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USING MACROECONOMIC MODELS FOR MONETARY POLICY IN UKRAINE

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ABSTRACT

An important precondition for successful implementation of inflation targeting is the ability of the central bank to forecast inflation given the fact that the inflation forecast has become an intermediate target. Certainly, this means there should be clear understanding of the monetary policy transmission mechanism functioning within the bank, because it is precisely through transmission channels that a central bank has to ensure convergence of its inflation forecast to the target. And it is almost impossible to pursue inflation targeting without a set of macroeconomic models that describes the monetary policy transmission mechanism and helps to analyse the current state of the economy as well as forecast (simulate) short- and medium-term macroeconomic scenarios. This article provides a review of the current state of macroeconomic modelling at central banks and describes the history of development and actual stance of the National Bank of Ukraine's system of macroeconomic models. The existing system provides quite reliable support for the current monetary policy decision-making process, but it has to be improved by implementing a more sophisticated model (such as a dynamic stochastic general equilibrium model) and enhancing the set of econometric models for short-term forecast purposes in the future.

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1. Introduction

Monetary policy decisions are based on solutions to multi-criteria problems with numerous constraints, dealing with large flows of information that come from current data analysis, expert opinions and forecast scenarios. Therefore, it has become necessary for a modern central bank to formalize and structure the decision-making process, which is usually accomplished by setting up an economic model system. Of course, models simplify reality and cannot fully reproduce all economic processes. At the same time, models provide a systematic approach to economic analysis that ensures consistency in monetary policy decisions.

Models have become especially important for the central banks that follow an inflation targeting regime and thus pursue quantitative goals because of the need to know the exact size and lags for final combination of economic shocks influence on inflation as well as on other indicators. Therefore the monetary policy decision-making process at central banks following inflation targeting (IT) is based on a forecasting and policy analysis system (FPAS) that usually has a set of models as its core, where each model has its own purpose. Such systems may become the basis for decision-making or at least be used for the verification of analysis and forecasting results, which are obtained by using of other tools, also by central banks that pursue other monetary policy types (e.g. when it is impossible to provide an independent monetary policy, e.g. under a currency board or because of monetary union membership).

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The key advantages of a model approach are as follows: 1) the understanding of economic processes under the admissible level of their simplification; 2) bringing discussions about economy to a common basis; 3) the high speed and flexibility of policy scenario generation.

The latest achievements in economic theory and computational methods encourage the inclusion of numerous economic phenomena in the models. However, trying to put too many of them into one large-scale model in an attempt to reflect as many of the economy's features as possible may substantially complicate the use of the model for regular forecasts. That's why, on the one hand, the core FPAS model must be quite complicated in order to reproduce the specifics of the monetary transmission mechanism, but on the other hand, it should be simple enough to be used for everyday tasks as well as to understand and discuss the model output. The lacunas that are generated by simplification of the core model can be filled with satellite and auxiliary models.

This paper is organized as follows. Section 2 describes the current central banks' organization approach to an analysis and forecast system that is based on a set of models, where the core model has a solid theoretical foundation, is a medium-term type and is used as the main tool for forecasting and simulation. Section 3 focuses on satellite and auxiliary models, which are used by central banks in order to ensure the plenitude of economic analysis, e.g. to assess the current state of auxiliary indicators, produce short-term forecasts and analyse non-standard problems. Section 4 describes the set of models used at the National Bank of Ukraine (NBU) for monetary analysis purposes. The last section offers concluding remarks and considers possible directions for enhancing the NBU's modelling tools system, especially within the context of transition to an inflation targeting regime.

2. Systemic approach to analysis and forecasting at central banks based on core structural model

Economic analysis and forecasting are inherent components of an IT central banks' activity, where forecast and simulation results stand as the basis of the monetary policy decision-making process. Significant progress in economic theory, mathematical and computational methods for economics as well as in information technologies is recognized by central banks as a great chance to improve their analysis and forecasting process. Needs in a fast and comprehensive policy reaction to external and internal shocks under significantly increased volatility of economic indicators encourage the organization and formalization of economic analysis and forecasting at central banks in the form of an FPAS.

A modern central bank FPAS may be characterized as a (1) formalized (via directives, resolutions that represent the forecast process), (2) organized (hierarchically), and (3) interdependent (e.g. connected into iterations and dependence on other stages) set of instruments and procedures intended to process and analyse historical economic data, to forecast the development of the economy, to determine the role of monetary policy and to find its optimal trajectory in order to achieve the target (e.g. inflation). Such systems represent the technical element of the political decision-making process. These systems allow raw data to be processed (seasonal adjustment etc.), to provide different measures of economic indicators (ratios, gaps, trends etc.) that help analyse the current economic stance, to create forecast scenarios and to assess policy scenarios.

A notable example of such an FPAS is the Bank of England's Forecasting Platform, which includes short- and medium-term forecasting models, enables aggregation of the models' forecasts through an automatic procedure, and provides a clear and coherent organizational process for developing regular forecasts and simulating various scenarios (Burgess et al., 2013). However, because of the substantial complexity of developing and maintaining such systems, only a limited number of central banks (European Central Bank, Federal Reserve Board of Governors, and the central banks of Canada, Norway, Sweden, the Czech Republic, New Zealand, etc.) currently explore this feature. At the same time, many other central banks actually follow the same approach, albeit at a more simple level.

The key elements of a prototype FPAS were structured as follows in the work by Laxton et al. (2009):

1) A database and reporting system based on a set of key macroeconomic indicators and providing the same information to every person involved in the forecasting and development of monetary policy-related decisions;

2) Regular updates of databases and short-term forecasts accompanied by reports on the effect of updated information on short-term forecasts (and its consequences for long-term forecasts, if applicable). Usually, short-term forecasts (2–3 quarters) are based primarily on the combination of econometric model results and expert judgments that allow the factors that are not covered by the core model to be taken into account;

3) A relatively simple model for medium-term forecasting reflecting the vision of monetary policy's transmission mechanism and the standard set of shocks affecting the economy. The most important requirement of this model is that it should be usable to quickly generate forecast scenarios, and understand and discuss results. In other words, the base model should not become a black box;

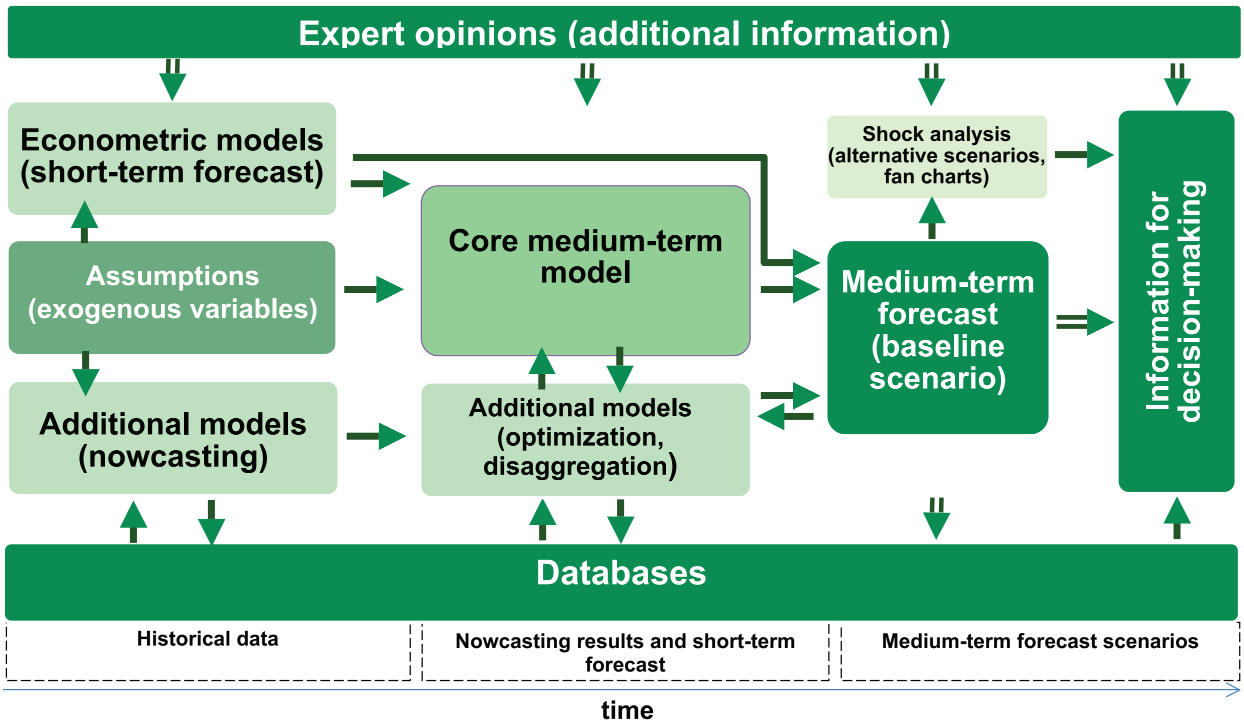
4) Regular harmonized macroeconomic forecasts for every quarter, including evaluation of changes vis-à-vis the previous base forecast;

5) Measures of forecast uncertainty, such as model-based confidence intervals. These measures may also be used to show the size of uncertainty both inside a central bank and for the society;

6) Identifying the specific risks of the baseline forecast scenario and developing a policy plan if risks become reality between publications of official forecasts.

The key elements of an FPAS within one forecasting cycle are shown schematically in Figure 1.

Figure 1. Interrelations between FPAS elements within one forecasting cycle



Usually, the core element of an FPAS is a r**elatively small (medium)-scale middle-term macroeconomic model with a solid theoretical basis.** The choice of a middle-term horizon is determined by lagged effects of monetary policy shocks on the economy, for instance, an interest rate shock effect lasts for one or two years. The theoretical principles of the model have to ensure the existence of a framework that allows the effects of monetary policy decisions on the economy to be explained, reflecting the monetary transmission mechanism vision of decision-makers and taking into account the influence of the policy on expectations (thereby eliminating, or at least minimizing, the "Lucas critique" problem[1] (Lucas, 1976)).

The FPAS core model size must be chosen in a way that ensures high-quality results; the model has to contain at least the most important economic indicators, albeit it must be simple enough to generate comprehensible results, as one has to avoid turning it into a "black box". The main targets of the monetary policy and, therefore, model variables are inflation and the

[1] The Lucas critique says that changes in macroeconomic policy based on an economic model should take into account the fact that economic agents' behaviour will change in response to policy measures. The appearance of the Lucas critique led to the loss of popularity of large econometric models based on historical relationships between common economic indicators and the transition to models that are built on "deep parameters" that express preferences, technology etc., i.e. factors determining the individual behaviour of economic agents driven by the principle of rationality.

aggregate output; however, information regarding the structure of consumption, labour market indicators (unemployment rate, level of income), productivity etc. is often needed as well. Adding these indicators to the model may lead to improvement of the model's statistical accuracy and improve the explanation of the model output. At the same time, the larger number of variables may lead to difficulties in forecasting some disaggregated variables and greater forecast errors compared to errors for aggregated variables, at least as a result of the larger inertia of the latter. In addition, excessive attention to the use of smaller variables may substantially complicate the explanation of the model's logic.

Therefore the core model usually has a medium size, whereas modelling other indicators (not included in the core model list) becomes a task for additional models. Altogether these models form the modelling component of an FPAS. This approach allows for a larger number of explained indicators and does not violate the principles of interpreting core model output results. The use of several models is also justified by their different capabilities in using data of different frequencies: a short-term forecast based on monthly data is traditionally more accurate than one that is based on quarterly data. At the same time, models on a quarterly basis better reflect the steady state of the economy, and therefore their results (forecasts or scenario simulations) are coherent with long-term trends.

We can highlight several different classes of macroeconomic models in the history of central banks that were used as core models for monetary policy purposes:

1) Large-scale models using empirical interrelations on the basis of econometric evaluations (however, the interest in these works has significantly diminished as a result of the criticism in the works of Lucas (1976) and Sims (1980);

2) Structural VAR models, which became very popular after an article by Sims (1980) due to their simplicity of use and the possibility of combining information coming from statistical data and theoretical constraints;

3) Hybrid models that combine long-term relationships, based on economic theory and confirmed by data, with short-term statistical relationships; such models were mostly performed in the form of vector error correction models);

4) Incomplete dynamic stochastic general equilibrium models such as gap models that combine long-term relationships that come from theoretical models with a microeconomic basis with equations that reflect short-term dynamics, thereby allowing for quite good statistical properties and keeping the desired steady-state properties of the economy;

5) Dynamic stochastic general equilibrium (DSGE) models where "dynamic" means that the model's solution sets the dynamics of all endogenous variables; "stochastic" means that the dynamics of variables are influenced by stochastic shocks; and "general equilibrium" means that supply equals demand in all markets in all periods.

In academic literature and the practice of central banks, DSGE models are now considered a benchmark. The appearance and rapid development of these models resulted from the consolidation of two competing modern economic schools. So-called "new Keynesian economics" (or "new neoclassical synthesis") combines the neoclassical theory of real business cycles with rational agents who optimize their behaviour and elements of the neo-Keynesian theory of market imperfections (Roger and Vlček, 2012). The key advantage of such models for monetary policy was the possibility of combining nominal rigidities (which make monetary policy non-neutral) with the completely specified dynamic structure of economy that tends toward general equilibrium.

Typical examples of DSGE models suitable for practical implementation in monetary policy are presented in the works by Smets and Wouters (2003), Woodford (2003), Gali (2008), Christiano et al. (2010) and lots of others. These are the models based completely on a microeconomic foundation and with implemented mechanisms that reflect nominal (for prices and wages) and real rigidities (e.g. investment adjustment costs).

These models have the following types of main economic agents that optimize their activity: households, firms, monetary and fiscal authorities. In some cases, such models include financial intermediaries (e.g. commercial banks) and regulatory as well as macroprudential policy instruments.

The principle of optimization modelling may be described by considering households as an example. A typical simplified model usually assumes the existence of a large number of identical (typical) households with an infinite lifespan, who split their time between work and leisure. Households are monopolistic suppliers of labour force, which allows them to influence wage rates. Households optimize their behaviour by differentiating their income (from work and capital) into consumption and savings and maximizing their function of usefulness (from consumption and leisure). They also meet limits on the maximum long-term level of borrowing to prevent a household from getting into a situation of the Ponzi scheme type, i.e. unlimited accumulation of debts.

In their turn, firms hire a labour force and combine it with capital to make specific products. That allows them to have monopolistic power, and therefore set the prices for their products (services). A typical firm uses the labour resources of households to produce different goods, thereby maximizing their profit.

An important feature (which has been standard for quite some time) of models is the use of mechanisms reflecting the existence of nominal and real rigidities. Nominal rigidities are modelled through special price- or wage-setting principles that reflect the limited contemporary reaction of firms to shocks; this results in only a partial revision of prices and wages. Real rigidities are the consequences of investment adjustment costs, costs of changing capital utilization, etc.

In the simplest models, fiscal policy is neutral toward demand, i.e. economic agents behave according to the Ricardian principles.[2] But now, lots of models use more complex mechanisms of the fiscal sector's effect, which are often implemented by dividing households into several types. In particular, some households are modelled as having limited rationality, i.e. households that have no savings (Coenen and Straub, 2004; Céspedes et al., 2012).

Monetary policy in a model is most often based on the Taylor rule: a central bank's target short-term interest rate is set as a neutral (average) nominal rate plus the sum of deviations of the inflation rate from the target inflation rate and of actual output from potential output.

Among the important recent trends are the growing role of the financial sector represented mainly by the financial accelerator model (Bernanke et al., 1999), models with an explicit banking sector (Goodfriend and McCallum, 2007), etc.

While, in the beginning, DSGE models were used mostly for theoretical analysis, afterwards they were found to be capable of explaining the actual dynamics of macroeconomic indicators and making relatively good forecasts. Therefore, more and more central banks are now implementing models of this class as the base models for their AFSs.

Such models have substantially improved the ability to analyse the economic trends, exploring the underlying motives of economic agents' behaviour, as well as simulating forecast scenarios.

At the same time, the main drawback of DSGE-class models is the overly hard constraints that theory places on ratios, which therefore cause problems with the reproduction of actual data dynamics (Sims, 2008). The practical use of these models in developing countries has become especially difficult due to problems with data as well as fast and significant structural changes, particularly in macroeconomic policy (Ukraine is a very typical example of such a country). It often requires substantial adjustment of equations obtained by optimizing the behaviour of particular economic agents (e.g. households) according to empirical data. In addition, the complexity of models requires substantial resources (both human and financial) and makes it harder to understand how models work and to explain results produced by these models to monetary policy decision-makers.

Many central banks have chosen simplified or incomplete dynamic stochastic models as the core models for their FPASs, often in the form of "gap models". Reflecting business cycles, gaps (deviations of variables from their long-term equilibrium trends) draw the biggest interest when designing the model's behaviour equations. Overall, these models are usually small in size, which, nevertheless, is sufficient to describe the monetary policy's transmission mechanism and, therefore, the role of the central bank in the dynamics of the key macroeconomic variables, output and inflation.

In fact, these models follow log-linearized versions of DSGE models based on optimizing microeconomic dependences, although they are not the result of explicit derivations. Nevertheless, they account for rational expectations (combining them with adaptive expectations), inertia in the economy (as a result of nominal and real rigidities) and the long-term neutrality of monetary policy, and all equations have an economic interpretation. Another key difference between these models and their fully fledged dynamic stochastic general equilibrium counterparts is the specific reproduction of long-term equilibrium levels (natural levels of variables), where supply effects are still rarely taken into account and the consistency of levels of variables is also often lacking. This, in particular, leads to difficulties in measuring the impact of financial sector turmoil on the economy in the case of substantial balance sheet effects (capital flight, revaluation of assets/liabilities caused by currency devaluation, etc.).

A typical example of this model is the Quarterly Projection Model of the Czech National Bank (Coats, Laxton, and Rose, 2003), which became a prototype for similar models employed by the central banks of many countries, in particular Ukraine, the Russian Federation, Turkey, Serbia, Armenia, Georgia, Romania, Chile and others.

[2] According to the Ricardian neutrality principle, current tax decreases have to be compensated by tax increases in the future and the presented value of taxes doesn't change. Similarly, the presented value of the future disposable income of households doesn't change either, which forms the composition of consumption and investment, therefore the consumption expenditure trajectory once again doesn't change.

3. Auxiliary models at central banks

As mentioned earlier, no model can fit all needs appearing every time in the course of monetary policy decision-making. And the desire to devise a model to answer all questions results in this model being turned into a "black box", which becomes harder and harder to maintain and its results impossible to communicate. Therefore, central banks employ a multi-model approach whereby the core model is supplemented by a suite of auxiliary models, each of which has its own purpose and appropriate specification. Overall, these models can be divided into four classes:

Models for current economic stance analysis

A forecasting cycle usually begins with the analysis of "current conditions", i.e. the stage of the business cycle the economy is presently at. The task is often complicated by significant lags in the publication of national account data, which serve as the basis for this analysis, although at the same time, substantial data arrays are available to economists at a higher frequency. Therefore, models for nowcasting, i.e. assessment of data for the current period, which would be published later, have gained wide popularity (after publication of the paper by Stock and Watson (1989)). Dynamic factor models are used for that purpose most often; vector autoregression models with mixed periodicity of data and also "bridge" equations or their modification called MIDAS (mixed data sampling) (see examples in the works by Lieberman (2011), Banbura et al. (2013), Schumacher (2014), etc.) are used more rarely. Dynamic factor models use a large number of variables, putting them together into several aggregated indicators (factors), which become the key elements. At the next stage, these factors (key elements) are aggregated, using factor loadings, to forecast the resulting variable. Vector autoregression models are based, with mixed periodicity, on the principle of using variables with higher frequency to forecast variables with lower frequency. For example, monthly data regarding manufacturing and agricultural production outputs, retail sales turnover, monetary and financial data, etc. are used to forecast quarterly GDP. Approaches based on simple equations also use mixed-frequency data, and equations themselves may come in various forms, for example, a composition of autoregressive distributed lags.

An important element of the assessment of the economy's current stance is the decomposition of macroeconomic indicators into trends and deviations or gaps that reflect a cyclic component of variables and, consequently, the position of the economy in the business cycle. In technical terms, signal extraction models or models clearing signals from "noise" are used for that purpose. In the simplest case, these are single-dimensional filters, for example, the Hodrick–Prescott filter, Beveridge–Nelson decomposition or frequency filters. But most often, these are multivariable state space models evaluated using the Kalman filter and whose structure fully reproduces the structure of the FPAS's core model.

Econometric models for short-term forecasting

The use of econometric (time series) models for short-term forecasting is based on the evidence that statistical relations between data in the past would, with a sufficiently high degree of probability, be the same over a short period of time (usually up to two quarters). The main selection criterion for models of this type is their ability to reproduce empirical data in both in-sample and out-of-sample fit.

Despite the significant diversity of models that can be used for short-term forecasting, models that could be classified into the following groups have become the most commonly used at central banks across the world:

- simple univariate autoregression models (unconditional mean, random walk, ARMA and other autoregression models);
- simple multivariate autoregression models (simple vector autoregression models, structured vector autoregression models, error correction models, vector error correction models, etc.);
- models for use in environments with a substantial number of variables and requiring complex evaluation procedures (dynamic factor models, "bridge" equations, factor-augmented vector autoregression models, Bayesian autoregression models, mixed-frequency state space models, MIDAS models, etc.);
- models with changing regime (Markov chain models, regime-switching models).

In particular, the Bank of England uses results produced by these models (systems of models) to make inflation and GDP statistical forecasts and as one of the sources of information for the Bank of England's Monetary Policy Committee (Burgess et al., 2013). A similar suite of models is used for forecasting purposes by other central banks; for instance, Norges Bank uses monthly and quarterly vector autoregression models, dynamic factor models, etc. (Gerdrup et al., 2011). The Central Bank of the Republic of Turkey develops short-term inflation forecasts using a large set of models as well, for example, vector autoregression models and Bayesian autoregression models, dynamic factor models, models with multi-frequency data and models with time-variable parameters, which helped improve the accuracy of forecasts for the following two quarters by 30% (Öğünc et al., 2013).

Additional optimization models for analysis of specific problems

Besides the base structural model per se, which usually reproduces only the key features of the monetary policy's transmission mechanism, central banks develop additional structural models to analyse particular specific matters. Usually, these models resemble DSGE models, but integration of additional blocks into the base model is not recommended because it has to remain sufficiently simple. However, results produced by these satellite models may be included in forecasts on the basis of the core model via appropriate shocks and transformations.

Among the most important issues that have recently been analysed using additional models are accounting for financial rigidities (i.e. financial accelerator channel), financial intermediation (i.e. banking funding channel), unconventional fiscal and monetary policies, in particular analysis of the government's and central bank's balance sheets, etc. All these issues have stirred up huge interest in the academic world and in the studies of central banks since the beginning of the global economic and financial crisis. Certainly, these issues could be of no less importance for many central banks, and therefore the inclusion of the financial sector (with its various rigidities) in the core DSGE models of leading central banks has recently become commonplace. MAPMOD, a model developed by the IMF to support analysis of macrofinancial and macroprudential policy, may serve as the prototype for these models, enabling explicit assessment of the effect of excessive credit expansion and formation of price bubbles on assets (Benes et al., 2014).

Additional models for disaggregation

The behaviour of components of aggregated indicators, e.g. GDP components by expenditures (private consumption, investments, etc.) or added value (by sectors), is quite possible to reproduce using a set of auxiliary models. Usually, these models use the core structural model's results regarding aggregated indicator dynamics and decompose this indicator using simpler behaviour models (regression, vector autoregression and other models). These models may provide additional explanations as regards the dynamics of aggregated indicators taking into account their factors. On the other hand, if they do not use aggregated variable forecasts as an instrumental variable but are based on forecasts of own exogenous variables, these models allow the quality of an aggregated variable forecast as the sum of separate components to be checked. A good example of that is the forecasted production output of particular sectors of the economy aggregated into the total GDP and comparison of the results with the core structural model's forecast.

4. NBU's forecast and policy analysis system

Before 2005, the forecasting process at the NBU (as well as at many other central banks of countries with emerging markets) was based on numerous small-scale models, usually with one or several equations. These econometric models were used as short-term forecasting tools mainly to corroborate expert forecasts. The NBU also used a large-scale semi-structural model developed under a joint project by the International Centre for Prospective Studies, the Ministry of the Economy of Ukraine and the National Bank of Ukraine. However, its regular use for analysis and forecasting purposes was complicated by the annual periodicity of data, large-scale and, consequently, large-maintenance efforts, and an obsolete theoretical foundation.

In response to these problems, in 2005–2006 the National Bank of Ukraine developed the **Quarterly Projection Model (QPM)**, which is still used today, albeit with certain modifications, as the FPAS's core model for monetary policy purposes. First of all, the QPM provides an organizational framework for the forecasting process and coordinates the process of combining nowcasting, short- and medium-term forecasts and expert opinions. Secondly, being an analysis tool, this model enables the functioning of the monetary transmission mechanism to be studied and analysis of the impact of exogenous shocks and political decisions on the basis of simulation experiments. And thirdly, this model plays a key role in assessing the uncertainty, and in particular, in building consistent alternative scenarios.

The QPM's class places it among gap models, close to dynamic stochastic general equilibrium models. This model takes into account rational expectations but has a lower degree of structuring; it also has a clear and easy-to-understand theoretical basis and is simple and convenient to use.

The QPM is built at a very aggregated level, describes only the most important macroeconomic interrelations in the Ukrainian economy and is focused on the features of the monetary policy transmission mechanism. This model converges to a well-defined steady state, although this steady state is exogenously obtained, quite simplified and not based on a microeconomic foundation. The modelling of macroeconomic variables' divergences from their equilibria (gaps) constitutes the model's basis. To evaluate gaps, it uses the multivariate filter with the structure based on the QPM structure.

The key difference between the QPM and similar versions of new Keynesian monetary transmission mechanism models used by other central banks is that it enables modelling of various interim regimes of monetary policy, from exchange rate pegging to inflation targeting. In fact, it enables the simultaneous use by a central bank of two policy instruments: interest rate and exchange rate. An especially useful feature in the modelling of Ukrainian realities is the implementation of a mechanism for partial breach of arbitration condition envisaging uncovered interest parity using, for example, sterilized interventions or administrative restrictions.

In addition, in order to improve the model's forecasting properties and the ability to reproduce particular specific features of the Ukrainian economy, a number of modifications have been implemented in recent years, including:

- expenditure-based decomposition of GDP gap: gaps in private consumption, public consumption, investments, exports and imports;
- fiscal block: identifying cyclical and structural components of a consolidated (state) budget's revenues and expenditures and evaluating fiscal impulse added to IS curve;
- equation for loans and deposits enabling clarification of the assessment of the state of an monetary area (besides the previously existing monetary conditions based on the weighted sum of the gaps in real interest rate and real exchange rate);
- equation for principal items of the balance of payments enabling implementation of a mechanism of dependence of risk premiums on the balance of payments position and exogenous shocks;
- equation for equilibrium real exchange rate depending on export and import trends (i.e. of the BoP's current account position) for accommodation of the key elements of a fundamental equilibrium exchange rate approach;
- improving the long-term loan interest rate formation principles by also accommodating the costs of banking (in particular, deposit) funding when modelling this interest rate's dynamics;
- block of agricultural supply shocks (when evaluating the gap as the difference between the aggregate demand and the trend level influenced by the supply).

Work on improving the QPM still continues; in particular, transition to a model with a more detailed and in-depth theoretical basis and full balance of stock and flow variables is currently underway. In fact, we are talking about the inclusion in this model of the financial sector in an explicit form (to show the effect of the credit crunch on the aggregate demand due to balance sheet problems in the banking system) and external imbalances (to improve the reflection of the effect that the external sustainability stance has on risk premium). These innovations are intended to improve understanding of the economy's behaviour during periods of instability and assess the reasons for, and probability of, their occurrence.

As at other central banks, macroeconomic analysis and forecasting at the NBU (which constructs a ground for monetary policy decision-making) is based not only on the core structural model (QPM) but also a set of auxiliary models is used, first of all, in short-term forecasting.

At the beginning, this set consisted of a number of simple econometric models and approaches, including simple mean, random walk, autoregressions, moving average and reduced-form vector autoregression models. These models were used to forecast inflation and gross domestic product (by forecasting their particular components and subsequently aggregating them). The forecast that this package of models produced was the simple average of forecasts by individual small models. This system was convenient to use thanks to automation of the process, but on the other hand, such a "machine" approach caused uncertainty as regards the accuracy of these models and, consequently, the forecasts they produced and also the low quality of explanations of the reasons behind the dynamics of this or that variable.

The desire to achieve extremely accurate forecasts, especially inflation forecasts, drove the development and maintenance of a **small semi-structural econometric model for inflation** that uses demand pressure, exchange rate, imported inflation, prices for raw materials and other indicators as explanatory variables, combining them into a system of equations. These equations have different forms depending on the inflation component – simple regression equations, error correction models or equations with autoregressive distributed lags.

The NBU's evaluation of GDP changes in a current quarter (official data are published only 45 days after the end of a quarter) and the two subsequent quarters is based on the **bridge model** approach, which allows the use of monthly indicators to evaluate quarterly data. In particular, the use of a set of Bayesian vector autoregression models with mixed-frequency data (monthly and quarterly) and constraints placed upon monthly indicators (they are not affected by quarterly data) helps substantially diminish the problem of a short length of time series with a large number of variables in models.

Currently, **the model forecasting GDP components**, both expenditures (private and public consumption, investments, export and import of goods and services) and production-related, is also an important FPAS component. The equation for most GDP components is set in the form of an error correction mechanism, and cross-relations are used as well (import is based on consumption and investments in past periods, etc.). These equations allow the overall GDP forecast and forecasts of its components to be harmonized and the forecasts produced by the core model to be verified.

The model for foreign trade in goods has a similar purpose. It consists of equations (or a system of equations) for export and import of particular product groups (value-based turnovers). Aggregated results produced by this model (together with expert opinions regarding particular components) concerning the dynamics of value-based export and import turnovers are also used as additional information for QPM-based forecasting.

The expansion of FPASs not only entailed the increased complexity of forecasting indicators that are of key importance for the NBU (inflation and GDP) but necessitated the creation of satellite models reflecting other sectors of the economy or other indicators. The most important of these satellite models were the following:

(1) Models for assessment of cyclical and structural components of the state budget's balance. This model consists of simple regressions for particular components of budget revenues and expenditures and then decomposing them into parts brought by the economic cycle and, as a result, balance, which, in our opinion, reflects the stance of fiscal policy. Subsequently, this model's results are used as additional information for QPM-based forecasting (where the fiscal block is more simplified).

(2) Equilibrium real effective exchange rate evaluation model based on the behavioural approach to the determination of equilibrium REER and using the BoP's current account, net external assets and interest rates as explanatory variables. The results of this evaluation are also used to adjust equilibrium REER dynamics in QPM-based forecasting.

(3) Augmented monetary conditions indicator. The QPM incorporates the effect of the monetary sector on the aggregate demand and price dynamics via money price indi cators (interest rates and exchange rate). Thus, the real monetary conditions index (RMCI) representing a weighted sum of deviations of the real loan interest rate for non-financial corporations and the real effective exchange rate from their equilibrium levels is an explanatory valuable for the output gap. In other words, changes in monetary conditions result in changes in aggregate demand, which, in turn, represents a source of pressure on prices. However, RMCI in the form of price-based indicators alone does not always correctly reflect the actual situation. In particular, with the interest rate being the same, the accessibility of financing may differ substantially due to, for example, strict requirements for borrowers. In that case, the amount of loans in the economy would decline, thereby reflecting more stringent conditions in the monetary sector. And vice versa, monetary conditions may soften without changing interest rates (which may already be quite low). An example of this situation is "quantitative easing". Therefore, the monetary conditions index requires certain supplementation, in particular by using loan volume indicators, monetary aggregates, etc. based on alternative models and approaches. An appropriate augmented monetary conditions indicator was developed on the basis of a principal components approach and is also used in the QPM as additional information to reflect the impact of monetary conditions on economic activity (for details, see Sholomytskyi (2012)).

5. Concluding remarks

Macroeconomic modelling at central banks is a live process, and the development of modelling tools for the purposes of monetary policy is only accelerating as we face new challenges. At the same time, one should remember that every model has drawbacks and only partially shows the reality. Nevertheless, macroeconomic models enable formalization of the vision of the economy's functioning and monetary transmission mechanism in mathematical formulae. The process of developing, testing and revising these models deepens the understanding of economic phenomena, intensifies debates on economic policy issues, and stimulates the research process.

In the last few years, the National Bank of Ukraine has achieved substantial progress in improving its FPAS as part of the preparation for transition to an inflation targeting regime. Currently, the NBU's forecasting process is based on the Quarterly Projection Model, which forms the core of its FPAS and enables consistent combining of the assessment of the current stance of the economy, based on the multivariate filter, expert judgments, and the results of time series models and satellite modules.

However, despite the progress that has been achieved, further improvement of the National Bank's modelling tools in order to enhance analytical and forecasting capabilities necessary to support the process of monetary policy decision-making is undoubtedly needed. The above regards both the improvement of the suite of short-term forecasting models and the core structural model.

Although the QPM has a solid theoretical foundation and good forecasting capabilities and may be used to forecast macroeconomic variables and in policy analysis, a DSGE model still needs to be developed and implemented. Today, models of this type are becoming more and more popular among central banks as the core models of their FPASs. The DSGE model-based approach allows, on the one hand, the latest achievements in macroeconomic and monetary theory to be employed, and on the other hand, it has proved its ability to produce forecasts with a sufficient level of accuracy.

The key advantage of DSGE models over the present version of the QPM lies in the microeconomic basis that enables the equilibrium of stock and flow variables to be ensured, the impact of structural economic shocks arising from changes in preferences of economic agents or technological changes to be simulated, and thus the overall impact of various shocks constantly occurring in the Ukrainian economy to be studied. The most important feature of DSGE models is the opportunity to deal with forward-looking variables, which are crucial for modelling the behaviour of inflation, exchange rates, interest rates, consumption and investment etc. This is especially relevant under the NBU's declaration on transition to inflation targeting – a monetary policy regime based on the control of inflation expectations. DSGE models enable the fullest reflection of the expectation channel of the monetary policy transmission mechanism, in contrast to reduced-form models that cannot use such a feature.

Undoubtedly, the DSGE model development project must provide a substantial impetus aimed at enhancing the FPAS and further research processes at the NBU.

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