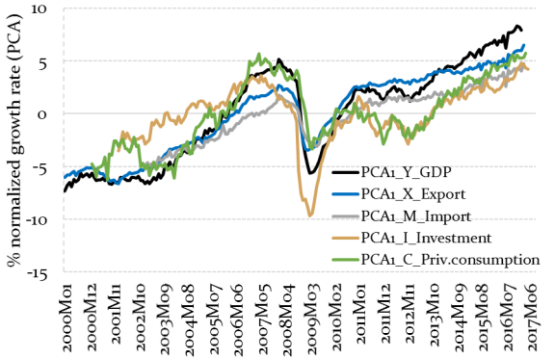
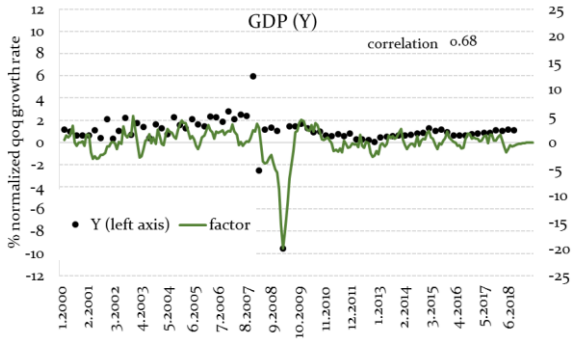


Figure 7: GDP and estimated monthly factor



Source: author

Selection of indicators for the **GDP model** starts from the original approach of Stock and Watson (1991). The coincident common factor is assumed to have close relation with real GDP structure based on three different computation approaches – supply side (production approach), demand side (expenditure approach) and revenue side (income approach). Aggregate monthly indicators are chosen for each of the three approaches, additionally, an indicator representing the labour market is added to the model.

The initial specification is then gradually supplemented by additional leading indicators that further improve the correlation of the unobserved common factor and GDP growth (incrementalistic approach). The final specification uses industrial production index (production side), turnover in selected sectors (demand side) and monthly wage base (income side). The labour market is represented by the rate of short-term unemployed with duration of less than one year. Additional improvement of the fit has been achieved by including real imports of advanced economies and DAX index from Frankfurt Stock Exchange. The correlation of monthly factor with quarterly growth of GDP is 0.68 (Figure 7).

The models for individual demand components are built directly by adding indicators to the forecasted variable until additional indicator fails to improve the fit. More indicators result in increasing correlation of idiosyncratic part with the factor and might result in biased estimation of the common factor. The correlation of the individual factors for GDP components is near 0.90, the lowest is recorded for monthly inflation (0.58) and gross fixed investment (0.72) due to its higher volatility. Estimated monthly factors for individual components are shown in Appendix 2.

The standard errors of parameter estimates are approximated by inverted information matrix (Fisher matrix) computed as a negative of second derivative of maximum likelihood function (Hessian matrix). Estimated parameters for the individual models are presented in Appendix 3. A complete list of indicators entering the models see Table 2 below.

Tab 2: List of indicators used in models for macroeconomic aggregates

Model/Indicator	Start	Source*	Release	Lead
GDP – Real gross domestic product	2000Q1	SO SR, NBS	t+70	0
Turnover in 10 branches, real	2000M1	SO SR, NBS, CBR	t+45	1
Imports of advanced economies, volumes, index	2000M1	CPB	t+55	2
Short-term unemployment rate	2002M1	NBS, COLSAF, CBR	t+45	0
Wage base in 10 branches, defl. by CPI	2000M1	SO SR, NBS, CBR	t+45	3
Industrial production index	2000M1	SO SR, NBS	t+45	3
DAX index, daily close	2003M2	BF	t+1	0
C – Real private household consumption	2000Q1	SO SR, NBS	t+70	0
Turnover in retail, real	2000M1	SO SR, NBS, CBR	t+45	1
Industrial production of consumer goods, index	2008M1	Eurostat, NBS	t+45	3
Import of final consumption goods, deflated by CPI	2003M1	NBS, CBR	t+60	3
Consumer sentiment, balances	2000M1	EC, NBS	t+0	1
Order expectations over the next 3 months in retail, balances	2000M1	EC, NBS	t+0	2
Factors limiting the business in services: demand, %	2003Q1	EC, NBS	t+0	1
G – Real government final consumption	2000Q1	SO SR, NBS	t+70	0
Intermediate consumption of central gov., deflated by CPI	2005Q1	MF SR, NBS, CBR	t+30	1
Compensations expenditures, central gov., deflated by CPI	2005Q1	MF SR, NBS, CBR	t+30	1
Natural social transfers, deflated by CPI	2000Q1	SO SR, NBS, CBR	t+40	0
Spending of EU funds, deflated by PPI	2011M1	CBR	t+30	1
I – Real gross fixed investment	2000Q1	SO SR, NBS	t+70	0
Import of capital goods from EU countries, deflated by PPI	2004M1	Eurostat, CBR	t+60	2
Industrial production of machinery and equipment, index	2008M1	NBS	t+45	3
Spending of EU funds, deflated by PPI	2011M1	CBR	t+30	0
Factors limiting the business in services: equipment, %	2003Q1	EC, NBS	t+0	2
Confidence in construction, balances	2000M1	EC, NBS	t+0	1
X – Real export of goods and services	2000Q1	SO SR, NBS	t+70	0
Export of goods, defl. by PPI-export	2000M1	NBS, CBR	t+45	2
Imports of advanced economies, volumes, index	2000M1	CPB	t+55	3
Hours worked in industry, index	2000M1	SO SR, CBR	t+50	0
IFO business expectations in Germany	2000M1	IFO, NBS	t-7	3
Production expectations for the months ahead, balances	2000M1	EC, NBS	t+0	0
Factor limiting the production: none, %	2000Q1	EC, NBS	t+0	0
M – Real import of goods and services	2000Q1	SO SR, NBS	t+70	0
Import of goods, deflated by PPI	2000M1	NBS, CBR	t+45	2
Exports of advanced economies, volumes, index	2000M1	CPB	t+55	2
Export of goods, defl. by PPI-export	2000M1	NBS, CBR	t+45	0
Confidence in industry, balances	2000M1	EC, NBS	t+0	1
Confidence in retail trade, balances	2000M1	EC, NBS	t+0	3
RI – Real inventories	2000Q1	SO SR, CBR	t+70	0
Dwellings, under construction (end of quarter)	2003Q1	SO SR, CBR	t+0	4
Turnover in industry, intermediate goods	2001M1	SO SR, CBR	t+45	6
Stock of finished products in industry	2000M1	SO SR, NBS	t+0	0
Building activity in construction over the past 3 months	2000M1	SO SR, NBS	t+0	2
Volume of stock in trade	2000M1	SO SR, NBS	t+0	2
NW – Nominal average wage	2000Q1	SO SR, NBS	t+70	0
Average wages in 10 sectors, nominal	2000M1	SO SR, NBS	t+45	2
Wages expenditures of central government	2008M1	MF SR, CBR	t+1	0
Demand expectations in services	2002M1	SO SR, NBS	t+0	0
Economic sentiment indicator	2000M1	SO SR, NBS	t+0	3

Tab 2 -contin.: List of indicators used in models for macroeconomic aggregates

Model/Indicator	Start	Source*	Release	Lead
CPI – Consumer inflation	2000M1	SO SR	t+15	0
Average fuel prices – Diesel Oil	2006M1	SO SR	t+5	2
Export prices of advanced economies, index	2000M1	CPB	t+55	3
Expected consumer inflation – price will grow faster	2003M1	SO SR	t+21	3
Selling price expectation in retail trade	2002M1	SO SR, NBS	t+0	0
EMP – Employment (ESA)	2000Q1	SO SR, NBS	t+70	0
Foreign citizens workers from EU with EU card	2008M1	COLSAF	t+20	1
Consumer expectations – unemployment	2000M1	SO SR, NBS	t+0	2
Employment expectations total	2002M1	SO SR, NBS	t+5	2
EMP – Employment (Enterprise Statistics)	2000Q1	SO SR, NBS	t+70	0
Foreign citizens workers from EU with EU card	2008M1	COLSAF	t+20	2
Inflow of job-seekers to unemployed	2004M1	COLSAF, NBS	t+20	1
Consumer expectations – unemployment	2000M1	SO SR, NBS	t+0	1
Employment expectations total	2002M1	SO SR, NBS	t+5	3

ZEW - Centre for European Economic Research, IFO - Ifo Institute for Economic Research, SO SR - Statistical Office of the Slovak Republic, NBS - National Bank of Slovakia, EC – European Commission, FRED - Federal Reserve Bank of St. Louis, MF SR - Ministry of Finance of the Slovak Republic, COLSAF - Central Office of Labour, Social Affairs and Family, CPB - CPB Netherlands Bureau for Economic Policy Analysis, IMF - International Monetary Fund.

** Includes original source, download source and seasonally adjustment (extrapolation) source* *Source: author*

5 Forecasting performance

Validation of models is performed through standard out-of-sample forecasts and daily real-time forecasts. Due to time-consuming simulations the out-of-sample forecasts are carried out iteratively only on the 14th day of the middle month of each quarter, starting from the 1st quarter of 2008 until last quarter of 2017, using available final vintages. On the other hand, real-time database with originally published data and subsequent revisions is available only from 1st January 2017 and serves as source for daily updated real-time forecasts exercises.

The horizon of the forecasting performance covers three quarters:

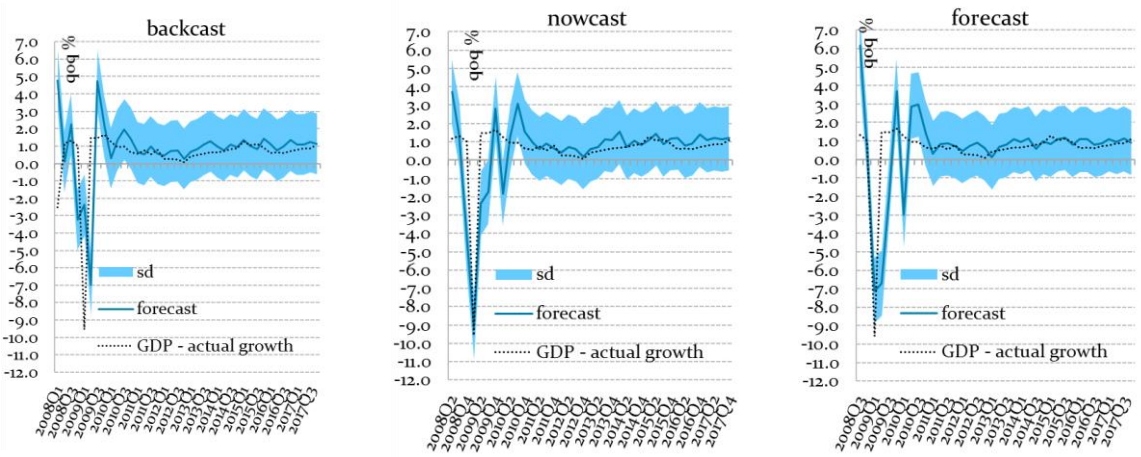
- **back-cast** – coincides with the so-called flash estimate (published regularly approximately on the 15th February, May, August and November). On this date the monthly indicators usually cover all three months of the previous quarter, however, the GDP and its structure are released only at the beginning of the next month.
- **nowcast** – forecast of the ongoing quarter. Only handful of indicators are published at given time, usually soft-indicators. However, several leading indicators exhibit a lead against the dependent series over the business cycle, i.e. some can cover already the whole quarter.
- **forecast** – forecast for the forthcoming quarter for which almost no information is available.

5.1 Out-of-sample forecasts tests

The model performance is assessed by several criteria, the most appropriate model is generally the one with near zero bias and the smallest forecast error. The forecast error increases with the forecast horizon, i.e. it is expected to be higher in forecast and lowest in back-cast. In long-term the best functional form of the model exhibits near-zero bias and variance proportion (systematic errors of forecast), with the covariance proportion near one (non-systematic error of the forecast). Formulas for the calculation and interpretation of the forecasting accuracy metrics is explained in Appendix 5.

The forecasting period for GDP consists of two contrasting periods, very volatile development during 2008-2009 and minimum volatility of quarterly growth rates since 2010 with standard deviation of 0.28 (1.8 for the whole sample). The forecasting accuracy is markedly affected by the performance during the period of 2008-2010. The GDP model forecast captures the quarterly growth rates within the confidence interval for back-cast, nowcast and forecast since 2010 (Figure 8a-8c). For the whole forecasting sample, the model shows a low bias proportion and variance proportion and performs markedly better in comparison to the naive model (Theil's U2 below one, Table 3). The testing sample to 2008-2017 shows bias for nowcast and forecast near zero. The forecasting statistics of the Q_{t+1} shows results similarly to the nowcast statistics, this reflects the small volatility of Slovak GDP growth rate.

Figure 8a-8c: Out-of-sample forecast of GDP (QoQ growth)



sd – sample standard deviation *Source: author*

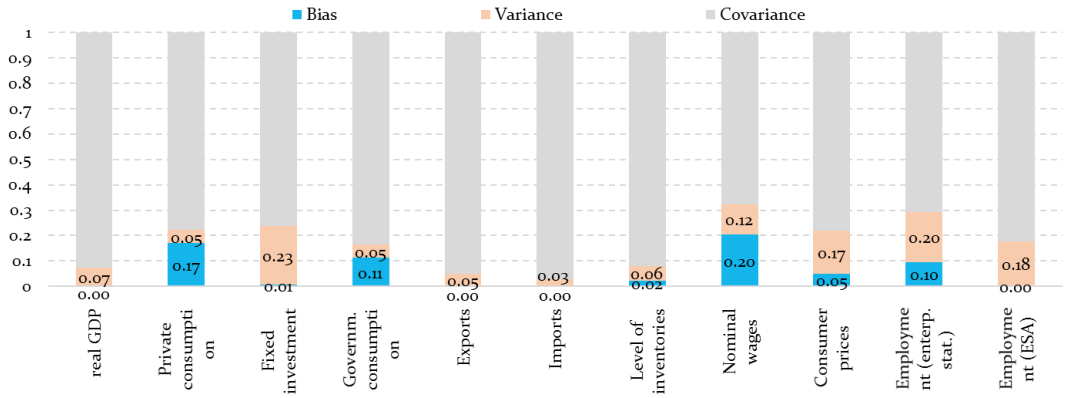
Tab 3: Forecasting accuracy statistics for GDP model

real GDP model	Back-cast (Q_{t-1})	Nowcast (Q_t)	Forecast (Q_{t+1})
Bias	0.33	-0.02	0.06
SE (sample SD=1.75)	2.28	1.42	1.93
MSE	5.33	2.01	3.72
RMSE	2.31	1.42	1.93
U2	0.82	0.56	0.78
Bias proportion	0.02	0.00	0.00
Variance proportion	0.00	0.07	0.07
Covariance proportion	0.98	0.93	0.92

Source: author

Forecasting performance statistics for the individual models are shown in Figure 9. Highest bias is recorded for private consumption and nominal wages, both show inconsistencies of monthly and quarterly indicators since the crisis of 2009. Largest unexplained volatility is found in nowcast of investments and employment.

Figure 9: Forecast error decomposition - nowcast t+0



Source: author

5.2 Balancing of GDP forecast

Given the higher volatility of GDP components compared to GDP, the forecast created as a sum of components is not fully consistent with the development of the aggregate. Although the chain-linked volumes are originally not additive, the resulting sum of forecasts of individual components is disproportionately high (Figure 10).

Figure 10: Forecast from individual GDP model and GDP components

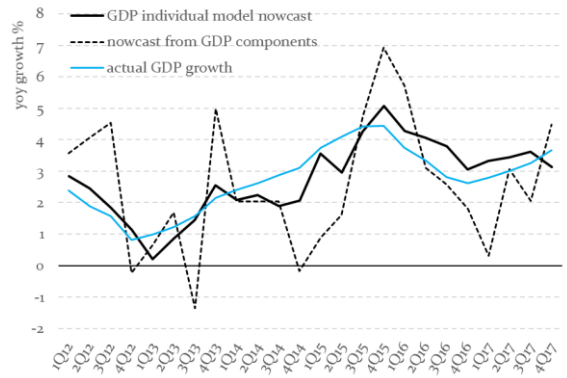
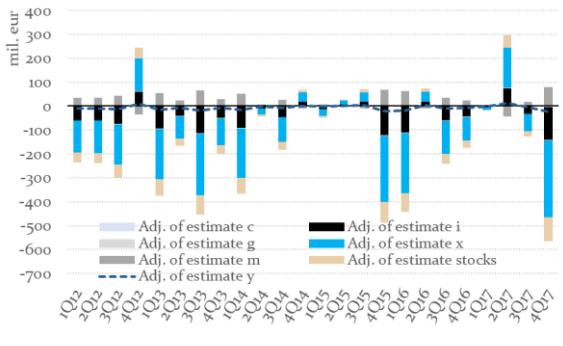


Figure 11: Adjustment of final estimates in balancing procedure of GDP



Source: author

To ensure the additivity of independent individual components to the resulting independent forecast of GDP we apply the balancing method of Van der Ploeg (1982), similarly to Cuevas et al. (2015). We consider the uncertainty of individual models as well as economic consistency in terms of co-movement of aggregates. We allow adjustment of individual

component forecasts as well as the aggregate GDP forecast to enable a potential reduction of past forecasting error of the GDP model.

Additivity is ensured by applying static linear constraints in the *1xn* matrix **A** on final estimates of individual aggregates in n*x1* matrix W (equation 2.1). The final estimates in **W** matrix are the result of optimization procedure ensuring minimization of squared deviations between final estimates **W** and initial estimates of sub-aggregates and the aggregate in *nx1* matrix **X** (equation 2.2). The extent of the adjustment of initial estimates is given in the variance-covariance matrix Σ. We link the variances to past forecast errors of models separately for back-cast, nowcast and forecast. This helps to shrink the forecasting bias of the individual models. The direction of adjustment is determined by covariances of variables, which are derived from historical correlations. For imports we use our own estimates of weights for demand components according to their import intensity.

$$AW = a \tag{2.1}$$

$$\min_{w} \theta = (W - Y)' \Sigma^{-1} (W - Y) \tag{2.2}$$

The most substantial adjustment between initial and final estimates is recorded for the variables with the highest forecast standard error, i.e. exports, investment, inventories and imports (Figure 11). The adjustment of GDP is very small (standard error up to 80 mill euro). The balancing procedure resulted in downward revision of initial forecast of investment, exports and inventories and upward revision of imports (Table 4).

Tab 4: Initial, final nowcast and latest official estimates

Nowcast Q_t	2017Q3			2017Q4		
(central forecasts)	initial	final	(official)	initial	final	(official)
Private consumption (C)	3.7	3.7	(3.9)	3.7	3.7	(3.7)
Government consumption (G)	0.2	0.2	(0.0)	1.2	1.2	(1.6)
Fixed investment (I)	3.6	2.4	(10.3)	10.0	7.8	(7.6)
Exports (X)	3.8	3.3	(3.8)	5.9	4.8	(5.6)
Imports (M)	2.7	2.8	(5.9)	4.4	4.7	(3.2)
Change in inventories (RI)	362.4	328.1	(174.6)	352.1	284.5	(-56.9)
Real GDP (Y)	3.9	3.8	(3.5)	3.7	3.7	(3.5)

Source: author, SO SR

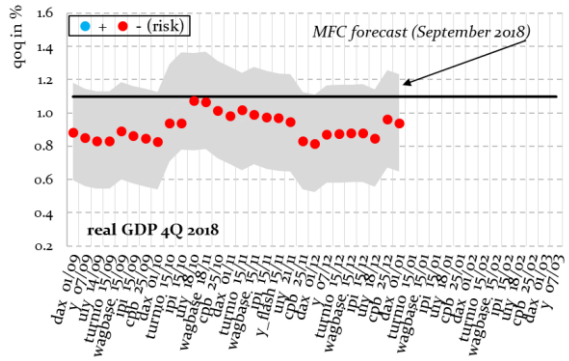
5.3 Real-time nowcasts

Real-time nowcast uses the actual original published data in daily vintages, the database covers the period from 1st January 2017. We show how nowcast are useful for evaluation of potential macroeconomic risks connected with latest official national forecast of the Macroeconomic Forecasting Committee (MFC).

The Figure 12 shows the nowcast of GDP quarterly growth rate for the 4th quarter of 2018 and the positive and negative risk associated with incoming data in comparison to the latest

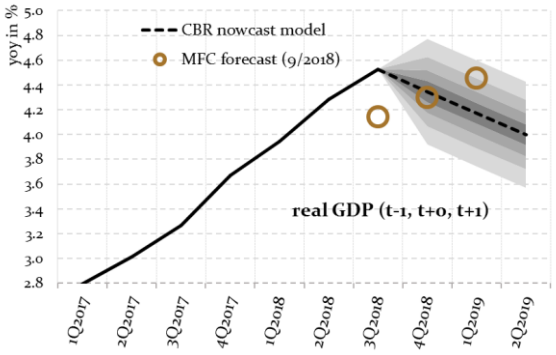
quarterly GDP forecast of the MFC[8]. With available backcast, nowcast and forecast from the model it is possible to evaluate the plausibility of the official forecast for current year and eventually the initial conditions for the forthcoming year (Figure 13).

Figure 12. Real time backcast/nowcast for 4th quarter of 2018



** DAX (German Stock Index), u1y (short-term unemployment rate), turn10 (turnover in selected branches), wagbase (wagebase in selected branches), ipi (Industrial production index), cpb (imports of advanced economies), y - real GDP.*

Figure 13. Development of risks for actual official forecast



**Confidence intervals are based on past forecast errors.*

Sources: author

The model also allows to distinguish the effect of specific incoming data on the forecast. The accumulated model-based news or surprise (Banbura et al., 2013) can reveal the development of specific sectors in the economy and its impact on the forecasted variable over the year. Three-months average of the news show in the case of GDP divergent domestic and foreign data on the actual quarterly growth rate during the year 2018 (Figure 14). Alternatively, one can show the effects of inflow of soft data and real data, as in the example of private consumption (Figure 15).

Figure 14. Surprise indices – GDP (domestic, foreign and labour market)

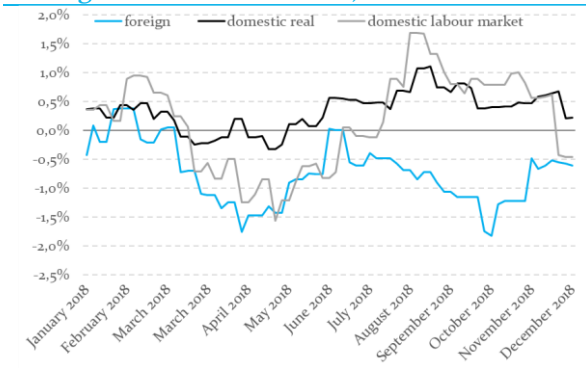
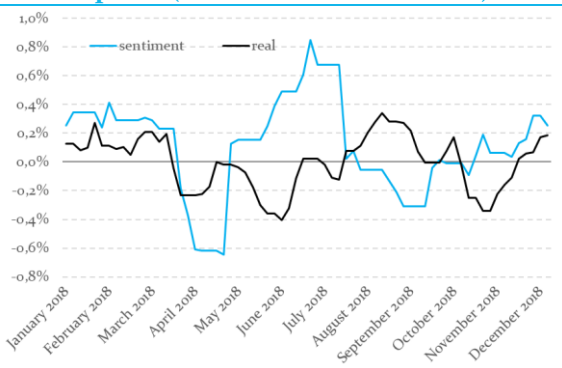


Figure 15. Surprise indices – Private consumption (sentiment and real data)



Source: author

8 The confidence intervals in Figure 12 represent one standard deviation of the quarterly growth rate of GDP. Alternatively, we can use confidence intervals based on past forecast errors.

The common factor estimated in individual models represents the state of the economy or economic sector as a result of common economic shocks. In case of GDP one can construct an index of economic activity representing the state of the whole economy and relate it to the quarterly growth rate of real GDP (Figure 16). Other property of real-time nowcasting is the evolution of forecast during the specific quarter, which shows in most cases improving nowcast with incoming new data during the quarter (Figure 17).

Figure 16. Index of economic activity*

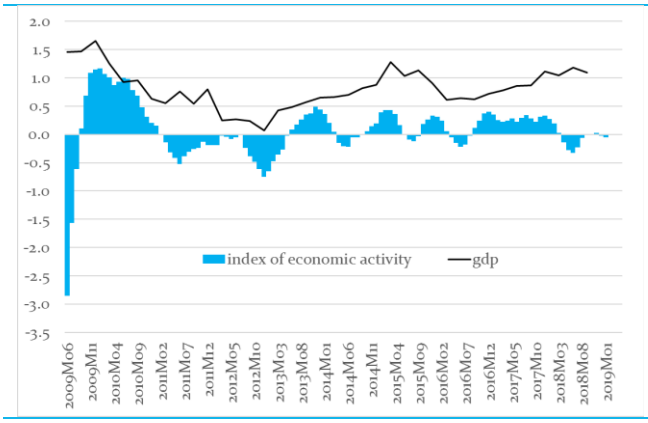
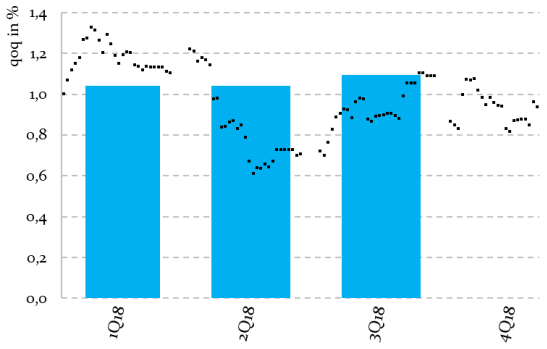


Figure 17. Real-time forecasts vintages and preliminary published results (GDP)



** Index is standardized to have zero mean and one standard deviation*

Source: author

6 Conclusion

The preparation of a multi-year budget requires an up-to-date macroeconomic forecast. The CBR's mandate is to identify potential risks of fiscal projections, which can, among others, come from an outdated macroeconomic baseline. We use seven models for GDP and its demand components – household consumption, investment, government consumption, exports, imports and level of inventories, to forecast on a real-time basis possible changes in dynamics of these main aggregates. This way it is possible with sufficient lead-time to identify possible risks of current available forecasts and measure their potential impact on the macroeconomic baseline. Additionally, nowcast models for wages, consumer inflation and employment are constructed for closer identification of positive and negative risk for the development of macroeconomic bases of tax revenues, which can be used subsequently as input to fiscal nowcasting.

The ongoing research should focus on possible new data inputs into the individual models beyond the official published statistics concentrating on the latest information on the market. These can also encompass the creation of variables from large-scale and multi-dimensional databases (big data).

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Appendix 1 – Database

Tab 5: List of indicators and publication delay against to the reference period

Indicator	Frequency*	Source	Delay in days
ZEW Germany	m	ZEW	t-14
IFO Germany	m	IFO	t-7
Sentiment indicators Slovakia	m	SO SR	t-1
Exchange rates	d	NBS	t-0
Commodity prices, stock indices	d	FRED	t+0
Other financial market indicators	d	FRED	t+0
DAX index	d	BF	t+1
Cash receipts and expenditures of state budget SR	d	MF SR	t+3
International commodity prices	m	IMF	t+7
Consumer inflation	m	SO SR	t+15
Production prices	m	SO SR	t+28
Interest rates, deposits, loans	m	NBS	t+30
Property prices	m	NBS	t+30
Foreign trade	m	SO SR	t+42
Monthly indicators from different branches	m	SO SR	t+42
Production in industry and construction	m	SO SR	t+42
Employment and unemployment	m	COLSAF	t+45
Flash estimate of GDP	q	SO SR	t+47
Orders and hours worked in industry	m	SO SR	t+50
World trade CPB	m	CPB	t+55
Balance of payments	m	NBS	t+60
Tax revenues of public administration	m	MF SR	t+60
Quarterly national and sector accounts	q	SO SR	t+70
Labour market indicators - vacancies	q	SO SR	t+70
Labour market indicators - labour force survey	q	SO SR	t+70
Finished, unfinished flats, houses	q	SO SR	t+70
Potential GDP	q	NBS	t+90

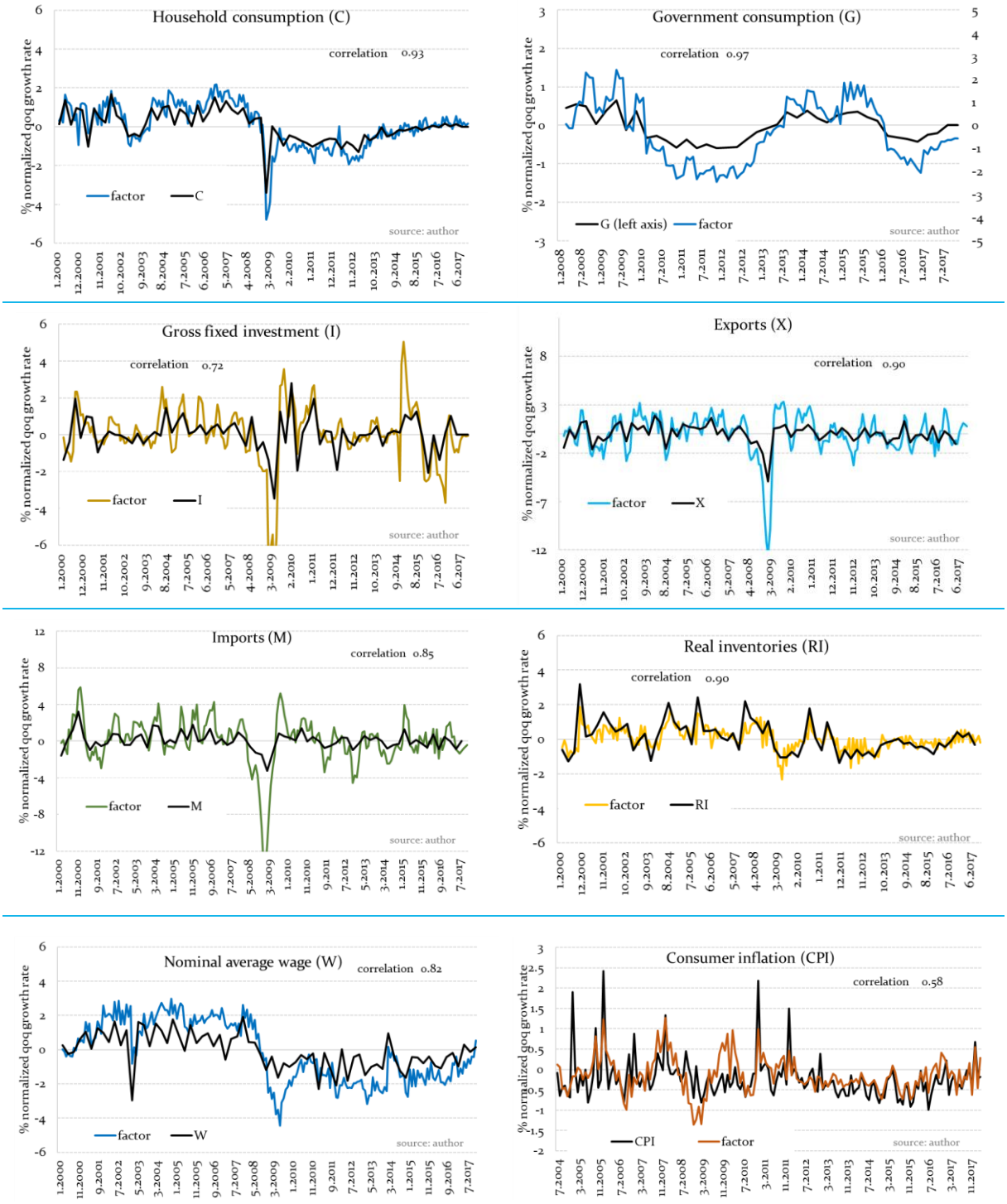
ZEW - Centre for European Economic Research, IFO - Ifo Institute for Economic Research, SO SR - Statistical Office of the Slovak Republic, NBS - National Bank of Slovakia, FRED - Federal Reserve Bank of St. Loius, BF – Börse Frankfurt (Frankfurt Stock Exchange), MF SR - Ministry of Finance of the Slovak Republic, COLSAF - Central Office of Labour, Social Affairs and Family, CPB - CPB Netherlands Bureau for Economic Policy Analysis, IMF - International Monetary Fund.

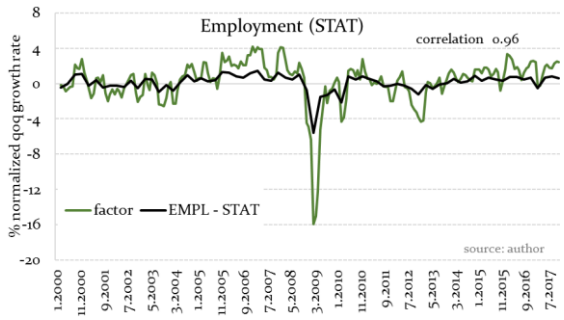
***Frequency: d-daily, m-monthly, q-quarterly**

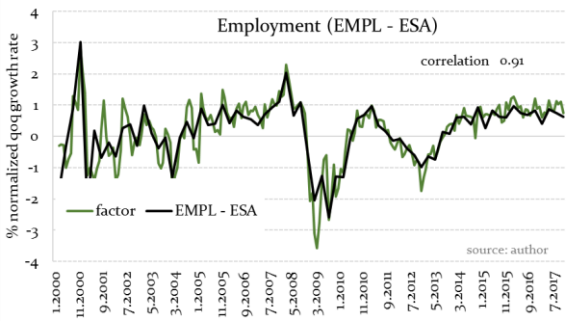
Source: author

Appendix 2 – Monthly unobserved factors

Figure 18: Unobserved factors for GDP and its components and other basic indicators*







** Factors in monthly growth rates, GDP and its components in quarterly growth rates.* *Source: author*

Appendix 3 – Model estimation statistics

Tab 6: Estimated models of GDP, its components and other basic indicators

GDP - Measurement equation		Relation to factor (standard error)		Idiosyncratic component AR1		AR2		Variance	
GDP	x_1	λ_1	0.058 (0.0003)	$\phi_{1,1}$	0.11	$\phi_{2,1}$	-0.87	σ_1	0.28
Turnover in selected branches	x_2	λ_2	0.082 (0.0002)	$\phi_{1,2}$	-0.57	$\phi_{2,2}$	-0.24	σ_2	0.65
Imports of advanced economies	x_3	λ_3	0.130 (0.0030)	$\phi_{1,3}$	-0.03	$\phi_{2,3}$	0.17	σ_3	0.66
Short-term unemployment rate	x_4	λ_4	-0.180 (0.0055)	$\phi_{1,4}$	0.57	$\phi_{2,4}$	0.02	σ_4	0.33
Wagebase in selected branches	x_5	λ_5	0.041 (0.0057)	$\phi_{1,5}$	-0.24	$\phi_{2,5}$	-0.12	σ_5	0.92
Industrial production index	x_6	λ_6	0.039 (0.0068)	$\phi_{1,6}$	-0.64	$\phi_{2,6}$	-0.45	σ_6	0.62
DAX index	x_8	λ_8	0.040 (0.0049)	$\phi_{1,8}$	0.23	$\phi_{2,8}$	-0.15	σ_8	0.90
Transition equation - factor	f_t	-	-	ψ_1	1.52	ψ_2	-0.62	σ_f	1.00
C - Measurement equation		**Relation to factor (standard error)**		**Idiosyncratic component AR1**		**AR2**		**Variance**	
Household consumption (C)	x_1	λ_1	0.157 (0.0013)	$\phi_{1,1}$	0.39	$\phi_{2,1}$	-0.91	σ_1	0.05
Turnover in retail	x_2	λ_2	0.096 (0.0051)	$\phi_{1,2}$	-0.35	$\phi_{2,2}$	-0.18	σ_2	0.85
Industrial prod. of consumption goods	x_3	λ_3	0.060 (0.0055)	$\phi_{1,3}$	-0.25	$\phi_{2,3}$	-0.12	σ_3	0.92
Import of consumer goods	x_4	λ_4	0.035 (0.0048)	$\phi_{1,4}$	-0.69	$\phi_{2,4}$	-0.42	σ_4	0.62
Consumer sentiment	x_5	λ_5	0.046 (0.2149)	$\phi_{1,5}$	0.88	$\phi_{2,5}$	0.07	σ_5	0.08
Orders expectations in retail	x_6	λ_6	0.032 (0.0003)	$\phi_{1,6}$	0.56	$\phi_{2,6}$	0.00	σ_6	0.53
Demand limitations in service	x_8	λ_8	-0.008 (0.0152)	$\phi_{1,8}$	0.98	$\phi_{2,8}$	-0.03	σ_8	0.08
Transition equation - factor	f_t	-	-	ψ_1	0.18	ψ_2	0.68	σ_f	1.00
G - Measurement equation		**Relation to factor (standard error)**		**Idiosyncratic component AR1**		**AR2**		**Variance**	
Government consumption (G)	x_1	λ_1	0.072 (0.0004)	$\phi_{1,1}$	-1.43	$\phi_{2,1}$	-0.69	σ_1	-0.03
Intermediate consumption - central gov.	x_2	λ_2	0.033 (0.1127)	$\phi_{1,2}$	0.43	$\phi_{2,2}$	-0.86	σ_2	0.24
Compensations - central government	x_3	λ_3	0.056 (0.0049)	$\phi_{1,3}$	-0.71	$\phi_{2,3}$	-0.08	σ_3	0.49
Natural social transfers	x_4	λ_4	0.020 (0.0132)	$\phi_{1,4}$	0.48	$\phi_{2,4}$	-0.59	σ_4	0.03
Spending of EU funds	x_5	λ_5	0.133 (0.0004)	$\phi_{1,5}$	0.07	$\phi_{2,5}$	0.26	σ_5	0.85
Transition equation - factor	f_t	-	-	ψ_1	0.13	ψ_2	0.77	σ_f	1.00
I - Measurement equation		**Relation to factor (standard error)**		**Idiosyncratic component AR1**		**AR2**		**Variance**	
Investment (I)	x_1	λ_1	0.095 (0.0019)	$\phi_{1,1}$	0.44	$\phi_{2,1}$	-0.82	σ_1	0.17
Import of capital goods	x_2	λ_2	0.085 (0.0123)	$\phi_{1,2}$	-0.37	$\phi_{2,2}$	-0.26	σ_2	0.82
Industrial production of equipment	x_3	λ_3	0.167 (0.0048)	$\phi_{1,3}$	-0.22	$\phi_{2,3}$	-0.17	σ_3	0.76
Spending of EU funds	x_4	λ_4	0.422 (0.0056)	$\phi_{1,4}$	-0.60	$\phi_{2,4}$	-0.20	σ_4	0.37
Equipment limitations in services	x_5	λ_5	-0.006 (0.0091)	$\phi_{1,5}$	0.16	$\phi_{2,5}$	0.77	σ_5	0.19
Confidence in construction	x_6	λ_6	0.016 (0.0370)	$\phi_{1,6}$	1.03	$\phi_{2,6}$	-0.07	σ_6	-0.05
Transition equation - factor	f_t	-	-	ψ_1	1.25	ψ_2	-0.44	σ_f	1.00
X - Measurement equation		**Relation to factor (standard error)**		**Idiosyncratic component AR1**		**AR2**		**Variance**	
Export of goods and services (X)	x_1	λ_1	0.105 (0.0012)	$\phi_{1,1}$	0.33	$\phi_{2,1}$	-0.81	σ_1	0.16
Export of goods	x_2	λ_2	0.097 (0.0047)	$\phi_{1,2}$	-0.51	$\phi_{2,2}$	-0.24	σ_2	0.73
Imports of CEE countries	x_3	λ_3	0.123 (0.0055)	$\phi_{1,3}$	0.13	$\phi_{2,3}$	0.26	σ_3	0.79
Hours worked in industry	x_4	λ_4	0.052 (0.0055)	$\phi_{1,4}$	-0.84	$\phi_{2,4}$	-0.55	σ_4	0.47
IFO expectations Germany	x_5	λ_5	0.040 (0.0043)	$\phi_{1,5}$	1.16	$\phi_{2,5}$	-0.22	σ_5	-0.06
Expectations in industry	x_6	λ_6	0.027 (0.0033)	$\phi_{1,6}$	0.33	$\phi_{2,6}$	0.10	σ_6	0.61
(No) activity limitations in industry	x_8	λ_8	0.020 (0.0063)	$\phi_{1,8}$	0.19	$\phi_{2,8}$	0.74	σ_8	0.17
Transition equation - factor	f_t	-	-	ψ_1	1.37	ψ_2	-0.53	σ_f	1.00
M - Measurement equation		**Relation to factor (standard error)**		**Idiosyncratic component AR1**		**AR2**		**Variance**	
Import of goods and services (M)	x_1	λ_1	0.067 (0.0016)	$\phi_{1,1}$	-0.42	$\phi_{2,1}$	-0.88	σ_1	0.59
Import of goods	x_2	λ_2	0.081 (0.0052)	$\phi_{1,2}$	-0.88	$\phi_{2,2}$	-0.48	σ_2	0.74
Exports of CEE countries	x_3	λ_3	0.075 (0.0063)	$\phi_{1,3}$	-0.48	$\phi_{2,3}$	-0.12	σ_3	0.87
Export of goods	x_4	λ_4	0.060 (0.0047)	$\phi_{1,4}$	-0.12	$\phi_{2,6}$	-0.26	σ_4	0.78
Confidence in industry	x_5	λ_5	0.027 (0.0059)	$\phi_{1,5}$	-0.26	$\phi_{2,4}$	-0.03	σ_5	0.29
Confidence in retail	x_6	λ_6	0.006 (0.0062)	$\phi_{1,6}$	-0.03	$\phi_{2,5}$	-0.45	σ_6	0.23
Transition equation - factor	f_t	-	-	ψ_1	1.47	ψ_2	-0.57	σ_f	1.00

RI - Measurement equation		Relation to factor (standard error)		Idiosyncratic component AR1		AR2		Variance	
RI – Real inventories	x_1	λ_1	0.272 (0.0151)	$\phi_{1,1}$	-0.54	$\phi_{2,1}$	0.00	σ_1	2.19
Dwellings, under construction (end of quarte	x_2	λ_2	0.140 (0.0071)	$\phi_{1,2}$	0.07	$\phi_{2,2}$	0.33	σ_2	0.21
Turnover in industry, intermediate goods	x_3	λ_3	0.238 (0.0047)	$\phi_{1,3}$	-0.06	$\phi_{2,3}$	0.16	σ_3	0.88
Stock of finished products in industry	x_4	λ_4	0.037 (0.0303)	$\phi_{1,4}$	0.52	$\phi_{2,4}$	0.22	σ_4	0.37
Building activity in construction over the pas	x_5	λ_5	0.034 (0.0013)	$\phi_{1,5}$	0.80	$\phi_{2,5}$	0.02	σ_5	0.28
Volume of stock in trade	x_6	λ_6	0.005 (0.0026)	$\phi_{1,6}$	0.54	$\phi_{2,6}$	0.21	σ_6	0.53
Transition equation - factor	f_t	-	-	ψ_1	0.05	ψ_2	0.62	σ_f	1.00
W - Measurement equation		Relation to factor (standard error)		Idiosyncratic component AR1		AR2		Variance	
Nominal average wage (W)	x_1	λ_1	0.115 (0.0011)	$\phi_{1,1}$	0.35	$\phi_{2,1}$	-0.79	σ_1	0.21
Monthly average wages	x_2	λ_2	0.038 (0.0002)	$\phi_{1,2}$	-0.66	$\phi_{2,2}$	-0.40	σ_2	0.64
Wages expenditures (central gov.)	x_3	λ_3	0.004 (0.0005)	$\phi_{1,3}$	-0.56	$\phi_{2,3}$	-0.21	σ_3	0.74
Demand expectations in services	x_4	λ_4	0.033 (0.0001)	$\phi_{1,4}$	0.68	$\phi_{2,6}$	0.16	σ_4	-0.14
Economic sentiment indicator	x_5	λ_5	0.032 (0.0001)	$\phi_{1,5}$	0.85	$\phi_{2,4}$	0.04	σ_5	0.11
Transition equation - factor	f_t	-	-	ψ_1	0.07	ψ_2	0.87	σ_f	1.00
CPI - Measurement equation		Relation to factor (standard error)		Idiosyncratic component AR1		AR2		Variance	
Consumer inflation (CPI)	x_1	λ_1	0.351 (0.0380)	$\phi_{1,1}$	-0.02	$\phi_{2,1}$	-0.18	σ_1	0.00
Average fuel prices – Diesel Oil	x_2	λ_2	0.007 (0.0900)	$\phi_{1,2}$	-0.18	$\phi_{2,2}$	0.54	σ_2	0.75
Export prices of CEE countries, index	x_3	λ_3	0.018 (0.0344)	$\phi_{1,3}$	0.54	$\phi_{2,3}$	-0.15	σ_3	0.83
Expected cons. infl. – price will grow faster	x_4	λ_4	0.013 (0.0020)	$\phi_{1,4}$	-0.15	$\phi_{2,6}$	0.00	σ_4	-0.12
Transition equation - factor	f_t	-	-	ψ_1	0.30	ψ_2	0.24	σ_f	1.00
EMPL-STAT - Measurement equation		Relation to factor (standard error)		Idiosyncratic component AR1		AR2		Variance	
Employment (enterprise statistics)	x_1	λ_1	0.082 (0.0027)	$\phi_{1,1}$	0.11	$\phi_{2,1}$	-0.89	σ_1	0.17
Foreign citizens workers from EU	x_2	λ_2	0.020 (0.0008)	$\phi_{1,2}$	-0.89	$\phi_{2,2}$	0.00	σ_2	0.98
Inflow of job-seekers to unemployed	x_3	λ_3	-0.041 (0.0010)	$\phi_{1,3}$	0.00	$\phi_{2,3}$	0.08	σ_3	0.93
Consumer expectations – unemployment	x_4	λ_4	0.019 (0.0002)	$\phi_{1,4}$	0.08	$\phi_{2,6}$	-0.19	σ_4	0.11
Employment expectations total	x_5	λ_5	0.018 (0.0001)	$\phi_{1,5}$	-0.19	$\phi_{2,4}$	-0.12	σ_5	0.09
Transition equation - factor	f_t	-	-	ψ_1	1.42	ψ_2	-0.50	σ_f	1.00
EMPL-ESA - Measurement equation		Relation to factor (standard error)		Idiosyncratic component AR1		AR2		Variance	
Employment (enterprise statistics)	x_1	λ_1	0.211 (0.0027)	$\phi_{1,1}$	0.64	$\phi_{2,1}$	-0.88	σ_1	0.01
Foreign citizens workers from EU	x_2	λ_2	0.069 (0.0008)	$\phi_{1,2}$	-0.01	$\phi_{2,2}$	0.08	σ_2	0.98
Consumer expectations – unemployment	x_3	λ_3	0.033 (0.0005)	$\phi_{1,3}$	0.80	$\phi_{2,3}$	0.10	σ_3	0.11
Employment expectations total	x_4	λ_4	0.040 (0.0006)	$\phi_{1,4}$	0.65	$\phi_{2,6}$	0.30	σ_4	0.09
Transition equation - factor	f_t	-	-	ψ_1	0.53	ψ_2	0.27	σ_f	1.00

Source: author

Appendix 4 – Out of sample forecasts tests

Figure 19: Household consumption - nowcast

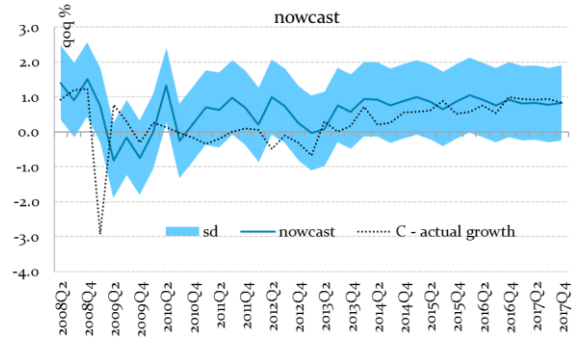
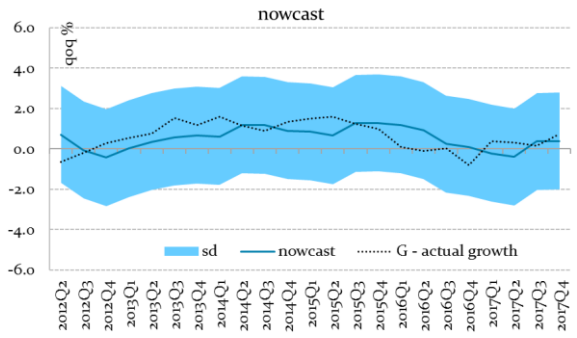


Figure 20: Government consumption - nowcast



Source: author

Figure 21: Fixed investment - nowcast

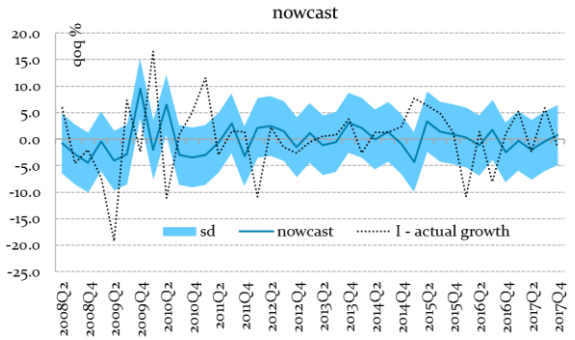
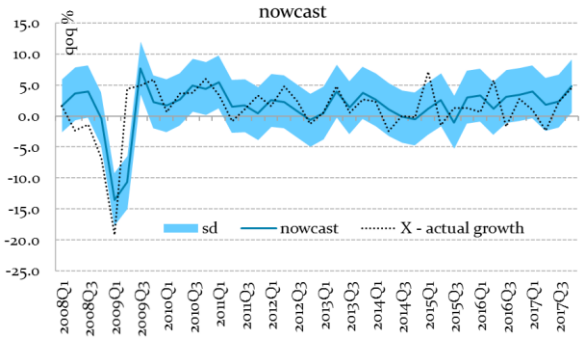


Figure 22: Export - nowcast



Source: author

Figure 23: Import - nowcast

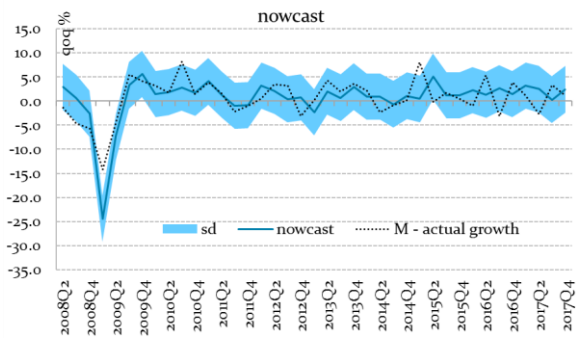
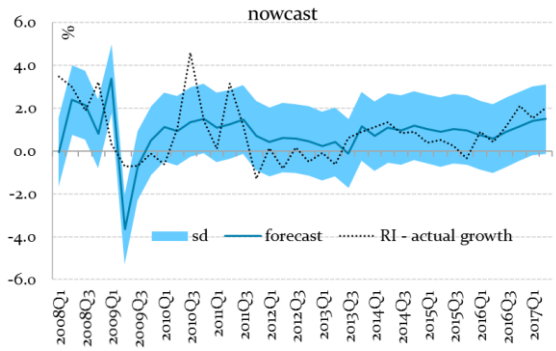


Figure 24: Real inventories - nowcast



Source: author

Figure 25: Nominal average wages (W) - nowcast

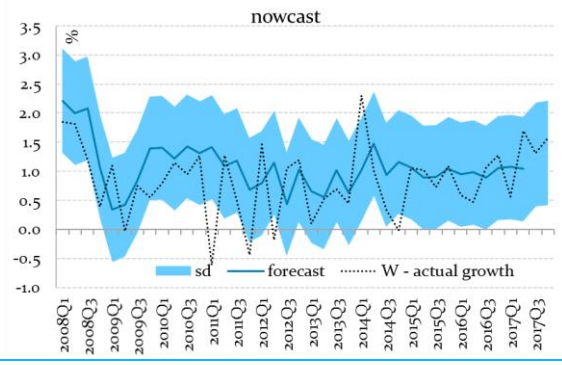
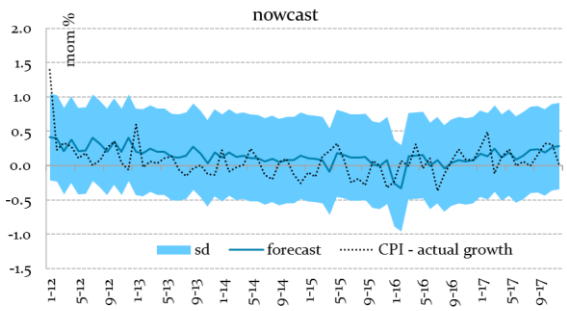


Figure 26: Consumer inflation (CPI) - nowcast



Source: author

Figure 27: Employment (enterprise statistics, EMPL) - nowcast

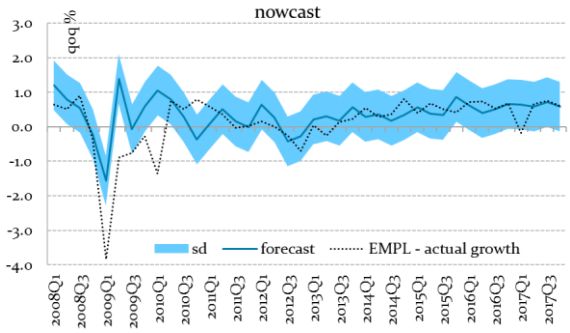
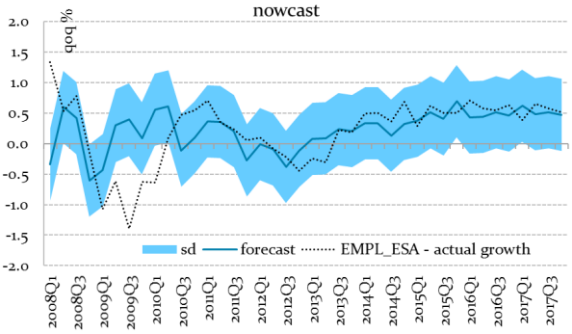


Figure 28: Employment (ESA, EMPL_ESA) - nowcast



Source: author

Appendix 5 – Forecasting accuracy statistics

Standard forecasting accuracy statistics – the forecast bias (BIAS), is the average distance between the forecasted value ($\hat{y}_t$) and the actual value (y_t) over the forecasting sample – (2.3 and 2.4). More accurate forecasts have a near-zero mean BIAS. With increasing number of forecasts f the bias should converge towards zero, i.e. the expected value of the forecast is heading towards unbiased forecast. BIAS is interpreted as the **persisting deflection of forecast from target in one direction.**

$$FE_t = \hat{y}_t - y_t \tag{2.3}$$

$$BIAS = \frac{1}{f}\sum_{t=1}^{f} FE_t \tag{2.4}$$

Further evaluation statistics distinguish between positive and negative deviations of forecasted values from actuals in which positive and negative deviations do not cancel out. The standard error (SE) is the spread of forecasted values from its own mean (SE, 2.5.). **SE defines a normal range of deviations of forecast outcomes from actual values**.

The mean square error metrics, **MSE, measures the closeness of actual and predicted values capturing also the magnitude of the forecast errors**, giving the larger errors high weights due to squared errors (2.6). The MSE also combines the variance of the forecast error and the difference of the forecasted from the correct value (2.7). The root of the MSE, the root mean squared error **(RMSE), measures the average distance of outcomes from reality directly in percentage points** (same quantities as the predicted values, 2.8).

$$SE = \sqrt{\frac{1}{f}\sum_{t=1}^{f}(FE_t - BIAS)^2} \tag{2.5}$$

$$MSE = SE^2 + BIAS^2 \tag{2.6}$$

$$MSE = \frac{1}{f}\sum_{i=1}^{f} {FE_i}^2 \tag{2.7}$$

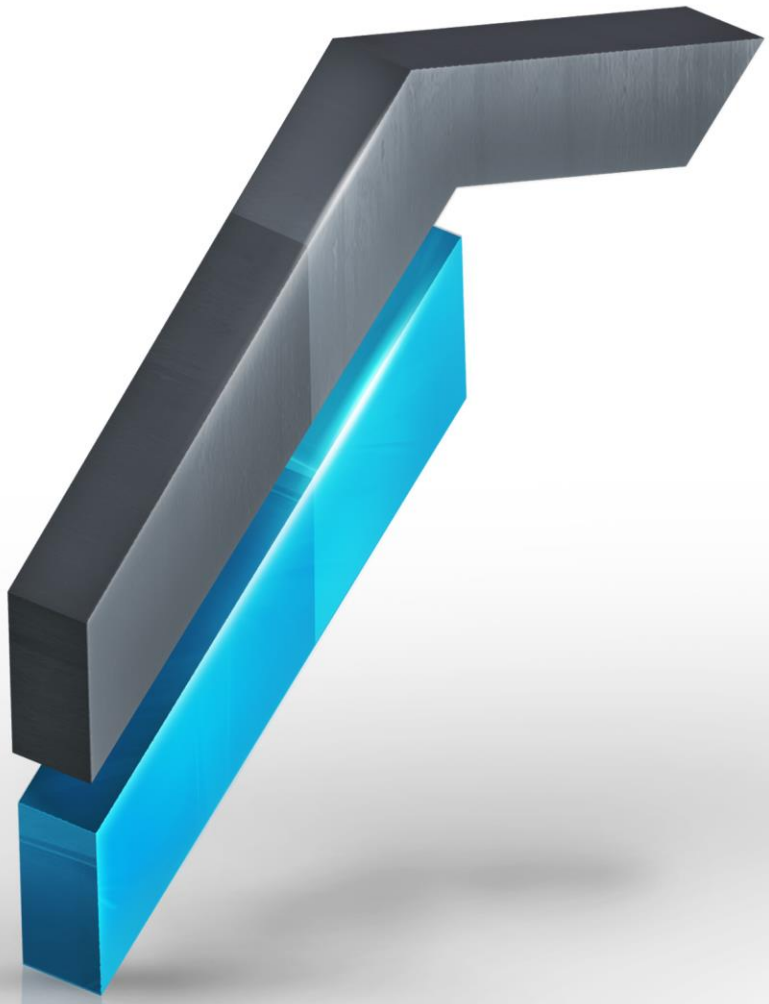
$$RMSE = \sqrt{\frac{1}{f}\sum_{i=1}^{f} {FE_i}^2} \tag{2.8}$$

Metrics comparing the relative accuracy of the model forecast to naive forecasts is the so-called *Theil's U2* statistics (2.9). A value less than one means the model performs better than a naive forecast (forecast is equal to the last known value). Zero value of U2 indicates a zero-forecast error, lower value of U2 is preferred when comparing multiple models.

$$U_2 = \sqrt{\frac{\frac{1}{f}\sum_{t=1}^{f}\left(\frac{\hat{y}_t - y_t}{y_{t-1}}\right)^2}{\frac{1}{f}\sum_{t=1}^{f}\left(\frac{y_{t-1} - y_t}{y_{t-1}}\right)^2}} = \frac{MSE\ (model\ forecast)}{MSE\ (naive\ forecast)} \tag{2.9}$$

We can further decompose the forecast errors into the proportion of the BIAS, variance and covariance (3.0). The BIAS proportion refers to the average forecast error in the reference period, the variance proportion to the distance of forecast variance to the variance of predicted time series, and covariance proportion declaring other non-systematic error of the forecast. The aim of the forecaster is to minimize the first two parts of the components and to maximize the covariance proportion of the forecast errors.

$$1 = \frac{BIAS^2}{MSE} + \frac{\left(s_y - s_{\hat{y}}\right)^2}{MSE} + \frac{2(1-r)s_y s_{\hat{y}}}{MSE} \tag{3.0}$$



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