Simple but Effective: The OeNB's Forecasting Model for Selected CESEE Countries

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This paper describes the new forecasting tool used by the Oesterreichische Nationalbank (OeNB) to derive near-term forecasts for GDP and imports for five Central, Eastern and Southeastern European (CESEE) countries, namely Bulgaria, Croatia, the Czech Republic, Hungary and Poland. An error correction (EC) model is estimated separately for each country by means of seemingly unrelated regressions. Each country-specific macromodel consists of six structural cointegration relationships that model private consumption, investment, exports, imports, the nominal exchange rate and the nominal interest rate using an augmented Taylor rule. Using quarterly data as of the first quarter of 1995, we produce forecasts for GDP and imports with this model. Notwithstanding the dynamic nature of the transition process as well as the limited availability and, in some cases, quality of data, our structural model for the CESEE countries performs fairly well and we expect further gains in forecasting accuracy as more data become available and their quality improves.

JEL classification: C32, C53, E17
Keywords: Error correction model, model validation, Central, Eastern and Southeastern Europe, GDP forecasts

1 The Need for Forecasts for CESEE Countries from the Austrian Perspective

Given the long-standing economic relationships between Austria and many Central, Eastern and Southeastern European (CESEE) countries in terms of trade and FDI flows, interest in high-quality forecasts for economic developments in this region is great, particularly on the part of the Oesterreichische Nationalbank (OeNB). Developments in this region feed into the OeNB's outlook for the Austrian economy as an important external assumption. Furthermore, Austrian investors in general, and especially Austrian commercial banks, are heavily involved in the CESEE countries and so macroeconomic projections for these countries also constitute an important input into the OeNB's regular stress-testing exercises. The OeNB has therefore started to produce its own outlook for selected Central, Eastern and Southeastern European countries in order to enlarge the set of available projections. Besides being used for internal purposes, this outlook is offered by the OeNB as additional input into the agreement on the external assumptions in the first round of the ECB's broad macroeconomic projection exercise (BMPE), which is published in the June and December issues of the ECB's Monthly Bulletin.

The OeNB has been providing forecasts for economic developments in three countries, namely the Czech Republic, Hungary and Poland, for a long time. These forecasts were based on informed expert judgments as well as on regression analyses and elasticity estimates (Reiniger, 2008). The existing set of tools for forecasting economic developments in the CESEE countries has now been complemented by a more formal approach. Since April 2009, the informed expert judgments

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have been supported by a simple macroeconomic model, which is estimated in a multivariate time series framework. More precisely, we now estimate an error correction (EC) model for each country by means of seemingly unrelated regressions. First and foremost, the model serves to check the consistency and plausibility of the expert judgments, which continue to play an important role in the OeNB's outlook. The OeNB's outlook for selected Central and Eastern European countries is published biannually in the second- and fourth-quarter issues of the Focus of European Economic Integration (FEEI), together with the outlook for Russia[2] compiled by Suomen Pankki – Finlands Bank. The small selection of countries reflects the OeNB's initial focus on the three largest (in terms of nominal GDP) Central European countries and Russia (given its strategic importance). However, this focus is gradually being expanded, with Bulgaria and Croatia being added in a first step. Romania will follow as soon as the necessary time series fulfill some basic requirements that essentially relate to length.[3] Owing to the comparably weaker economic ties between Austria and the Baltic countries, the OeNB decided against the development and maintenance of country-specific models for these three countries. However, Austria's tight economic linkages with Croatia and the heavy involvement of its banking sector in Croatia, as well as Croatia's advanced status in terms of EU accession, justified the development of a separate country model for Croatia.

In the next section, we describe the forecasting model. Section 3 discusses the dataset and the time series properties of the relevant variables that are necessary for our EC model, while section 4 deals with the evaluation of the out-of-sample model performance from a historical perspective. Section 5 concludes.

2 A Simple but Effective Macroeconomic Model for CESEE Countries

Our forecasting tool is a country-specific macromodel, the core part of which consists of six structural cointegration relationships. The structure of the model is based on a simple aggregate demand and aggregate supply model as used by Merlevede, Plasmans and Van Aarle (2003). Keeping our model as simple as possible, we focus on private consumption, investment, exports, imports, the nominal exchange rate and the nominal interest rate. These variables are modeled within the framework of a small, predominantly Keynesian macromodel, which includes some neoclassical features, such as the dependence of private consumption on interest rates. The interest rate itself is estimated using an augmented Taylor rule. The model's core structure is derived from the following structural equations:

$$c\_priv = \alpha_1 * gdp + \alpha_2 * (ir - cpi) \quad (1)$$

$$inv = \beta_1 * gdp + \beta_2 * (ir - ppi) \quad (2)$$

[2] See http://www.bof.fi/bofit_en/seuranta/ennuste/index.htm?year=2009.

[3] For the time being, real data for Romania's quarterly GDP and its components are only available from the first quarter of 2000 and, as such, the time series are too short for OeNB analysis. Given the negative GDP growth rates during the period from 1997 to 2000, an imputation of these data using available yearly price indices does not seem to be advisable. Furthermore, extending the time series to include the current severe recession would probably not be helpful for the derivation of long-run structural parameters, which we need for out-of-sample estimates and which serve as the basis for our forecasts. The OeNB's forecast for Romania is therefore based on a broad range of available information from various sources and on expert judgments.

$$exp = \gamma_1 * (er * pc\_ea / pc) + \gamma_2 * gdp\_eu + \gamma_3 * exp\_eu + \gamma_4 * gdp \quad (3)$$

$$imp = \delta_1 * gdp + \delta_2 * (er * pc\_ea / pc) \quad (4)$$

$$er = \kappa_1 * (ir - ir\_ea) + \kappa_2 * (m3 - m3\_ea) + \kappa_3 * (gdp / er - gdp\_ea) \quad (5)$$

$$ir = \varphi_1 * cpi + \varphi_2 * gdp + \varphi_3 * er + \varphi_4 * ir\_ea \quad (6)$$

The basis for using the cointegration framework is that the variables of interest are linked by a long-run relationship as determined by each of the six equations listed above. Private consumption (*c_priv*) is assumed to be in an equilibrium relationship with economic output (*gdp*) and nominal interest rates deflated by consumer prices (*ir – cpi*). In the same vein, the investment equation (*inv*) is modeled as a function of GDP (*gdp*) and interest rates, this time, deflated by producer prices (*ir – ppi*). Exports (*exp*) depend primarily on domestic GDP and the real exchange rate (*er*pc_ea/pc*).[4] While the latter captures a country's competitiveness on the world markets, the former is meant to approximate its export supply capacities. Additionally, we introduce GDP (*gdp_eu*) and exports of the EU-27 (*exp_eu*). The former is supposed to control for the foreign demand for a country's exports on the grounds that the lion's share of its exports goes to the EU.[5] By contrast, exports of the EU-27 are meant as a proxy for the global trade volume and thus capture world trade trends that are common to all countries. The import equation (*imp*) is modeled more parsimoniously, relating the respective country's imports to GDP approximating domestic demand and to the real exchange rate. In the spirit of Merlevede, Plasmans and Van Aarle (2003), we model the nominal exchange rate (*er*) as a function of interest rate differentials with regard to the euro area (*ir – ir_ea*), money supply differentials (*m3 – m3_ea*) and GDP differentials (*gdp/er – gdp_ea*). We deviate slightly from Merlevede, Plasmans and Van Aarle (2003) in the case of the nominal interest equation (*ir*). Here we use an augmented Taylor rule incorporating inflation (*cpi*), the nominal exchange rate (*er*) and nominal interest rates in the euro area (*ir_ea*). GDP is introduced as an additional term in order to capture the cyclical position of the economy, which is traditionally measured by the output gap. Furthermore, the lack of reliable data impedes the use of an unemployment gap in our model.

This core model is adapted for each country by dropping highly insignificant parameters in the system of six equations, in order to obtain the best fit to the data and to save degrees of freedom. Thus, we arrive at five models with small country-specific nuances. Owing to the currency board arrangement in Bulgaria, a more far-reaching deviation from the core model is used in this case: The exchange rate and interest rate are both assumed to be constant and to follow an autoregressive (AR) process.[6]

[4] *Here, "pc" refers to the domestic consumer price index and "pc_ea" to that of the euro area.*

[5] *As an alternative, we tried using imports rather than GDP of the EU-27 to proxy for foreign demand. However, the equation's explanatory power was greater when using GDP.*

[6] *In the future, we envisage modeling interest rates in Bulgaria according to the specification used by the Bulgarian National Bank. We would like to thank Emilia Penkova from the Bulgarian National Bank for drawing our attention to this possibility.*

Table 1

p-Values of the Augmented Dickey-Fuller Test for the Stationarity of DOLS Residuals

	Bulgaria	Czech Republic	Croatia	Hungary	Poland
Consumption	0.000	0.001	0.000	0.020	0.000
Exchange rate	–	0.047	0.024	0.006	0.016
Exports	0.000	0.000	0.000	0.001	0.000
Imports	0.000	0.001	0.021	0.037	0.000
Investment	0.000	0.024	0.014	0.000	0.006
Interest rate	–	0.000	0.000	0.000	0.003

Source: Authors' calculations.

Note: p-values of the augmented Dickey-Fuller unit root tests (without constant or trend) on the residuals of the DOLS regression. A p-value < 0.05 indicates that the null of a unit root can be rejected at the 5% level of statistical significance.

To check whether the cointegration assumption is justified and whether the long-run relationships are well specified, we carry out a cointegration test. In this test, we take account of the possible endogeneity among the variables in the form of a simultaneity bias by using the dynamic ordinary least squares (DOLS) method developed by Stock and Watson (1993). This test essentially boils down to estimating the long-run equilibrium relationship extended by lags and leads of all included variables by ordinary least squares (OLS) and testing the deviations from the long-run relationship (i.e. the residuals) for stationarity. The results are presented in table 1,[7] which displays the p-values of a unit root test on the residuals obtained in the DOLS regression. All of the DOLS residuals are stationary at the 5% significance level, which suggests that both the cointegration assumption and the model specification are correct. In economic terms, each long-run relationship identifies the determinants of the long-run growth of the respective GDP component in our model. The presence of these cointegrating relationships implies the stability of the investment, consumption, export and import ratios in GDP, augmented by other variables. It also implies common stochastic trends in our variables.[8]

Once we have successfully completed the necessary tests for nonstationarity in all time series and for cointegration in the long-run equilibrium relationships, we then estimate the entire system of equations. Each of the six structural equations outlined in equations (1) to (6) is specified in the form of an EC model, with γ denoting the error correction parameter:

$$\Delta y_t = a\Delta y_{t-1} + b'\Delta X_{t-1} + \gamma(y_{t-1} - \alpha - \beta' X_{t-1}) + \varepsilon_t \qquad (7)$$

This parameter reflects how quickly the cointegrated (i.e. cotrending) variable returns to its long-run relationship once it is out of equilibrium.

All other exogenous variables (i.e. those variables not appearing on the left-hand side of equations (1) to (6)) entering the model are assumed to follow a simple AR(1) process, which is the least costly modeling option in terms of lost observa-

[7] *Owing to degree of freedom constraints, we used only one lag and one lead in the DOLS estimations.*

[8] *Given the short- to medium-term nature of our forecasts, we do not think that demographic change plays an important role in our forecasts.*

Table 2

Adjustment Parameters Associated with the Equilibrium Correction Terms

	Bulgaria	Czech Republic	Croatia	Hungary	Poland
Consumption	**−0.539**	**−0.213**	**−1.195**	**−0.162**	**−0.343**
t-statistic	(−5.9523)	(−3.9939)	(−5.16507)	(−2.7675)	(−3.6699)
p-value	0.000	0.000	0.000	0.006	0.000
Exchange rate	**–**	**−0.124**	**−0.332**	−0.108	**−0.092**
t-statistic	–	(−3.3875)	(−5.0211)	(−1.5885)	(−2.2661)
p-value	–	0.001	0.000	0.113	0.024
Exports	**−0.773**	**−0.344**	**−1.345**	**−0.315**	**−0.641**
t-statistic	(−9.6034)	(−2.7979)	(−10.0714)	(−4.0128)	(−5.5351)
p-value	0.000	0.005	0.000	0.000	0.000
Imports	**−0.786**	**−0.118**	**−0.161**	−0.049	**−0.351**
t-statistic	(−5.8490)	(−1.6962)	(−1.9514)	(−1.4822)	(−3.8359)
p-value	0.000	0.090	0.051	0.139	0.000
Investment	**−0.649**	**−0.224**	−0.087	−0.148	**0.101**
t-statistic	(−4.2423)	(−2.9369)	(−1.0254)	(−1.5048)	(1.4551)
p-value	0.000	0.003	0.306	0.133	0.146
Interest rate	**–**	−0.161	**−0.392**	**−0.436**	**−0.128**
t-statistic	–	(−1.5577)	(−3.2282)	(−4.4106)	(−2.7646)
p-value	–	0.120	0.001	0.000	0.006

Source: Authors' calculations.

Note: Parameters significant at the 10% level are highlighted in bold.

tions and degrees of freedom. However, it should be noted that the results do not change significantly if the optimal lag length of the AR processes is chosen according to standard information criteria. This is probably due to the fact that the optimal lag length proved to be 1 in most cases anyway.[9]

This system of six structural equations and 11 AR processes[10] is then estimated by means of seemingly unrelated regressions in order to account for correlations between the model components through the unobserved correlation in the error terms. The joint estimation of these six equations is meaningful from both an economic point of view (to account for shocks common to all variables, such as business cycle fluctuations, etc.) and a statistical point of view (the joint estimation enhances statistical efficiency). More precisely, we estimate only eight of the ten AR(1) processes, while we update the time series for the EU-27 (GDP and exports) with the most recent ECB forecasts in order to qualitatively improve our baseline forecast. In most cases, the estimated parameters in the model behave well. In table 2, we report the most important coefficients of the equilibrium correction terms, all of which (except one) show up with the expected, in most cases significant, negative sign. Instances where this parameter has no significance sometimes occur in the investment equation, in the exchange rate equation for Hungary and the interest rate equation for the Czech Republic. In Croatia, there are two instances where the adjustment parameter is greater than 1 in absolute value terms,

[9] *Owing to the limited sample size, the maximum number of possible lags was restricted to four.*

[10] *For the following exogenous variables: euro area inflation, inflation in the respective country, euro area money supply, money supply in the respective country, EU-27 GDP, EU-27 exports, euro area GDP, euro area interest rates, producer prices, stock changes and public consumption.*

which does not pose a statistical problem, but implies some overshooting in the adjustment.[11]

The structural parameters obtained through the seemingly unrelated regression are then used to derive one- to eight-steps-ahead dynamic forecasts. Our GDP forecast is derived as the sum of the forecasts for the individual components.

3 Description of the Database

For each country, we use quarterly data on GDP and its components, as published by Eurostat. Our sample ranges from the first quarter of 1995, or in the case of Bulgaria from the first quarter of 1998, to the most recent quarter for which data have been published. In cases where the time series provided by Eurostat do not extend back to the beginning of 1995, we have completed our dataset with monthly data from the Vienna Institute for International Economic Studies (wiiw) and from national sources. Thus, we estimate the structural equations in the model, using a sample that is supposedly unbiased by the deep recession which followed the fall of communism. Apart from the most recent crisis, there are no obvious major structural breaks in the estimation sample, which should provide for rather stable coefficients for our variables of interest.[12] We use real data generated by the chain-link method used by Eurostat and take logs. All series are seasonally detrended according to the Census X12 method.[13]

Table 3 provides a list of all variables used in the model, along with a short description of their time series properties. At the heart of our empirical framework is the concept of cointegration. Hence, we aim to model long-term equilibrium relationships between the economic variables of interest. In particular, we estimate the long-run relationships between economic variables by means of an EC model. The prerequisite for cointegrated time series is that they are integrated of the same order, namely $d>0$. In macroeconomics, this order of integration is typically one. In this case, the time series is said to have a unit root in levels. Thus, we initially test for this form of nonstationarity, using the augmented Dickey-Fuller test. The results of these tests are summarized in table 3 for all countries. All variables have a unit root, albeit with a few exceptions, namely producer price inflation in most countries and the real interest rate in Bulgaria and Hungary. Of course, for some of these time series, the test rejects the null of a unit root, but a visual inspection suggests that nonstationarity is a more plausible assumption. In particular, the inflation paths in the Czech Republic, Hungary and Poland show a rather strong disinflationary trend at the beginning of the sample. In fact, most of the applied econometrics literature does indeed treat these trend stationary series as unit root processes (see Enders and Granger, 1998; Engle and Granger, 1991). Other series, which are clearly stationary, such as the nominal exchange rate or interest rates in Bulgaria owing to its currency board arrangement, or stock changes in Poland, are less problematic in our context as they do not enter these

[11] In the most recent projection round, however, where the sample was extended to include data up to the second quarter of 2009, all parameters remained below 1. This suggests that the previously observed overshooting was of a temporary nature and possibly related to the unfolding economic crisis.

[12] EU membership and its economic impact on the countries covered in this analysis can be considered a smooth process and is not what is referred to as a "structural break" in the time series literature.

[13] We chose this method as it is also used by Eurostat to deseasonalize the EU and euro area series.

Table 3

List of Variables Included in the Model and Summary of Their Time Series Properties

Variable name	BG	HR	CZ	HU	PL	EU/EA
GDP, constant prices	+	+	+	+	+	n.u.
Private consumption	+	+	+	+	+	n.u.
Public consumption	+	+	+	+	+	n.u.
Gross fixed capital formation, constant prices	x	+	+	+	+	n.u.
Exports, constant prices	+	+	+	+	+	+
Imports, constant prices	+	+	+	+	+	+
Stock changes, constant prices	+	+	+	+	z	n.u.
Nominal exchange rate (local currency/euro), period average	z	+	+	+	+	n.u.
Real exchange rate, CPI deflated	+	+	+	+	+	+
Real exchange rate, PPI deflated	+	+	+	+	+	+
Nominal 3-month interbank deposit rate, period average	+	+	+	+	+	+
Real 3-month interbank deposit rate, CPI deflated	z	+	+	z	+	+
Real 3-month interbank deposit rate, PPI deflated	z	z	+	z	+	+
PPI index	+	+	+	+	+	+
PPI inflation, year on year	z	z	+/z	+/z	+/z	
CPI index	+	+	+/z	+	+	+
CPI inflation, year on year	z	+	+	+/z	+/z	+
Central government expenditure	+	+	+	+	+	n.u.
Central government revenues	+	+	+	+	+	n.u.
M3, EUR million	+	+	+	+	+	+

Source: Authors' calculations.

Note: z denotes that a unit root can be rejected, i.e. the corresponding time series is not considered to be I(1); x denotes that the time series can be considered to be trend stationary. For all other time series, the hypothesis of a unit root cannot be rejected and hence they are considered to be I(1) and thus fulfill the necessary requirements for use in our error correction model. "n.u." means "not used."

countries' cointegration equations as endogenous variables. Overall, we can therefore conclude that the time series largely fulfill the necessary requirements for use in our econometric model.

4 Model Validation

To evaluate the forecasting power of our model in terms of accuracy and direction of change, we carry out the following exercise: We exclude a time window of eight quarters at the beginning of the sample and use the remaining data to simultaneously estimate the parameter values for (1) our EC model and (2) a parsimonious benchmark model, in which all variables are modeled as simple AR(1) processes. Using these parameter estimates, we produce an out-of-sample forecast with both models – the structural model and the AR benchmark model – for one to eight quarters for the eight-quarter time window previously excluded. The forecasting errors are computed by comparing both sets of forecasts with the realized values.

Based on a rolling regression framework, the eight-quarter time window is subsequently moved one quarter ahead, the models are re-estimated and new out-of-sample forecasts are obtained for the shifted eight-quarter time window. In principle, this procedure could be repeated until the time window reaches the end of the sample and all available observations have been used to estimate the model parameters. However, in order not to spoil the model estimation, we prefer to exclude the recent period of financial turmoil. We therefore move the eight-quarter time window over the sample until its start reaches the third quarter of 2008.

This means that the last model parameters are estimated using data only up to the second quarter of 2008.

For each of the eight forecasting horizons, we compute three quality indicators to evaluate the forecasting ability of our EC model: the hit rate, an indicator of the growth rates' sign matching and the Diebold-Mariano test (a description of these indicators is given in the annex). The results of these calculations – carried out for all five countries and for three selected variables: GDP, imports and the exchange rate – are rather mixed (see table A1). Starting with the hit rate, a few striking observations are worth noting. First, the hit rate is particularly high for Poland, the Czech Republic and Hungary, while it is significantly lower for Croatia and rather poor for Bulgaria. Second, except for the Czech Republic and Bulgaria, the hit rate is typically slightly higher for GDP than for imports, and is substantially lower for the exchange rate. Nevertheless, against the backdrop of the well-documented fact that predicting the exchange rate is an extremely challenging task, the hit rate for the exchange rate is comparatively high, especially in the case of the Czech Republic. Similar conclusions to those for the hit rate may be drawn for the growth rates' sign matching indicator, although the differences between the variables and countries are much less pronounced. Moreover, the sign of the forecast growth rates rather tends to coincide with the actual growth rates at shorter horizons.

Furthermore, the results of the Diebold-Mariano test reveal that the forecasting performance of the EC model is moderate. Our structural model seems to significantly outperform the benchmark AR model only when forecasting the exchange rate for Poland (at most horizons), the GDP in Hungary (four to eight quarters ahead) and imports in the Czech Republic (in the medium run). In some cases, the simple benchmark model has a significantly better forecasting ability than our structural model, particularly at some horizons, for GDP in Poland and Croatia, and for both GDP and imports in Bulgaria. In all other cases, both models demonstrate equal forecasting power in the statistical sense.

Although the flexible design of our model allows for some country-specific adjustments that might still leave scope for improvement in the predictive power, the mixed results of the evaluation exercise most likely reflect the dynamic nature of the transition process as well as the limited availability and, in some cases, quality of data. This can best be seen by comparing the forecast results for Bulgaria with those of the other countries. Such a comparison shows that the latter forecasts outperform the forecasts for Bulgaria by a wide margin. Against this backdrop, our structural model for the CESEE countries performs fairly well, and we expect further gains in forecasting accuracy as more data become available and their quality improves.

5 Conclusions

Given the strong economic linkages between Austria and the CESEE region, well-founded, timely and reliable estimates of future developments of fundamental macroeconomic variables are highly relevant in general, but especially for the OeNB, as it is involved in banking supervision in Austria and monetary policy decision making within the ESCB.

In this paper, we have therefore provided an overview of our country-specific macroeconomic EC model as it currently stands, which is estimated in a multivariate time series framework for five CESEE countries. The model provides an additional tool for forecasting short-term macroeconomic developments in the CESEE countries, a region for which model-based forecasts other than those generated by national institutions are still rare. Our structural model has been kept rather simple and well-specified from a statistical point of view. As such, however, it does not yet outperform even more simple time series models in terms of forecasting ability. This may be related to the dynamic developments that the transition countries have been experiencing over the last few years as well as to data limitations (both in terms of the shortage and quality of available time series). It was our intention, however, to include economic reasoning in our model, and so we did not opt for a pure time series model. We have conducted a range of validation tests, but will continue to validate the model outcome on a regular basis, by also extending the range of tests to include tests for structural breaks in the time series and by estimating impulse response functions to important policy-control variables.

Despite the fact that there is still scope for improvement in the model's forecasting power, we believe that our simple macromodel is superior to other econometric forecasting tools for several reasons. To begin with, our model provides a simple and flexible framework for obtaining forecasts for GDP and its components. It relies exclusively on estimated parameters and therefore avoids any uncertainty associated with calibration based on deep parameters that are not country-specific. This is particularly relevant for the CESEE countries, where part of the transition dynamics is systematically interpreted as an out-of-equilibrium adjustment. Furthermore, we can readily include country-specific factors based, for instance, on monetary policy strategies (exchange rate regimes, inflation targeting, etc.). Yet another advantage of this framework is that some of the variables can easily be made exogenous, should this be necessary for the incorporation of information emanating from forecasts outside the model framework or from expert assessments. Finally, owing to its autoregressive components, the model reacts extremely quickly to exogenous shocks, albeit at the cost mostly of missing turning points. Moreover, as has been documented in the literature, simpler and less resource-consuming aggregate supply and aggregate demand models often outperform even sophisticated dynamic stochastic general equilibrium (DSGE) models in terms of predictive power and accuracy (see for instance Colander et al., 2008; Rubaszek and Skrzypczyński, 2008; Wang, 2008).

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Annex: Model Validation

The following three measures are used to evaluate the forecasting ability of our model:

– the Diebold-Mariano test (Diebold and Mariano, 1995), for which the null hypothesis is that the forecasting ability of the EC model and the benchmark AR model are equal. In other words, we test whether the difference between the root mean squared error (RMSE) of the EC model and the benchmark AR model is statistically different from 0. The RMSE is a measure of the forecasts' accuracy and is defined as

$$\text{RMSE}_\text{h} = \sqrt{\frac{\sum_{n=1}^{N_h}(g_n - \hat{g}_n)^2}{N_h}},$$

whereby N_h denotes the number of h-steps ahead forecasts computed, g_n is the actual value of the respective variable and $\hat{g}_n$ is the corresponding forecast.

– the hit rate states, for a given horizon, the percentage of cases in which the forecast movement direction of a variable relative to its current level coincides with the direction of change of the realized data. Hence, formally, the hit rate for a horizon h (HR_h) is defined as follows:

$$\text{HR}_\text{h} = 1 \text{ if } \{(g_{t+h} - g_t)>0 \text{ and } (\hat{g}_{t+h} - g_t)>0\} \text{ or if } \{(g_{t+h} - g_t)<0 \text{ and } (\hat{g}_{t+h} - g_t)<0\}$$

and $\text{HR}_\text{h} = 0$ else.

g_{t+h} denotes the actual value of the respective variable h-steps ahead from time t, while $\hat{g}_{t+h}$ is again the corresponding forecast.

– finally, the growth rates' sign matching indicates, for each horizon, the percentage of cases in which the sign of the year-on-year growth rate of the forecast series matches the sign of the year-on-year growth rate of the realized data series.

Table A1

Results of the Model Evaluation

Bulgaria

Forecast horizon (quarters)	Number of observations	Diebold-Mariano test		Hit rate		Growth rates' sign matching	
		GDP	IMP	GDP	IMP	GDP	IMP
1	38	**−8.3E-05** (−2.2605)	−1.4E-04 (−0.4628)	0.737	0.763	1.000	1.000
2	38	5.5E-05 (0.5835)	−4.5E-04 (−0.5775)	0.895	0.816	1.000	0.974
3	38	−4.5E-05 (−0.2394)	−2.6E-04 (−0.3090)	0.921	0.868	0.974	0.947
4	37	9.6E-05 (0.2885)	−8.5E-05 (−0.0465)	0.892	0.811	0.947	0.921
5	36	4.1E-04 (0.8038)	1.1E-03 (0.4768)	0.889	0.861	0.921	0.895
6	35	7.1E-04 (1.1013)	2.7E-03 (0.9333)	0.914	0.886	0.895	0.868
7	34	1.0E-03 (1.0565)	2.8E-03 (0.6631)	0.912	0.853	0.868	0.842
8	33	**2.0E-03** (1.6846)	3.6E-03 (0.7188)	0.939	0.909	0.842	0.816

Czech Republic

Forecast horizon (quarters)	Number of observations	Diebold-Mariano test			Hit rate			Growth rates' sign matching		
		GDP	IMP	ER	GDP	IMP	ER	GDP	IMP	ER
1	47	**5.9E-05** (1.6647)	1.1E-04 (0.9595)	−4.2E-05 (−0.4352)	0.660	0.830	0.638	0.915	0.979	0.957
2	47	**2.1E-04** (1.7022)	−4.1E-04 (−0.9694)	−2.0E-04 (−0.5048)	0.766	0.894	0.745	0.851	0.957	0.894
3	47	5.0E-04 (1.4535)	−2.0E-03 (−1.6231)	−6.5E-04 (−0.9680)	0.830	0.979	0.596	0.872	0.957	0.894
4	46	**1.0E-03** (1.7104)	−2.1E−3 (−1.5781)	−6.3E-04 (−0.8380)	0.848	0.957	0.652	0.851	0.957	0.745
5	45	**1.6E-03** (1.7808)	**−2.2E-03** (−1.8664)	−4.1E-04 (−0.5078)	0.911	0.933	0.711	0.851	0.872	0.787
6	44	**2.4E-03** (1.9416)	−2.5E-03 (−1.6258)	−6.9E-04 (−0.6151)	0.909	0.932	0.818	0.851	0.851	0.872
7	43	**3.2E-03** (1.9628)	−2.8E-03 (−1.2980)	−1.2E-03 (−0.7546)	0.907	0.977	0.814	0.830	0.830	0.872
8	42	**4.0E-03** (1.8803)	−3.3E-03 (−1.2586)	−2.2E-03 (−1.0418)	0.929	0.976	0.857	0.830	0.809	0.894

Hungary

Forecast horizon (quarters)	Number of observations	Diebold-Mariano test			Hit rate			Growth rates' sign matching		
		GDP	IMP	ER	GDP	IMP	ER	GDP	IMP	ER
1	47	−1.4E-05 (0.4965)	−5.1E-05 (−0.3773)	1.0E-04 (−1.3411)	0.702	0.766	0.638	1.000	1.000	0.936
2	47	−4.2E-06 (0.0403)	1.1E-04 (0.1567)	−2.6E-04 (−0.7717)	0.787	0.830	0.596	1.000	0.979	0.872
3	47	−5.0E-04 (−1.4172)	−2.2E-04 (−0.0931)	−2.3E-04 (−0.2829)	0.957	0.915	0.638	1.000	0.957	0.851
4	46	**−7.8E-04** (−1.7106)	2.7E-04 (0.0989)	7.4E-06 (0.0051)	1.000	0.957	0.609	0.979	0.936	0.894
5	45	**−1.1E-03** (−1.9570)	4.2E-04 (0.1437)	−1.0E-04 (−0.0483)	0.978	0.956	0.511	0.957	0.915	0.872
6	44	**−1.4E-03** (−1.9966)	1.7E-04 (0.0485)	−3.8E-04 (−0.1386)	0.977	0.955	0.477	0.936	0.894	0.809
7	43	**−1.8E-03** (−1.9919)	−1.5E-04 (−0.0360)	−6.1E-04 (−0.1781)	0.977	0.953	0.465	0.915	0.851	0.745
8	42	**−2.4E-03** (−1.9448)	2.0E-04 (0.0421)	−1.7E-03 (−0.4158)	0.976	0.976	0.429	0.894	0.830	0.723

Table A1 continued

Results of the Model Evaluation

Croatia

Forecast horizon (quarters)	Number of observations	Diebold-Mariano test			Hit rate			Growth rates' sign matching		
		GDP	IMP	ER	GDP	IMP	ER	GDP	IMP	ER
1	47	**3.4E-04**	2.1E-04	2.3E-05	0.660	0.596	0.574	1.000	1.000	0.830
		(2.6356)	(0.7954)	(0.9892)						
2	47	7.7E-04	4.6E-04	1.5E-04	0.617	0.617	0.447	0.979	0.957	0.766
		(1.5228)	(0.6422)	(1.6392)						
3	47	1.7E-03	2.3E-04	**3.2E-04**	0.638	0.596	0.426	0.957	0.894	0.766
		(1.3882)	(0.1509)	(1.9741)						
4	46	**3.3E-03**	1.3E-03	3.0E-04	0.565	0.543	0.478	0.915	0.872	0.702
		(1.8100)	(0.5469)	(1.2612)						
5	45	**4.4E-03**	1.1E-03	−8.8E-06	0.644	0.600	0.600	0.894	0.872	0.723
		(1.6504)	(0.3334)	(−0.0304)						
6	44	5.6E-03	1.3E-03	−3.4E-04	0.659	0.636	0.523	0.872	0.851	0.681
		(1.4461)	(0.3023)	(−0.9725)						
7	43	6.9E-03	1.5E-03	−5.7E-04	0.651	0.651	0.581	0.830	0.830	0.532
		(1.3670)	(0.2794)	(−1.3621)						
8	42	9.2E-03	2.2E-03	−8.1E-04	0.667	0.690	0.548	0.809	0.830	0.468
		(1.4501)	(0.3517)	(−1.6004)						

Poland

Forecast horizon (quarters)	Number of observations	Diebold-Mariano test			Hit rate			Growth rates' sign matching		
		GDP	IMP	ER	GDP	IMP	ER	GDP	IMP	ER
1	47	**2.0E-04**	−5.6E-04	−3.8E-04	0.745	0.638	0.638	1.000	0.894	0.851
		(1.7399)	(−1.1249)	(−1.5348)						
2	47	**5.4E-04**	−3.8E-04	−6.8E-04	0.766	0.745	0.532	1.000	0.915	0.809
		(2.6867)	(−0.4908)	(−1.3767)						
3	47	**7.9E-04**	-01.9E-04	**−1.9E-03**	0.766	0.702	0.638	0.979	0.894	0.745
		(2.7561)	(−0.1140)	(−1.8728)						
4	46	**9.7E-04**	9.4E-04	**−3.0E-03**	0.826	0.804	0.587	0.957	0.809	0.617
		(2.8986)	(0.3555)	(−2.0718)						
5	45	**1.0E-03**	1.9E-03	**−5.2E-03**	0.889	0.844	0.533	0.936	0.787	0.574
		(2.9687)	(0.5925)	(−2.6300)						
6	44	**8.8E-04**	2.4E-03	−7.7E-03	0.955	0.864	0.591	0.915	0.766	0.553
		(2.2149)	(0.6268)	(−3.0989)						
7	43	5.9E-04	1.1E-03	**−1.0E-02**	0.977	0.907	0.605	0.894	0.766	0.532
		(1.1152)	(0.2316)	(−3.4557)						
8	42	4.7E-04	5.2E-04	**−1.4E-02**	1.000	0.881	0.595	0.872	0.745	0.447
		(0.7063)	(0.0975)	(−3.8108)						

Source: Authors' calculations.

Note: t-values are reported in parentheses below the Diebold-Mariano test statistics and values in bold imply rejection of the null hypothesis of no difference between the EC model and the AR(1) benchmark model at the 10% or higher significance level. If the test statistic is negative (positive), the EC (the AR) model performs better in terms of predictive accuracy. The hit rate reports the percentage of cases in which the forecast movement direction of a variable relative to its current level coincides with the direction of change of the realized data. The growth rates' sign matching indicates, for each horizon, the percentage of cases in which the sign of the year-on-year growth rate of the forecast series matches the sign of the year-on-year growth rate of the realized data series.