A structural model of the Slovak economy

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Slovakia's accession to the euro area terminated one phase of monetary policy in Slovakia. The model approaches used for forecasting and analytic purposes until 2008 do not meet the needs of the central bank resulting from its participation in the Eurosystem any more. For this reason, the NBS has been using a new model apparatus – a structural model of a small open economy – since the day of the adoption of the common European currency.

The cyclical (gap) model[1], used until recently, described the active role of monetary policy consisting in correcting the cyclical part of the economy (i.e. deviations of economic fundamentals from their long-term or equilibrium trends) under an inflation targeting regime. The new structural model, by contrast, is a stock-flow model (i.e. modelled economic quantities do not occur in the form of deviations from the equilibrium, but in absolute volumes, be it flow quantities such as deficit, investments and net foreign assets or their stock counterparts such as cumulative debt, capital stock and wealth) with an exogenous monetary policy consistent with the current euro area membership.

The new model is used to meet two basic needs resulting from this membership and from domestic requirements, too. It is used for *forecasting purposes* – twice a year, the process of producing a forecast for the Slovak economy is part of the forecasting process of the Eurosystem (Broad Macroeconomic Projection Exercise – BMPE) and, twice a year, the model is used to prepare the internal forecast of the central bank. Further, the model meets the *analytical needs* – it is used to simulate monetary-policy, fiscal, price or supply shocks, the reactions to which serve as inputs for analyses conducted by ECB and focused on the entire euro area or analyses related exclusively to the domestic economy.

The new model can be briefly characterised as a standard medium-sized econometric model based on a synthesis of the AWM model[2] used by European Central Bank. The model is backward-looking as it takes a simplified approach to expectations by including lagged values of the modelled economic quantities. Thus, only adaptive expectations actually occur in the model. The external environment is considered to be exogenous and since the model describes solely the domestic economy, it is a so-called *one-country model*. The aim of the presented model description is to provide a brief overview of its theoretical fundaments and a simplified description of its structure; detailed model documentation will be published independently.

With regard to the current trends in macroeconomic modelling, it is necessary to state that, looking ahead, the new model represents a kind of intermediate step on the road to the development of a complex model of the Slovak economy based on microeconomic foundations. The model apparatus of the central bank used for the above mentioned purposes should comprise a dynamic stochastic general equilibrium (DSGE) model in the future.

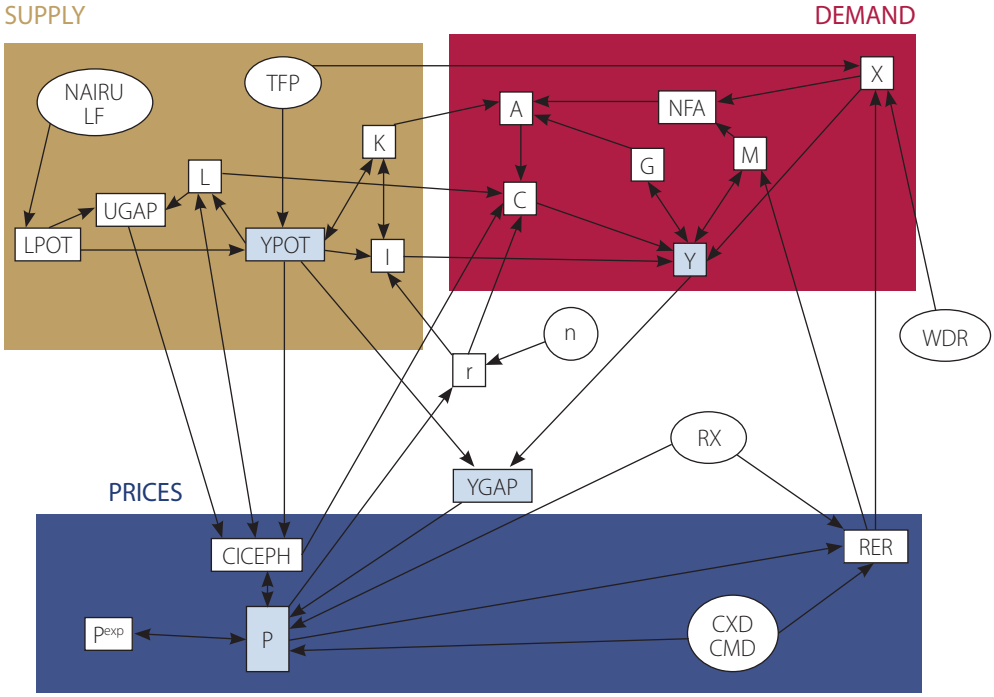
Model characteristics

The structural model of a small open economy is formulated in a way ensuring that a set of basic economic relationships holds in the long run. These relationships theoretically correspond to a so-called steady state, in which the production level is determined by the supply side of economy, i.e. by factors of production and their total productivity or technological progress. However, in the short run, economic performance, as measured by the gross domestic product, is determined from the demand side.

The model architecture ensures that, in the long run, the steady state is achieved and, in case of supply, demand or price shocks, returned to equilibrium. In most cases, the long-term model relationships are directly derived from theory (for example from the first order conditions for labour and capital resulting from maximisation of profit generated by production of aggregate product), while short-term dynamics are estimated to fit historical data as accurately as possible. In estimation, necessary restrictions were imposed ensuring the required model properties in the long run (convergence and homogeneity).

Households, firms and the government play the role of domestic agents in the model. Monetary policy is performed outside the domestic economy, which implies the absence of domestic monetary authority. Along with foreign economy, the monetary-policy setting is thus exogenously given. The households are owners of capital and labour. Both factors of production are offered to firms which produce the aggregate product, their production technology being described

1 *Gavura, M. and Reľovský, B: A simple model of the transmission mechanism of Slovakia's economy, its structure and properties. BIATEC, volume 13, 4/2005, National Bank of Slovakia.*
2 *Area-wide model; see Fagan, G., Henry, G. and Maestre, R.: An area-wide model (AWM) for the euro area. ECB Working Paper No 42, January 2001, European Central Bank.*



by a Cobb-Douglas production function.[3] The objective of the firms is to maximize the production profit, i.e. the difference between sales of the product produced at the given price level and labour and capital costs at the given factor prices.[4] The objective function of a representative firm in an above-described framework can be defined as follows:

maximize

$$YPOT.PY - CICEPHN.LPOT-(r + \delta + \lambda).K.PY$$

subject to technology

$$YPOT = TFP.K^{\beta}.LPOT^{1-\beta}$$

The objective function implies that firms maximize their profit if and only if the first order condition with respect to capital $K/YPOT = \beta/(r + \delta + \lambda)$ holds simultaneously with the first order condition with respect to labour $CICEPH.LPOT/YPOT=1- \beta$. The optimality conditions characterize the steady state of the modelled economy and are valid in the long run, when it also holds that the real production is equal to the potential product of the economy. However, deviations of reality from the equilibrium exist objectively in the short run, both in the sense of a non-zero output gap and, more importantly, in the sense of invalidity of the first order conditions. The temporary disequilibrium on the goods market is achieved in the model by determining the production from the demand side in the short run. The temporary invalidity of the first order conditions, but at the same time the necessity to fulfil them in the long run, is provided for by an error-correction formulation of the model equations.

The model consists of three blocks – the block of the supply side of the economy, the block of the demand side of the economy and the price block. The diagram above shows the structure of links within the individual blocks and illustrates which economic quantities ensure the links between blocks within the model as a whole (and how).

The block of the supply side of the economy describes the technology of production of the aggregate product and the way of accumulation or level determination of the factors of production. The Cobb-Douglas production function determines the volume of potential output (YPOT) as a function of[5] the capital stock (K), potential employment (LPOT) and total factor productivity (TFP), which is exogenous[6]. The capital stock in the economy increases from period to period by investment (I) and decreases by depreciation (the depreciation rate is determined by the parameter δ)[7]. At the same time, it holds that in the long run investment is given by the first order condition with respect to capital, the real interest rate (r) being unambiguously determined by projecting the price level (P) to the nominal interest rate (n), which is given exogenously due to the loss of independent monetary policy. Employment (L) is determined by an inverse production function in the long run, while the natural rate of unemployment (NAIRU) together with the labour force (LF) determine the potential employment (LPOT). The difference between the actual and the potential employment, or between the actual and the natural rate of unemployment, defines the labour market disequilibrium (UGAP).

While the block of the supply side of the economy determines the level of production achieved in the long run, the block of the demand side of

3 The volume of production, or potential GDP (YPOT), depends on the total factor productivity (TFP), the capital stock (K) and the number of persons which can be involved in the production process – i.e. the potential employment (LPOT). The parameter β determines the relative weights of capital and labour in the production process.

4 Sales, expressed in nominal terms, depend on the volume of production (YPOT) and the price level (PY denotes the GDP deflator). The wage costs are determined by the number of working persons (LPOT) and the level of nominal compensations per employee (CICEPHN). The costs of capital are determined by the nominal value of employed capital (K.PY) and by effective costs per unit of capital r+δ+λ (r stands for the real interest rate, δ stands for the rate of capital depreciation and λ is the risk premium).

5 The arrows show links between individual quantities occurring in the model; for example: X → Y means that the X variable directly influences the Y variable.

6 The variable names framed by round line are exogenously given, while those framed by broken line are endogenous model variables.

7 A more detailed view on the individual identities as well as behavioural equations of the model is provided by the overview box below, which provides an abbreviated notation of all of the model equations. The above diagram captures only the most important links within the model.

Box 1

The block of the supply side of the economy

$YPOT = TFP \,.\, K^{\beta} \,.\, LPOT^{1-\beta}$

$K \equiv (1-\delta) \,.\, K_{-1} + I$

$I = I\,(I_{-1},\ Y,\ r,\ I^*(r, \delta, \lambda,\ Y / K))$

$LPOT \equiv LF \,.\, (1 - NAIRU)$

$L = L\,(LPOT,\ Y / TFP,\ CICEPH / TFP,\ L^*(Y / (TFP \,.\, K^{\beta})))$

$YGAP \equiv Y / YPOT$

$UGAP \equiv (LPOT - L) / LF$

The block of the demand side of the economy

$Y \equiv C + G + I + X - M$

$C = C\,(C_{-1},\ DISPY,\ r,\ C^*(DISPY,\ A))$

$DISPY = DISPY\,(CICEPH,\ L)$

$A \equiv K + D + NFA$

$D \equiv D_{-1} + G - \tau \,.\, Y$

$NFA \equiv NFA_{-1} + X - M$

$G = G\,(G_{-1},\ Y,\ G^*(D / YPOT))$

$X = X\,(WDR,\ WDR_{-1},\ RER,\ TFP,\ X^*(WDR,\ RER,\ TFP))$

$M = M\,(WDI,\ RER,\ M^*(WDI,\ RER))$

$WDI = WDI\,(C,\ G,\ I,\ X)$

The price block

$CICEPH = CICEPH\,(LPROD_{-1},\ PC / PY,\ UGAP,\ CICEPH^*(LPROD))$

$PY = PY\,(PY_{-1},\ PM,\ YGAP,\ PY^*(ULC))$

$PC = PC\,(HICP)$

$HICP = HICP\,(HEG,\ HEX)$

$HEG = HEG\,(POIL,\ RXUSD,\ PY)$

$HEX = HEX\,(HEX_{-1},\ CMD,\ RXEUR,\ PY,\ YGAP_{-1},\ HEX^*(PY))$

$PG = PG\,(PG_{-1},\ PI,\ PC,\ PG^*(PC,\ PI))$

$PI = PI\,(PI_{-1},\ PY_{-1},\ PI^*(PY,\ PM))$

$PM = PM\,(CMD,\ RXEUR,\ POIL,\ RXUSD,\ PM^*(PY,\ CMD,\ RXEUR,\ POIL,\ RXUSD))$

$PX = PX\,(PY,\ CXD,\ RXEUR,\ PX^*(PY,\ CXD,\ RXEUR))$

the economy formalises the assumption that the level of economic activity in the short run is determined only by demand. The gross domestic product (Y) thus equals the sum of the individual demand components – private consumption (C), general government consumption (G), investment (I) and net exports (X-M). The consumption of households (C) depends on the level of disposable income (DISPY) and accumulated wealth (A), but the interest rate (r) also influences its level through the channel of deciding on what portion of disposable funds is directed to savings and what portion goes to immediate consumption. As regards the general government, its consumption spending follows a simple fiscal rule of maintaining a given debt to GDP ratio. The imports (M) are determined by production activity (Y) via import intensity, while the exports (X) are driven by external demand (WDR). The net foreign assets (NFA) increase by net exports (X-M) each period, and the sum of NFA, capital stock (K) and government debt (D) defines wealth (A)[8], which together with disposable income determines private consumption.

Within the price block, the domestic price level (P) is unambiguously determined by the unit labour costs (ULC) in the long run. Besides that, competitors´ prices on the import (CMD) and the export side (CXD) as well as the exogenous nominal exchange rate (RX) and the output gap (YGAP) are reflected in the price level. The price level and the price of labour (CICEPH) significantly influence each other, because on the one hand higher wages exert demand pressures on inflation by means of higher consumption, while on the other hand the higher prices put higher pressure on the growth of compensations as demanded by employees during wage negotiations. Of course, when negotiating the wages, the households take into account consumer inflation (PC), relevant to them, while production prices (PY) are crucial for the firms in their decisions. Such differentiation is reflected in a considerable degree of disaggregation of the price block in the model, the uniform price level for the whole economy (P) being replaced by a set of deflators for all GDP components. The basic deflator, in the sense of anchoring the price level, is the GDP deflator (PY); other deflators depend on it and are derived from it. More detailed information about links within the price block is shown in the above box providing an overview of all model equations.[9]

The individual model blocks are not isolated from each other. The connection between the supply block and the price block is provided for by the labour market disequilibrium (UGAP), which plays a crucial role in wage negotiations, because the amount of compensation for work (CICEPH) determines the actual labour demand (L) and vice versa, the number of competing job candidates

8 *The model assumes that both capital and government bonds are owned by households.*

9 *To provide an accurate elucidation of the error-correction specification, the abbreviated equation notations express both short-term dynamics (the list of function arguments begins with the quantities which occur in short-term relations) and the long-term links (the function argument indicated as the last one, marked with an asterisk, denotes the value of the function in the long run – the brackets after the argument contain a list of variables on which this long-term level depends). For example, the notation C = C (C–1, DISPY, r, C* (DISPY, A)) means that current private consumption (C) is determined by the level of consumption in the last period (C–1), the value of disposable income (DISPY) and real interest rate (r), as well as the deviation from its equilibrium value (C*), which, in turn, depends on disposable income (DISPY) and accumulated amount of wealth (A).*

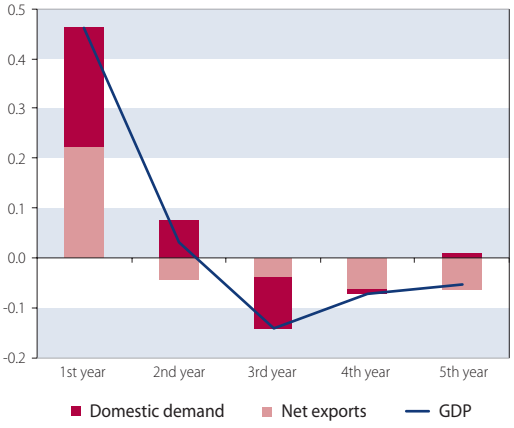
determines the strength of a successful candidate in wage negotiations. Wages are governed by the first order condition in the long run according to which the growth of wages must correspond to the growth of labour productivity in the steady state.

The supply block is interconnected with the demand block through the link of exports (X) to total factor productivity (TFP). This link represents a formulation of the real convergence hypothesis supposing that a faster growth in labour productivity (and thereby also in TFP) as compared to foreign countries provides the domestic economy with a competitive advantage, from which domestic exporters benefit. Other interconnections are provided for by the capital stock (K), determining the wealth (A) and thus ultimately household consumption (C); and the employment (L), which together with compensations (CICEPH) defines the disposable income of the population (DISPY) determining its final consumption again (C).

The interconnections between the price block and the demand block are provided for by wages (CICEPH) determining the level of private consumption (C) by means of disposable income (DISPY). An important link is also constituted by the domestic price level (P), which – adjusted for the nominal exchange rate (RX) and foreign prices (CMD, CXD) – defines the real exchange rate (RER) determining foreign trade competitiveness and performance (both X and M). While nominal convergence (a faster growth in domestic price level compared to the trading-partner economies) causes an appreciation of the real exchange rate and deteriorates net exports by weakening the exports and increasing the import attractiveness, real convergence, a faster growth in labour productivity and a positive differential in the development of domestic and foreign TFP have the opposite impact on the development of net exports. As mentioned previously, the growth of total factor productivity supports the exports and thereby eliminates the negative influence of nominal convergence.

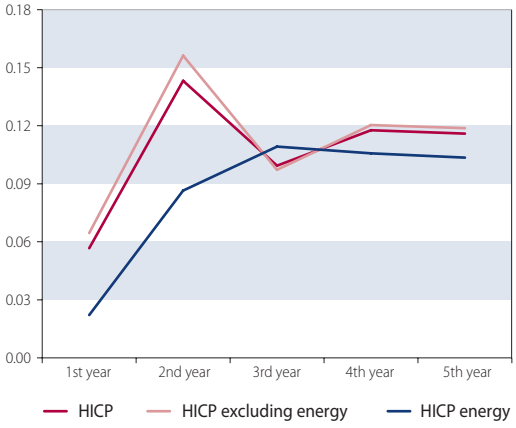
Due to a missing domestic monetary authority, it is not possible to close the model by a monetary policy rule. Therefore, disequilibrium between aggregate supply (YPOT) and demand (Y)

Chart 1 Demand shock – GDP and its components (p.p.)



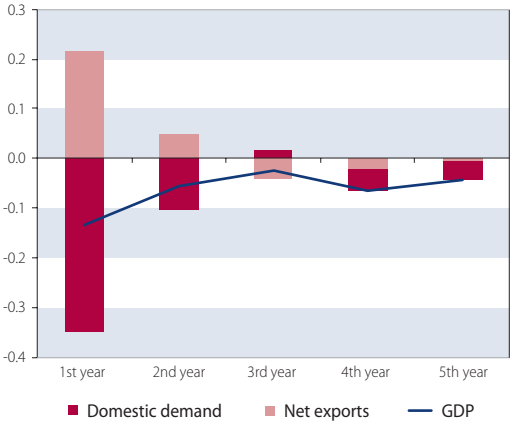
Source: NBS.

Chart 2 Demand shock – HICP and its components (p.p.)



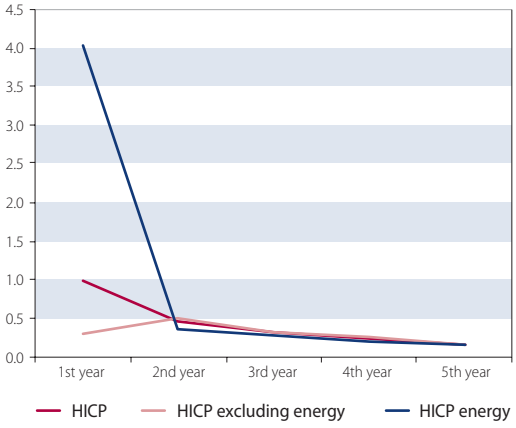
Source: NBS.

Chart 3 Supply shock – GDP and its components (pp.)



Source: NBS.

Chart 4 Supply shock – HICP and its components (p.p.)



Source: NBS.

provides for a closure of the model in that the cyclical position of the economy (YGAP) is reacted to directly by the price level (P or PY). In simplified terms, the mechanism of establishing the equilibrium consists in the correction of domestic price level causing such a shift of the real exchange rate and terms of trade that the subsequent reaction of net exports brings the demand side in line with the supply side and thereby leads to equilibrium on the goods market.

Model properties

To verify the predictive and analytical model qualities, testing on series of shocks is used as a standard. The testing confirms not only the model's proper structure, but also the estimated model parameters. Two types of shock are simulated on quarterly data – a demand shock is simulated by increasing external demand and a supply shock by an increase in oil prices. The results are presented on annual data in the form of differences between year-on-year growth rates of the shock scenario and the baseline scenario (in percentage points (p.p.)).

The demand shock – an increase in external demand

This shock simulates a permanent increase in external demand by 1%. Such an impulse stimulates foreign trade immediately. Exports grow immediately and imports grow as well due to import intensity of exports. The growth of external demand is reflected in a growth of labour productivity and real wages, which also stimulates domestic demand. By means of investment, the capital stock is increasing and thereby the supply side of the economy is also getting higher permanently. The GDP growth will rise by 0.45 p.p. in the first year of the shock; both domestic and external demand components exhibit positive contributions to this. The GDP growth is higher by approximately 0.05 p.p. in the second year. Domestic demand exhibits a positive contribution to the growth, but the contribution is negative on the part of foreign trade, since export performance is already stagnating and imports are increasing because of domestic demand. In the following years, the GDP dynamics slows down due to both domestic demand and foreign trade. The price development in the given shock is influenced by a faster growth of demand than of the supply side of the economy. HICP inflation will increase approximately by 0.06 p.p. in the first year of the shock, its dynamics will accelerate subsequently and it will be 0.14 p.p. higher in the second year. In the remaining years, the price level growth dynamics is approximately 0.1 p.p. higher.

The supply shock – an increase in oil prices

This shock simulates a permanent increase in oil prices by 20%. The increase in oil prices causes a growth in energy expenditures of businesses and households. Such an increase in prices immediately induces a contraction of demand and thereby also of production. Labour productivity is on the decline along with real wages. Domestic demand drops sharply and negatively affects the GDP growth. Net exports, by contrast, stimulate GDP growth, because the decline in imports exceeds the decline in exports. However, the GDP as a whole is on the decline; the GDP growth is expected to contract by 0.13 p.p. in the first year of the shock and up to 0.1 p.p. in the remaining years. Regarding the price development, a noticeable item is the growth of energy prices, as the growth in oil prices is gradually translating to the energy prices and secondarily also to other HICP components. Overall, the HICP growth will rise by about 1 p.p. in the first year of the shock, energy prices (HICP energy inflation up by 4 p.p.) significantly contributing to the rise. In the second year of the shock, the growth in prices is not as significant as in the first year, but secondary effects due to the growth in oil prices are gradually going to become evident in other consumer basket items, too. The dynamics is still higher; the HICP inflation will rise approximately by 0.5 p.p. in the second year. In the remaining years, the dynamics of the growth in prices is gradually decelerating; however, it is still above its pre-shock level.

Conclusion

The structural model implemented by Národná banka Slovenska simultaneously with the introduction of the euro represents another important milestone in econometric modelling at the NBS. The requirements resulting from the Eurosystem membership, as well as the efforts to extend the analytical apparatus used so far, have created room for a new tool, which makes it possible not only to solve complex tasks in the field of forecasting and monetary policy, but also to analyze various economic policy instruments. The model created will be further developed and extended, representing a natural continuation of this work.

List of abbreviations used:

A – wealth
C – private consumption
CICEPH – compensations per employee
CICEPHN – nominal compensations per employee
CMD – competitors´ prices on the import side
CXD – competitors´ prices on the export side
D – government debt
DISPY – disposable income of the households
G – public consumption
HEG – HICP index of energy prices
HEX – HICP index excluding energy prices
HICP – HICP index
I – investment
K – capital stock
L – employment
LF – labour force
LPOT – potential employment
LPROD – labour productivity
M – imports of goods and services
n – nominal interest rate
NAIRU – natural rate of unemployment
NFA – net foreign assets
P – price level
PC – private consumption deflator
P^{exp} – inflationary expectations
PG – public consumption deflator
PI – investment deflator
PM – import deflator
POIL – oil price
PX – export deflator
PY – GDP deflator
r – real interest rate
RER – real exchange rate
RX – nominal exchange rate
RXEUR – nominal exchange rate (SKK/EUR)
RXUSD – nominal exchange rate (SKK/USD)
TFP – total factor productivity
UGAP – unemployment gap
ULC – unit labour costs
WDI – composite import demand indicator
WDR – foreign demand
X – exports of goods and services
Y – gross domestic product
YGAP – output gap
YPOT – potential gross domestic product
β – capital share of income
δ – capital depreciation rate
λ – risk premium
τ – ratio of government revenues to GDP