

Macroeconomic development model for the national economy (second extension)

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Abstract

The macroeconomic model presented in this paper describes the complex functioning of national economy and can be used to forecast the effect of various economic policies on development trends. It is an extension of [2,3] and adaptation of [4]. To determine the effect on national economy of state policies related to credits, taxes and interest rate, national economy is considered within the framework of four sectors: Government, Private, Monetary and External.

The model is developed based on a system of equations, which describes balances of sector incomes and expenditures and allows to present the whole flow of necessary historical information in a coordinated form. The system is completed by behavioral functions which describe interrelations between main macroeconomic variables, and allows to use it to predict the effect of economic policies. The system of equations is solved for all economic sectors simultaneously.

There are several types of variables in the model: exogenous variables, which are defined by the user, endogenous variables, which are calculated with the help of the model, and policy variables, which serve as means for adjustment of the economic policies under consideration. All endogenous variables are calculated in base year prices, in current prices and in prices of the previous year. Some variables are represented only in local currency terms, while some are represented in local currency and in dollar terms. To distinguish them the variable notation

ends with an appropriate letter: R, L, or D. Nominal figures are transformed into real figures by means of appropriate price indexes. The transition from dollar figures to corresponding local currency figures is made by applying the appropriate exchange rate. All variables that represent changes in financial flows in real terms, have *chn* at the end of the variable notation, those that represent percentage changes have *ch* or %.

Public sector

The budget constraint for the Public Sector is written as follows:

$$\begin{aligned} & NGTDL + NGTIL - NGSTL + NGNTL + NGYCL - \\ & -NGTRL - NEGTRL - NGIDL - NGEDL - \\ & -NGCNL = NGINVL + NGNLL - FCRGVL \text{ chn} - \\ & -TDGVD \text{ chn} - FNONBL \text{ chn}. \end{aligned}$$

The equation means that current income of Public Sector less current expenditure should equal net savings. Current income consists of direct (*NGTDL*) and indirect taxes (*NGTIL*) less subsidies (*NGSTL*), plus nontax public revenue (*NGNTL*) and capital income (*NGYCL*). Current expenditure is defined as the sum of transfers to the Private Sector (*NGTRL*) and External Sector (*NEGTRL*), interest payments for external (*NGIDL*) and internal debt (*NGEDL*), and government consumption (*NGCNL*). Net government savings is calculated as government investments (*NGINVL*), which is set exogenously, plus net government loans (*NGNLL*), internal loans (*FCRGVL chn*), nonbank financing (*FNONBL chn*) and external (*TDGVD chn*) loans.

Following, the equation will be described in details. Direct taxes consist of corporate taxes (*NGTCL*), personal income taxes (*NGTHL*) and other direct taxes (*NGTOL*):

$$NGTDL = NGTCL + NGTHL + NGTOL.$$

Direct corporate and personal income taxes are calculated by the following formula:

$$\begin{aligned} NGTCL &= NYBSL * NCTX\%, \\ NGTHL &= NYHSL * NHTX\%, \end{aligned}$$

where ($NYBSL$) is gross corporate income, ($NYHSL$) is total personal income of the population, and ($NCTX\%$) and ($NHTX\%$) are the corporate tax rate and personal tax rate, accordingly. The tax rates are policy variables that can be used to measure the effect of fiscal policies on economic development.

Indirect taxes are the value added tax and excise tax ($NGVTV$), tax on imports ($NGMTL$), other indirect taxes in the government budget ($NGOIL$):

$$NGTIL = NGMTL + NGVTL + NGOIL.$$

To be able to determine a value for taxes on import and indirect taxes it is necessary to set an implicit tax rate for import ($NMTX\%$) and an implicit tax rate on value added and excise ($NVAT\%$). Then,

$$\begin{aligned} NGMTL &= MGNFSL * NMTX\%, \\ NGVTL &= NCONL * NVAT\%. \end{aligned}$$

The overall tax income is defined as the sum of direct and indirect taxes:

$$NGTXL = NGTDL + NGTIL.$$

Current income ($NGCRL$) consists of tax income ($NGTXL$), nontax income ($NGNTL$), and capital income ($NGYCL$):

$$NGCRL = NGTXL + NGNTL + NGYCL.$$

Nominal government consumption ($NGCNL$) is calculated as current government expenditure ($NGCEL$) less subsidies ($NGSTL$), interest payments for internal ($NGIDL$) and external ($NGEDL$) debts, and government transfers ($NGTRL$):

$$\begin{aligned} NGCNL &= NGCEL - (NGSTL + \\ &+ NGIDL + NGEDL + NGTRL). \end{aligned}$$

Real government consumption ($NGCNR$) is defined as nominal government consumption adjusted by a government expenditure deflator ($NGCNP$):

$$NGCNR = NGCNL/NGCNP.$$

Real government expenditure ($NGCER$) is defined as a residual variable, and nominal government expenditure ($NGCEL$) is defined as follows: $NGCEL = NGCER * NGCNP$, where $NGCNP$ is government expenditure deflator, which is also equal to GDP deflator: $NGCNP = GDPLP$.

Subsidies ($NGSTL$) are divided into corporate subsidies ($NGSBL$) and personal subsidies ($NGSHL$), which are proportional to personal ($NYHSL$) and corporate incomes ($NYBSL$). ($SUBYH\%$) and ($SUBYB\%$) are policy variables that represent the rate of corporate and personal subsidies accordingly:

$$\begin{aligned} NGSBL &= NYBSL * SUBYB\%, \\ NGSHL &= NYHSL * SUBYH\%. \end{aligned}$$

The total sum of subsidies is defined as:

$$NGSTL = NGSBL + NGSHL.$$

Current saving ($NGSVL$) is the difference between current income ($NGCRL$) and government expenditures ($NGCEL$):

$$NGSVL = NGCRL - NGCEL,$$

and government budget deficit ($NGDFL$) is defined as current government savings ($NGSVL$) less capital expenditure ($NGCCL$) and net government loans ($NGNLL$):

$$NGDFL = NGSVL - NGCCL - NGNLL.$$

Monetary Sector

The budget constraint for the Monetary Sector is written as follows:

$$\begin{aligned} FMSUPL\ chn &= FCRGVL\ chn + FCRPRL\ chn + \\ &+ FASCL\ chn + FASFRL\ chn + FOTHLL\ chn. \end{aligned}$$

This equation states that the change in the money supply ($FMSUPL\ chn$) is equal to the change in government loans

(*FCRGVL chn*) plus the change in private loans (*FCRPRL chn*), the change in loans given to state enterprises (*FASCL chn*), accumulation of net foreign assets (*FASFRL chn*), and other items (net) (*FOTHLL chn*).

The equation is described as follows. Changes in Public Sector loans (*FCRGVL chn*), Private Sector loans (*FCRPRL chn*) and state enterprises loans (*FASCL chn*), are calculated with respective alterations in percentage, which are set exogenously:

$$\begin{aligned} FASCL\ chn &= seed\ FASCL\ chn; \\ (1 + FASCL\%) &* previous(FCRSTL), \\ FCRPRL\ chn &= seed\ FCRPRL; \\ (1 + FCRPRL\%) &* previous(FCRPRL), \\ FCRGVL\ chn &= seed\ FCRGVL; \\ (1 + FCRGVL\%) &* previous(FCRGVL). \end{aligned}$$

Change in net foreign reserves in local currency terms (*FASFRL chn*) is defined as the sum of net foreign assets of the government (*FASGL chn*) and commercial banks (*FASBL chn*), which, in turn, are equal:

$$\begin{aligned} FASGL\ chn &= FASGL\ chn + FASBL\ chn \\ FASGL\ chn &= (TBCACD + TCAPD) * REXCHL, \\ FASBL\ chn &= (1 + FASBL\ ch) * previous(FASBL\ chn). \end{aligned}$$

FOTHLL chn is the change in other items (net), which is defined as a residual variable. The money demand depends on interest rate and real GDP, or on the rate of inflation and real GDP. *TDIMFL chn* is an exogenous variable, which describes change in nominal debt to the International Monetary Fund (IMF). The money demand is specified as a function of nominal interest rate (*NINTEL*) and nominal GDP (*NGDPL*):

$$\begin{aligned} FMDEML &= exp(fmdeml\ coef1 + \\ &+ fmdeml\ coef2 * ln(NINTEL) + \\ &+ fmdeml\ coef3 * ln(NGDPL)), \end{aligned}$$

where $NINTEL$ is the nominal interest rate, which is calculated as follows:

$$NINTEL = NINTER + GDPLP\%$$

where $NINTER$ is the real interest rate, and $GDPLP\%$ is the rate of inflation.

External Sector

The budget constraint for the External Sector is written as follows:

$$\begin{aligned} TBCACD = & TBMCHD + TBFSRD + \\ & +TCAPID + TUNRTD \\ TDGVD\ chn + & TDIMFD\ chn + TDPRD\ chn = \\ TBCACD + & TRESDD + TEAOD. \end{aligned}$$

$TDIMFD\ chn = previous(TDIMFD) + TDIMFD\ chn$ is set exogenously.

Current account is divided into net income ($TCAPID$), net transfers ($TUNRTD$), and balance of services ($TBFSRD$) which are set exogenously, and trade balance ($TBMCHD$).

The financing of current account deficit is given in the capital account. The Public Sector, Monetary Sector, and Private Sector all borrow abroad ($TDGVD\ chn$), ($TDIMFD\ chn$), ($TDPRD\ chn$). The Monetary Sector accumulates foreign assets in the form of international reserves ($TRESDD$). The Private Sector accumulation of assets can be estimated on the base of the ($TEAOD$) error and omissions of the BOP (Balance of Payments).

The export of goods and services ($XGNFSD$) is defined as the sum of export of goods ($XMRCHD$) and export of services ($XGFSD$). Real export of goods ($XMRCHR$) is determined by a behavioral function, which depends on real gross domestic product ($FGDPR$) and the temporal variable (t):

$$XMRCHR = (1 + xmrchr\ coef1(t)) * previous(XMRCHR).$$

Nominal export of goods is described as follows:

$$XMRCHD = XMRCHR * XMRCHDP,$$

where $XMRCHDP$ is the index of world prices for export of goods, a behavioral function, dependent on world prices ($TMUVPD$):

$$XMRCHDP = \exp(xmrchdp\ koef1 + xmrchdp\ koef2 * \ln(TMUVPD) + xmrchdp\ koef3 * TREND).$$

The trade balance ($TBMCHD, TBMCHL$) is calculated as:

$$\begin{aligned} TBMCHD &= XMRCHD - MMRCHD, \\ TBMCHL &= XMRCHL - MMRCHL. \end{aligned}$$

The balance of services ($TBFSRD$) is defined as:

$$TBFSRD = XGFSRD - MGFSRD.$$

Export of goods in current prices ($XMRCHL$) is calculated as export of goods in dollar terms ($XMRCHD$) multiplied by the exchange rate:

$$XMRCHL = XMRCHD * REXCHL.$$

Export of goods and services ($XGNFSD$) is the sum of the export of goods ($XMRCHD$) and the export of services ($XGFSRD$) which are set exogenously:

$$XGNFSD = XMRCHD + XGFSRD.$$

Export of goods and services in dollar terms ($XGNFSD$) is adjusted to local currency ($XGNFSL$) by the exchange rate $REXCHL$:

$$XGNFSL = XGNFSD * REXCHL.$$

The volume of import of goods and services ($MGNFSD$) is subdivided into import of goods ($MMRCHD$) and import of services ($MGFSRD$). The import of goods includes import of power resources ($MOILD$) and import of other goods ($MOTHD$).

Volume of import depends on the real GDP and relative prices for import. The real import of power resources is represented by

a behavioral function, dependent on the real GDP ($NGDPR$) and relative prices for import of power resources ($MOILD P / (GDPLP / REXCHL)$).

$$MOILR = \exp(moilr\ koef1 * \ln(NGDPR) + \\ + oilr\ koef2 * \ln(MOILD P * REXCHL / GDPLP) + \\ + oilr\ koef3 * D92).$$

where $D92$ is a binary variable, equal to one in 1992 and zero in other years of the historical period.

Real import of other goods is also represented by a behavioral function, dependent on real GDP ($NGDPR$) and relative prices for import of other goods ($MOTHDP / (GDPLP / REXCHL)$):

$$MOTHR = \exp(mothr\ koef1 * \ln(NGDPR) + \\ + mothr\ koef2 * \ln(MOTHDP * REXCHL / GDPLP) + \\ + mothr\ koef3 * D92).$$

where $D92$ is a binary variable, equal to one in 1992 and zero in other years of the historical period.

Total volume of real import of goods is the sum of import of power resources and other goods:

$$MMRCHR = MOILR + MOTHR.$$

Price indices for import are determined for power resources ($MOILD P$), and for other goods ($MOTHDP$). The index of world prices for import of power resources is determined by a behavioral function, dependent on the general level of world prices ($TMUVPD$):

$$MOILD P = \exp(moildp\ koef1 + moildp\ koef2 * \ln(TMUVPD)).$$

The index of world prices for import of other goods ($MGNFSD$) is defined similarly:

$$MOTHDP = \exp(mothdp\ koef1 + \\ + mothdp\ koef2 * \ln(TMUVPD)).$$

The formula by which import components are calculated in dollar terms are shown below:

$$\begin{aligned} MOILD &= MOILR * MOILD P, \\ MOTHD &= MOTHR * MOTHD P, \\ MMRCHD &= MOILD + MOTHD. \end{aligned}$$

The general price index of the import of goods ($MMRCHDP$) is determined by dividing nominal import ($MMRCHD$) by real import ($MMRCHR$):

$$MMRCHDP = MMRCHD / MMRCHR.$$

Total nominal import of goods and services ($MGNFSD$) is determined as a sum of import of goods ($MMRCHD$) and import of services ($MGFSRD$) which is set exogenously:

$$MGNFSD = MMRCHD + MGFSRD.$$

Import indices ($MMRCHL$, $MGNFSL$) in dollar terms are translated into local currency by the exchange rate:

$$\begin{aligned} MMRCHL &= MMRCHD * REXCHL, \\ MGNFSL &= MGNFSD * REXCHL. \end{aligned}$$

Currency reserves of the current year ($TRESVD$) are equal to currency reserves of the previous year plus change in net currency reserves ($TRESDD$), which are set exogenously:

$$TRESVD = previous(TRESVD) + TRESDD,$$

where $previous(TRESVD)$ is currency reserves of the previous period needed for external financing.

External Debt

Total volume of External Debt ($TAEXTD$) is paid off as the sum of external debt to IMF ($TDIMFD$), government debt ($TDGVD$) and Private Sector debt ($TDPRD$):

$$TEXTDD = TDIMFD + TDGVD + TDPRD,$$

where

$$\begin{aligned} TDIMFD &= previous(TDIMFD) + TAEXTD, \\ TDGVD &= previous(TDGVD) + TDGVD \text{ chn}, \\ TDPRD &= previous(TDPRD) + TDPRD \text{ chn}, \end{aligned}$$

Private Sector

The budget constraint for the Private Sector is as follows:

$$\begin{aligned} &NYHSL + NYBSL + NGTRL + NGIDL + \\ &+ TUNRTD * REXCHL + NGEDL - NPCNL - \\ &- NGTDL = NPINVL + FMSUPL \text{ chn} - FCRPRL \text{ chn} + \\ &+ FASFRL \text{ chn} + FNONBL \text{ chn} - OTHLL \text{ chn} - \\ &- NGNLL - TDPRL \text{ chn}. \end{aligned}$$

On the left hand side of the equation Private Sector savings are presented as the excess of the sum of income ($NYHSL$ are wages; $NYBSL$ is profit), transfers ($NGTRL$), interest payments for internal debt ($NGIDL$), transfers from abroad ($TUNRTD$), interest payments for external debt ($NGEDL$) over the sum of expenditures on consumption ($NPCNL$) and direct taxes ($NGTDL$). The right hand side of the equation shows, that Private Sector savings are used to finance private investment ($NPINVL$), increase money supply ($FMSUPL \text{ chn}$), for internal loans ($FCRPRL \text{ chn}$), and also for creation of net foreign assets ($FASCL \text{ chn}$).

Each variable of the constraint will be explained in more detail. The nominal income of population ($NYHSL$) is compound of labor income ($NPWSL$) and other income ($NYHOL$):

$$NYHSL = NPWSL + NYHOL,$$

and the real income of population is determined as:

$$NYHSR = NYHSL/GDPLP.$$

Labor income ($NPWSL$), in turn, depends on the nominal wage rate ($NWAGEP$) and number of workers ($NWORK$):

$$NPWSL = NWAGEP * NWORK.$$

The nominal wage rate (*NWAGEP*) is a function of real wages (*NWAGER*) and GDP deflator (*GDPLP*):

$$NWAGEP = NWAGER * GDPLP.$$

The real wage (*NWAGER*) is defined as a behavioral function, dependent on real GDP (*NGDPR*) and on previous year real salary (*previous(NWAGER)*):

$$NWAGER = \exp(nwager\ koef1 + nwager\ koef2 * \ln(NGDPR) + nwager\ koef3 * \ln(previous(NWAGER))).$$

Nominal consumption (*NPCNL*) is a real variable (*NPCNR*), determined by a behavioral function, multiplied to the consumer price index (*NPCNP*):

$$NPCNL = NPCNR * NPCNP.$$

Private investment is determined as the difference between total (*NTINVL*) and government (*NGINVL*) investment:

$$NPINVL = NTINVL - NGINVL.$$

Gross corporate income (*NYBSL*) is compound of total investments (*NTINVL*), total consumption (*NCONL*) and export of goods and services (*XGNFSL*):

$$NYBSL = NTINVL + NCONL + XGNFSL.$$

Total nominal profit (*NPRFTL*) is calculated as the difference between gross domestic product (*NGDPL*) and indirect taxes (*NGTIL*), subsidies (*NGSTL*) (entering with a negative sign), nontax incomes of the government (*NGNTL*), net income of population (*NYHSL*), payments in social fund ($0.3 * NPWSL$):

$$NPRFTL = NGDPL - NGTIL + NGSTL - NGNTL - NYHSL - 0.3 * NPWSL.$$

Total real income is calculated as follows:

$$NPRFTR = NPRFTL/GDPLP.$$

National Account.

Summing the sectoral budget constraints side by side gives us the aggregated budget constraint for the economy as a whole:

$$\begin{aligned} &NGTDL - NGSTL + NGYCL + NYHSL + \\ &+ NYBSL - NGCNL - NPCNL + XGNFSL - \\ &- MGNFSL - NTINVL = 0 \end{aligned}$$

This equation shows, that the demand for goods is equal to the supply. Some of the variables included in this equation are described below.

Total nominal investment ($NTINVL$) is defined as:

$$NTINVL = NTINVR * NINVLP.$$

Here we set the investment deflator ($NINVLP$) equal to the GDP deflator ($GDPLP$): $NINVLP = GDPLP$, and total real investment ($NTINVR$) is divided into direct capital investment ($NGFIVR$) and change in reserves ($NDINVR$):

$$NTINVR = NGFIVR + NDINVR.$$

In turn, direct capital investment ($NGFIVR$) depends on real GDP ($NGDPR$), total profit ($NPRFTR$) and real interest rate ($NINTER$) of the previous year:

$$NGFIVR = ngfivr\ koef1 + ngfivr\ koef2(t) * NGDPR.$$

The real interest rate ($NINTER$) is the difference between nominal interest rate ($NINTEL$) and the rate of inflation ($GDPLP\%$):

$$NINTER = NINTEL - GDPLP\%.$$

The change in reserves ($NDINVR$) is described as a residual variable.

The nominal total consumption is the sum of private and government consumption:

$$NCONL = NPCNL + NGCNL.$$

Real total consumption ($NCONR$) is compound of private ($NPCNR$) and government consumption ($NGCNR$):

$$NCONR = NPCNR + NGCNR.$$

Model updatings

The model allows two variations: available model and requirement model. The first variation starts with available resources, and the second starts with needs. Real GDP ($NGDPR$) is determined by a method of final use, i.e. as a sum of consumption ($NCONR$), investment ($NTINVR$) and net export ($XGNFSR - MGNFSR$), in the first case:

$$NGDPR = NCONR + NTINVR + XGNFSR - MGNFSR,$$

and nominal GDP ($NGDPL$) is determined as:

$$NGDPL = NCONL + NTINVL + XGNFSL - MGNFSL.$$

For the second case real GDP is determined by given rates of growth ($NGDPR\%$):

$$\begin{aligned} NGDPR &= seed\ NGDPR; \\ previous(NGDPR) &* (1 + GDPLP\%/100). \end{aligned}$$

All internal price indices (consumer, investment and government expenditure indices) were set equal to the GDP deflator. Then consumption, investment and government expenditure became linearly dependent to GDP. Export is determined by rates of growth, other behavioral functions are presented in exponential form. All behavioral equations

in the model describe interdependences between main macroeconomic variables. Using a time series processor (TSP), these functions were run with the help of the two-stage least square method.

Starting with the general form of behavioral functions stated earlier the values for factors are obtained by using logarithmic dependence between variables. For each equation the coefficient of multiple correlation (R), the Durbin-Watson statistic (D.W.), the significance level of the equation (F-statistics) and the estimation coefficient (t-statistics) were computed.

The values of exogenous variables are provided by historical data, obtained from statistical bodies.

Policy variables are: direct corporate and personal tax rates, indirect tax rate, the prospective level of corporate and personal subsidies.

Besides policy variables, a target variable - the rate of GDP growth $NGDPR\%$ - is used in model. So, real GDP ($NGDPR$) is calculated as:

$$NGDPR = (1 + NGDPR\%) * previous(NGDPR).$$

Based on the model described above, a computer program was elaborated and experimental calculations produced the results in the form of five tables - National Account, Public Sector, Monetary Sector, External Sector and Private Sector.

The accounting data proved the hypothesis about the dynamics change of exogenous and political variables were accepted at the calculations.

References

- [1] P.Cojuhari, A.Barțalkin, L.Batîrmurzaev, M.Diaconov, E.Naval, L.Smolin. Experiența modelării macroeconomice în sistemul Javelin. - A treia Conferință de matematică aplicată și industrială, Oradea (România), Chișinău (Republica Moldova), August, 17-25, 1995.

- [2] E.Naval, M.Diaconova, L.Batirmurzaeva. Macroeconomic model of national economy development. Computer Science Journal of Moldova, vol.3, No.3, 1995, Kishinev.
- [3] M.Diaconova, E.Naval, L.Savenko. Macroeconomic model of national economy development (extended). Computer Science Journal of Moldova, vol.5, No.2, 1997, Kishinev.
- [4] Montaque J. Lord. Model macroeconomic pentru România. August, 1993.
- [5] W.Easterly. A consistency framework for macroeconomic analysis, 1989. The World Bank Working papers.

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