

THE CAUSAL MODEL FOR THE MULTIVARIANT ANALYSIS AND FORECAST OF ECONOMIC DEVELOPMENT

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Abstract. *A long-term causal simulation model (macro from micro) for the multivariate analysis and forecast of economic development was developed. The adequacy of the model increased by modelling not only the final products but also intermediate consumption. Shadow economy was included. The model intentionally omits all the hypotheses (monetarists, Keynesian, theory of equilibrium) which strictly predetermine economy behaviour. The model makes it possible to analyze the influence of prices, under- or overproduction, bank loans on each product, the rates of taxes etc. on the development of all economy and of each manufacturer. Furthermore, this model can help in developing recommendations for the National Bank, government, each manufacturer, importer and exporter. This model has been developed for the Ukrainian economy whose peculiarities were duly accounted for. However, the model can be easily adjusted to study any other country's economy.*

Key words: *systemic model, regulated non-equilibrium, modelling of intermediate consumption product, illegal sector, multivariate analyzes and forecasts*

I. Introduction

The Nobel laureate Paul Krugman (2009) pointed out the inadequacy of the economic models. The main drawbacks of known models, in the author's opinion, are:

1. At present, the most appropriate for multivariate analysis and forecast of economic development are macro models based on the microeconomic mechanisms 'macro from micro' (Cooley, 1995, Tae-Jeong et al., 2010, et al.). However, each author has included only a few mechanisms and factors. For example, in most models, absent are the differentiation of the government sector, financial markets, and households (Khan, Tsoukalas, 2011). In the paper of Baldini et al. (2012), the DSGE model with households, firms, government and banking sectors is proposed, but other sectors are not represented in the model. Thus, a **complete closed system of micro- and macro-economic mechanisms** does not exist in any model.
2. In SNA, all products are aggregated into groups which behave under devaluation and inflation equally: final consumption, intermediate one, export, import. But this

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principle of aggregation is barely used in known models. The GDP (not output) was used as a primary result of production. It is particularly important that there is no macro model that reflects the production of raw materials. Without this it is impossible to reflect accurately the value of all goods and of the income from intermediate goods in the total GDP. Besides, the adoption of an output variable GDP implicitly assumes the effectiveness constancy of any economy.

3. When creating models (DSGE, ACE, ASPEN, etc.), economists incorporated in them their views on the impact on the economy of state, monetary policy, equilibrium, etc. Therefore these models in fact reflect **not only real economy, but mostly economists' views**. All these hypotheses **a priori rigidly predefine the economy behavior**. In the language of the control theory, this means to mix the object and the control system, which makes it impossible to analyse a “pure” economy (as a system with an internal positive feedback it is unsustainable) and the synthesis of a correct control system. All known hypotheses relate to the sphere of economy management and not to economy itself.
4. There are models of both equilibrium and non-equilibrium economies. However, no models in which a constant (not short-term run) deviations from the equilibrium were regulated. There are also no models in which one can turn on or off the traditional macroeconomic hypotheses (SNA balances, influence of money supply according to monetarists or Keynesian, etc.).
5. In foreign trade models, devaluation is identified with the change in prices of exports / imports, while in reality they are three separate factors.
6. The Ukrainian economy has a big shadow production, but there is no model that reflects it.

The author builds a long-term model which can analyse and predict the most common features of economic development quantitatively. In particular, to find the degree of factors influence (under- or overproduction, illegal production, prices, exports, and so on), the limit of loans in which the development will occur without “overheating” which then causes crises. Therefore, it must be free of these disadvantages.

Back in the early 60-ies of the 20th century, von Bertalanffy wrote: “UTS opens new horizons for us, but its compliance with the empirical data still remains scant”. Therefore, the author tried to stay away from theories and to be closer to life. He simulates real-world economic processes which undoubtedly exist in the economy, not forcing them into the Procrustean bed of theories and the macroeconomic hypothesis (*hypothesis non fingo*), which *a priori* rigidly predefine the behavior of the economy. Many of a above has been done in the short model (Vasylenko, 2010), but the present model has a long-term nature.

II. Differences of this model

A. Unlike the known models, in this causal model the behavior of the whole economy is caused by a **more detailed and complete system of basic micro- and macroeconomic mechanisms** (formation of prices, cost, producers' and state incomes, taxes, emission, bank rates, loans, investments, etc.). **The system** has turned out because **all** (not several) **mechanisms are interconnected (all roles (functions) of the same elements in different mechanisms were considered)**.

B. The aggregation of products, of their producers and consumers was made like in the SNA. Then, the groups are behaving equally both under devaluation and inflation. The output (not the GDP) was used as a primary result. The basis for a proper modeling of the relationship among prices, costs and revenues is to simulate not only the goods of final consumption and investment, but also of intermediate consumption (the latter are divided into domestic goods, imports, and bank services).

a) the groups of goods are as follows:

- 1) non-tradable consumer goods and services (index $j = 1$ lower in formulas);
- 2–5) tradable goods of final, intermediate, and investment (without housing) consumption and housing, which are sold domestically ($j = 2, 3, 3_N, 3_H$); Ukrainian builders (3_H) get an advance payment, so they do not take loan for the working capital, so in formula (1) for them the cost of bank services $z_F n_{Fj}$ is absent;
- 6–9) their import ($IM_4, IM_5, IM_{5N}, IM_{5H}$); producers are abroad;
- 10–13) import distribution and retail ($j = 4, 5, 5_N, 5_H$);
- 14–15) exports of consumer and intermediate goods ($j = 2_E, 3_E$);
- 16–17) consumer goods' distribution and retail ($j = 2_D, 2_R$);
- 18) bank services ($j = F$);
- 19) the budget sphere ($j = B$).

Each product, except the 19th, is produced by two companies: private and public. So, the model includes 29 enterprises;

- b) final consumers are state ($i = ST$), households which are divided into 86 groups: 1–28) 28 employees of all 14 types of private ($m = Pr$) and state-owned ($m = St$) enterprises (without foreign producers of imports); 29–56) 28 business owners¹ (sometimes they are combined in one group $i = BG$); 57) pensioners ($i = PN$); 58) public servants ($i = BD$); 59–86) 28 officials-takers from 28 enterprises;
- c) users of intermediate goods are 29 producers of group a) without producers of foreign imports;
- d) consumers of investment goods are 28 enterprises and the state.
- e) consumers of housing are 28 enterprises, 29 employees, 28 officials-takers, and the state.

¹ In Ukraine, the behavior of the director of a state enterprise is similar to the behavior of a business owner.

C. The perfect equilibrium option is put into the model at first when the production of goods is defined as the total demand on it of all customers. The total demand is equal to the sum of the parts of wages, profits and taxes which each consumer allocates from its income in this type of product. But in reality the manufacturer does not know these volumes, so the model provides an adjustable deviation from this ideal, and hence you can predict and analyze the impact of such deviations.

D. In foreign trade, this model takes into account not only the devaluation (which in known models is identified with price changes), but also the other factors: the prices and elasticity of export / import, the domestic prices of all goods.

E. The model includes illegal production by the following ways: in private companies, the shade increases the production of each product, the illegally paid out parts of wages, taxes on all illegal amounts are not paid (increasing net income), material costs are overstated in order to avoid the payment VAT and income tax; in public procurement, prices are overstated; state returns of VAT for fictitious sales both domestically and for export, VAT returns not in time or not fully; officials receive bribes, which reduces the company income. All shadow parameters are variables.

F. Short- and long-term investments, loans, deposits and their implications: emergence of new products at higher prices, technological change, including reducing material and / or labor costs per unit of output, increase in depreciation, loan repayment, etc. were reflected.

G. The possibility to switch on and off the hypothesis of classical dichotomy or of the Keynesian mechanism of neutralization emission by idle resources was provided.

III. Description of the model

This model of economic development is discrete. It was built as the sum of static models successive cycles of reproduction (of economic cycles). Each cycle model is a model of the transition from the previous cycle (index 0 or $t - 1$) to the current (without index) under the influence of exogenous factors; this is the modified model (Vasylenko, 2010; Vasylenko, Bazhenova, 2014). All formulas represent a complete system of fundamental causal relationships among production, consumption, savings, and investment.

Costs, income. The cost of a j -th product was modelled as a sum of conditionally variable (δ_{vj0} – their share) and constant (the last summand) expenses for domestic and imported materials, bank services, wages, contributions to the pension and social insurance funds with the norm σ (being changed due to devaluation and inflation), amortization am_j , and taxes (value added t_{DWj} , natural resources t_{Rj} , excise and import duties t_{IM} and others taxes t_{INj}):

$$S_{SMj} = \delta_{vj0} \cdot K_{SMj} \cdot (z_3 \cdot n_{3j} + z_5 \cdot n_{5j} + z_F \cdot n_{Fj} + w_j \cdot p_j) + K_{Lj} \cdot [w_{Pj} \cdot p_j \cdot \theta_{Vj} / (1 - \tau_V) \cdot (\tau_V + \sigma) + t_{IMj} \cdot I + t_{INj} + t_{Rj}] + T_{VATj} + T_{Dj} + z_{js} \cdot K_{SMj} + (AM_{j0} + (1 - \delta_{vj0}) \cdot K_{Lj0}) \cdot (z_3 \cdot n_{3j} + z_5 \cdot n_{5j} + z_F \cdot n_{Fj} + w_j \cdot p_j), j = 1, 2, 2_D, 2_R, 3, 3_H, 3_N, 4, 5_H, 5_N, 5, F, B \quad (1)$$

where K_{Lj} , K_{SMj} are legal and complete (with shadow) quantities of j -th goods; I is the devaluation index, $z_3, n_{3j}, z_5, n_{5j}, z_F, n_{Fj}, w_j, p_j$ are the prices and amounts of domestic and imported materials, bank services and person-years required for a j -th product unit (after the investment amounts decrease), w_{j0} is average annual salary, $\theta_{Vj} < 1$ – the legal part of the salary; θ_j – exceeding the total production of its legal part; $z_{js} = z_{j0} \cdot I$ – the import price at the border; this term is only for the imports distribution; AM_{j0} is the depreciation on the j -th item.

Taxes were combined into six groups according to the homogeneous behavior of their bases: the payroll tax with the rate of τ_{I^s} , the corporate income tax T_{Dj} with the rate of τ_D , the value-added tax T_{VATj} at the rate of τ_{DW} (for Ukrainian banks is absent, what, in my opinion, is wrong both methodologically and as regards their profitability), VAT, excise and import duties on import unit t_{IMj} , fee for the natural resources use t_{Rj} , other taxes t_{INj} ; all – on a unit of goods.

Specific costs (which will then be multiplied by the total amount of goods (legal and illegal) are equal to:

$$s_{SMj} = S_{SMj} / K_{SMj} = z_{js} + [\delta_{vj} + (1 - \delta_{vj}) / I_{KPrSMj} / \theta_{j0}] \cdot (z_3 \cdot n_{3j} + z_5 \cdot n_{5j} + z_F \cdot n_{Fj} + w_{Pj} \cdot p_j) + [w_{Pj} \cdot p_j \cdot \theta_{Vj} / (1 - \tau_V) \cdot (\tau_V + \sigma) + t_{IMj} \cdot I + t_{INj} + t_{Rj}] / \theta_j + (T_{VATLj} + T_{DLj}) / K_{SMj} + am_j / (I_{KPrSMj} \cdot \theta_{j0}). \quad (2)$$

The following expenses are legalized:

$$S_{Lj} = K_{Lj} \cdot \{\delta_{vj} \cdot [(z_3 \cdot n_{3j} + z_5 \cdot n_{5j}) \cdot \theta_{Oj} + z_F \cdot n_{Fj} + w_j \cdot p_j \cdot \theta_{Vj}]\} + K_{Lj0} \cdot (1 - \delta_{vj}) \cdot [(z_3 \cdot n_{3j} + z_5 \cdot n_{5j}) \cdot \theta_{Oj} + z_F \cdot n_{Fj} + w_j \cdot p_j \cdot \theta_{Vj}] + K_{Lj} \cdot [w_j \cdot p_j \cdot \theta_{Vj} \cdot (\tau_V + \sigma) / (1 - \tau_V) + t_{IMj} \cdot I + t_{INj} + t_{Rj} + t_{VATLj} + t_{DLj}] + z_{js} \cdot \theta_{Oj} + AM_{j0}, \quad (3)$$

where $\theta_{Oj} > 1$ is the oversize material costs in order to reduce the income tax and VAT.

The legalized part of the net profit (without depreciation) with the tax paid out of it is equal to:

$$D_{Lj} = K_{Lj} \cdot z_j - (S_{Lj} - K_{Lj} \cdot t_{DLj}) = K_{Lj} \cdot z_j - S_{Lj} + T_{DLj}. \quad (4)$$

The income tax (if positive) is equal to:

$$T_{DLj} = IF(D_{Lj} > 0; \tau_D \cdot D_{Lj}; 0). \quad (5)$$

The legalized value added is equal to:

$$DW_{Lj} = D_{Lj} + B, \quad (6)$$

where $B = \{w_j \cdot p_j \cdot \theta_{Vj} \cdot [I + (\tau_V + \sigma) / (1 - \tau_V)] + \delta_{IN} \cdot t_{INj}\} \cdot K_{Lj} + AM_{j0}$; δ_{IN} – the part of other taxes, which is included in the value added.

Per unit values are equal to:

$$d_{Lj} = z_j - s_{Lj} + t_{DLj}; \quad (7)$$

$$dw_{Lj} = d_{Lj} + w_j \cdot p_j \cdot \theta_{Vj} \cdot [(1 + (\tau_V + \sigma)/(1 - \tau_V))] + \delta_{IN} \cdot t_{INj} + am_j / I_{KLj}. \quad (8)$$

The legalized, aka real, VAT is:

$$T_{DWj} = \tau_{DW} \cdot (D_{Lj} + B). \quad (9)$$

Solving the equations system (1–9):

$$D_{Lj} = K_{Lj} \cdot (z_j - z_{jsj} - [\delta_{vj} + (1 - \delta_{vj}) / I_{KLj}] \cdot [(z_3 \cdot n_{3j} + z_5 \cdot n_{5j}) \cdot \theta_{Oj} + z_F \cdot n_{Fj} + w_j \cdot p_j \cdot \theta_{Vj}] - w_j \cdot p_j \cdot \theta_{Vj} \cdot [(\tau_V + \sigma) / (1 - \tau_V) \cdot (1 + \tau_{DW}) + \tau_{DW}] - t_{Imj} \cdot I - t_{INj} - t_{Rj} - \delta_{IN} \cdot t_{INj} \cdot \tau_{DW} - am_j \cdot (1 + \tau_{DW}) / I_{KLj} / (\tau_{DW} + 1). \quad (10)$$

The other unknowns are determined from the equations (1–9).

The actual gross profit (including depreciation), which remains at the enterprise owner (without tax on it), includes also the illegal part in the amount of the fictitious material costs and two additions: 1) D_{Zj} from overpricing public procurement prices in θ_{Zj} times (only for goods $j=1, 2, 3_H, 3_N, 4, 5_H, 5_N$) and 2) d_{VATj} from the fictitious return of the part θ_{PDVj} of VAT except bribes to officials h_{ij} amounting to δ_{Hj} . If there is a production surplus in I_{rj} times (at $I_{rj} < 1$ – underproduction), then the costs of all unsold products are going at a loss:

$$D_{SMj} = (z_j - s_{SMj} \cdot IF(I_{rj} > 1; I_{rj}; 1) - h_{Tj} - h_{Mj} + d_{VATj} - dw_{Lj0} \cdot \tau_{DW} \cdot \theta_{VATj0}) \cdot K_{SMj} + am_j \cdot K_{Lj} + D_{Zj}, \quad (11)$$

$$h_{Tj} = \delta_{Hj} \cdot (0.059 \cdot (\theta_j - 1) + 0.056 \cdot (1 - \theta_{Vj})) \cdot z_j, \quad (12)$$

where I_{rj} is the degree of overproduction; 0.059 and 0.056 are the average coefficients of bribes in Ukraine; $s_{SMj} = S_{SMj} / K_{SMj}$.

Bribes for fictitious material are equal to:

$$h_{Mj} = \delta_{Hj} \cdot (z_3 \cdot n_{3j} + z_5 \cdot n_{5j} + z_{js}) \cdot (\theta_{Oj} - 1) \cdot (\tau_D + \tau_{DW}). \quad (13)$$

The addition from fictitious VAT refund (minus bribes δ_{Hj}) equals to:

$$d_{VATj} = IF(t_{DWj} < 0; 0; IF(\theta_{VATj} < 0; 0; (\theta_{VATj0} - \delta_{Hj0} \cdot (1 + \theta_{VATj}))) \cdot t_{DWj0}, \quad (14)$$

bribe:

$$h_{VATj0} = IF(t_{DWj0} < 0; 0; IF(\theta_{VATj0} < 0; 0; \delta_{Hj0} \cdot (1 + \theta_{VATj})) \cdot t_{DWj0}. \quad (15)$$

The addition from overpricing of public procurement prices (net of bribes δ_j):

$$D_{Zj} = (1 - \delta_j) \cdot \delta_{Prj} \cdot K_{SMDUj} \cdot (\theta_{Zj} - 1) \cdot z_j, \quad (16)$$

where δ_{Prj} is the share of private enterprises in all release of the goods j . Here, it is assumed that the percentage of public procurement in private and public enterprises in relation to their production volume is the same. The distributors (not the manufacturers) get this addition.

Of course, all the shadow supplements are not taxed.

The actual VA is equal to:

$$DW_{SMj} = \{D_{SMj} + K_j [w_j \cdot p_j \cdot (\theta_j + \theta_{Vj} \cdot \sigma_j) / (1 - \tau_V) + am_j + \delta_{IN} \cdot t_{INjj}] \} \cdot \theta_{VATj}. \quad (17)$$

Here, there is a vicious circle: the indices I_{Kj} , I_{DWj} , I_{Wj} are defined below using the variable s_j and others, the determination of which requires these indices, i.e. the system of equations is recursive. In the model, there are many such recurrent equation systems. Some of them include logic equations such as “if – then”, for example, (5), i.e. they are strongly nonlinear. They are solved iteratively: in the first step, you substitute any values of all unknown variables in the equations and the first results are defined; on the second step, you substitute these first results in the equations and their second approximations are defined, and so on. The author did not investigate the convergence of the recurrent procedure, but already in the 5th–6th steps the error did not exceed 0.001%. After similar iterations for other goods, it is necessary to return to the product j . Usually, three–six such returns are enough.

Consumption, accumulation, and production

The volume of exports depends on the demand of the external world, i.e. it depends on the price of good 2_E or 3_E in a foreign currency $z_j^{\$}$:

$$K_j = a_j \cdot (z_j^{\$})^{b_j}, j = 2_E, 3_E, \quad (18)$$

where a_j is a constant, and $b_j < 0$ is the price elasticity.

The output of other goods according to the accepted principle of equilibrium is determined by the amount of their final and intermediate consumption C_{SMji} and investment INV_{mij} :

$$W_{SMj0} = \Sigma C_{Vjtu} + C_{PNSj} + C_{Dmij} \quad j = 1, 2_R, 4, B; m = Pr, St, \quad (19)$$

$$W_{SMj0} = \Sigma INV_{mij} \quad j = 3_H, 3_N, 5_H, 5_N, \quad (20)$$

which, in turn, are determined by the relevant consumers' incomes (see (22–31)).

Each employee allocates a portion δ_C of his salary for final consumption and from it δ_{Cj} for the j -th commodity. We have assumed that these parts are the same for all. Of course, $\Sigma \delta_{Cj} = 1$ ($j = 1, 2_R, 4$). In addition, he uses part δ_{Sbt} of his past savings, interest on deposit IND_{it} , takes out new loans Kr_t and pays on old ones with the interest rate Ps . In the t -th cycle, he saves:

$$Sb_{NRt} = V_{SMt} \cdot (1 - \delta_C) \quad (21)$$

and consumes (the index $i = NR$ corresponds to all employees):

$$\begin{aligned} C_{Vit} = & V_{SMt} \cdot \delta_C + \delta_{Sbt} \cdot (Sb_{NR0} + Sb_{NR1} + \dots + Sb_{NRt-1}) + Krc1_{NRt} + Krc3_{NRt} + \\ & Kr10_{NRt} + IND_{it} - Krc1_{NRt-1} \cdot (1 + Ps1_{NRt-1}) - [Krc3_{NRt-1} \cdot (1 + Ps3_{NRt-1}) + \\ & Krc3_{NRt-2} \cdot (1 + Ps3_{NRt-2}) + Krc3_{NRt-3} \cdot (1 + Ps3_{NRt-3})] \cdot 0,3(3) - \\ & [Kr10_{NRt} \cdot (1 + Ps10_{NRt}) + Kr10_{NRt-1} \cdot (1 + Ps10_{NRt-1}) + \dots + \\ & Kr10_{NRt-10} \cdot (1 + Ps10_{NRt-10})] \cdot 0,1 \end{aligned} \quad (22)$$

He spends on the j -th item:

$$C_{Vj} = C_{V3} \cdot \delta_{Cij}. \quad (23)$$

We have assumed that he does not do investments, does not buy housing from the salary. To buy a home, an employee takes a portion of his past savings δ_{Ji} and / or a mortgage by an average of 10 years:

$$C_{VJmi} = Sb_{i-1} \cdot \delta_{Ji} + Kr10_{NRi} \quad i \in I. \quad (24)$$

The retirees consume:

$$C_{PNSj} = PNS \cdot \delta_{Cj}, \quad j = 1, 2, R, 4, \quad (25)$$

$$\text{where } PNS = PNS_0 \cdot [1 + b_{PNS}(I_{sz} - 1)]. \quad (26)$$

The company pays firstly on loans Kr_{mt} and receives the interest Ps_{mi} on deposits. Thereafter, in the t -th cycle, it has:

$$\begin{aligned} Z_{mti} = & D_{SMmi3} + \delta_{Sbt} \cdot (Sb_{mi0} + Sb_{mi1} + \dots + Sb_{mit-1}) + Kr3_{mt} + Kr10_{mt} + \\ & IND_{mit} - Kr1_{mit-1} \cdot (1 + Ps1_{mit-1}) - [Kr3_{mit-1} \cdot (1 + Ps3_{mit-1}) + \\ & Kr3_{mit-2} \cdot (1 + Ps3_{mit-2}) + Kr3_{mit-3} \cdot (1 + Ps3_{mit-3})] \cdot 0.3(3) - [Kr10_{mit} \cdot (1 + Ps10_{mit}) + \\ & Kr10_{mit-1} \cdot (1 + Ps10_{mit-1}) + \dots + Kr10_{mit-10} \cdot (1 + Ps10_{mit-10})] \cdot 0.1, \quad m = Pr, St. \quad (27) \end{aligned}$$

The owner of the i -th private or a director of a state enterprise allocate a portion of the $1 - \delta_{Sb}$ remainder of his income C_{Dmi} for savings, part δ_{CBg} for the final consumption, and from it δ_{CBgj} for the j -th good ($\sum \delta_{CBgj} = 1, j = 1, 2, R, 4$), part δ_{INVj} for residential investment ($j = J$) and the development of the enterprise ($j = N$). A private owner, in addition, removes $1 - \delta_{Gr}$ abroad:

$$Gr_i = (1 - \delta_{Grj}) \cdot Z_{Pri}, \quad (28)$$

$$Sb_{mi} = (1 - \delta_{Sbm}) \cdot Z_{mi}, \quad (29)$$

$$C_{Dmij} = \delta_{CBgm} \cdot \delta_{CBgmj} \cdot Z_{mi}, \quad j = 1, 2, R, 4, \quad (30)$$

$$INV_{mij} = \delta_{INVBgm} \cdot \delta_{INVBgmj} \cdot Z_{mi}, \quad j = H, N, i \in I, m = Pr, St. \quad (31)$$

The officials' bribes from the i -th company:

$$D_{CHPri} = (h_{TPri} + h_{MPri} + h_{VATPri}) \cdot K_{Pri0} \cdot I_{KPri} + \delta_i \cdot D_{ZPri}, \quad (32)$$

where $h_{TPri}, h_{MPri}, h_{VATPri}, D_{ZPri}$ are determined by formulas (12–16). Bribes on public procurement exist only for goods $j=1, 2, 3, 4, 5, N$.

In SOEs, takers “earn” only on VAT and state purchases:

$$D_{CHSTi} = h_{VATSTi} \cdot K_{STi0} \cdot I_{KSTi} + \delta_i \cdot D_{ZSTi}. \quad (32)$$

Officials only from bribes (their salary is included in V_{SMB}) consume and invest like legal owners, only they a) do not take loans and do not return them, and b) do not receive assistance from the state:

$$Gr_{CHmi} = (1 - \delta_{GrCHmj}) \cdot D_{CHmi}, \quad (33)$$

$$Sb_{CHmi} = (1 - \delta_{SbCHm}) \cdot D_{CHmi}, \quad (34)$$

$$C_{DCHmij} = \delta_{CBgCHm} \cdot \delta_{CBgCHmj} \cdot D_{CHmi}, j = 1, 2, R, 4, \quad (35)$$

$$INV_{CHmij} = \delta_{INVBgCHm} \cdot \delta_{INVBgCHmj} \cdot D_{CHmi}, j = H, N, i \in I, m = Pr, St. \quad (36)$$

All these consumers (23–36) use j -th goods in the amount of:

$$C_j = C_{PNSj} + C_{Vj} + \sum_{m=Pr, St} \sum_{i \in I} (C_{Dmij} + C_{DCHmij}), j = 1, 2, R, 4. \quad (37)$$

Therefore, it is necessary to produce them so much:

$$K_{Pj} = C_j / z_j, j = 1, 2, R, 4. \quad (38)$$

Consumers (24) and others are investing a total of j -th commodity:

$$INV_{Pj} = \sum_{m=Pr, St} \sum_{i \in I} (C_{Vjmi} + INV_{mij} + INV_{CHmij}), j = H, N, \quad (39)$$

where the first summand is only for housing $j = H$.

The share of domestic goods δ_{INVDj} in all investments is determined by the existing level of technology. We took it for all businesses equally. Thus, the number of units of domestic investment is

$$K_{P3j} = INV_j / (z_{3j} + z_{5j} \cdot (1 / \delta_{INVDj} - 1)) \quad (40)$$

and import

$$K_{P5j} = K_{3j} \cdot (1 / \delta_{INVDj} - 1), j = H, N. \quad (41)$$

The government sector from the budget B (budget and emission were described in Vasylenko and Bazhenova (2014)) provides the services of public administration, health, education, science, etc., as well as consumes and invests:

$$C_{Bj} = \delta_{CBgB} \cdot \delta_{CBgBj} \cdot B, j = 1, 2, R, 4, \quad (42)$$

$$INV_{jB} = \delta_{INVB} \cdot \delta_{INVBj} \cdot B, j = H, N. \quad (43)$$

But it buys them at excessive prices so much:

$$K_{jB} = C_j / (\theta_{Zj} \cdot z_j), j = 1, 2, R, 4 \quad (44)$$

$$K_{3jB} = INV_j / (\theta_{Z3j} \cdot z_{3j} + \theta_{Z5j} \cdot z_{5j} \cdot (1 / \delta_{INVH} - 1)), j = H, N, \quad (45)$$

$$K_{5jB} = K_{3jB} \cdot (1 / \delta_{INVH} - 1), j = H, N. \quad (46)$$

To simplify the model, the author assumes that part of foreign investment, which is equal to net imports, is available only to private enterprises in the real sector and only for imports of investment (part δ_{5NFI}) and consumer goods ($1 - \delta_{5NFI}$). Then we get the following additives:

$$\Delta K_4 = ChIM \cdot (1 - \delta_{5NFI}) / z_4, \quad (47)$$

$$\Delta K_{5N} = ChIM \cdot \delta_{5NFI} / z_{5N}. \quad (48)$$

Thus, private and public enterprises together should produce the total number of the j -th good:

$$K_j = K_{Pj} + K_{jB}, j = 1, 2, R, \quad (49)$$

$$K_4 = K_{P4} + K_{4B0} + \Delta K_4, \quad (50)$$

$$K_j = K_{Pj} + K_{jB0} + \Delta K_{jB}, j = 3_H, 3_N, \quad (51)$$

$$K_{5H} = K_{P5H} + K_{5HB0} + \Delta K_{5HB}, \quad (52)$$

$$K_{5N} = K_{P5N} + K_{5NB0} + \Delta K_{5NB} + \Delta K_{5N}. \quad (53)$$

The share of a state-owned enterprise in the production of the j -th product δ_{STj} usually does not change but is changed after the processes of privatization or nationalization:

$$K_{STj} = \delta_{STj} \cdot K_j, \quad (54)$$

$$K_{PrSMj} = K_j - K_{STj}, j = 1, 2, 4, 3_H, 3_N, 5_H, 5_N. \quad (55)$$

The number of intermediate goods is defined ideally: by the total needs of all producers in material and financial resources, including the producers of intermediate goods themselves:

$$K_3 = \sum_{j \in J} K_j \cdot n_{3j} = K_3 \cdot n_{33} + K_5 \cdot n_{35} + K_F \cdot n_{3F} + \sum_{j \neq 3,5,F} K_j \cdot n_{3j}, \quad (56)$$

$$K_5 = \sum_{j \in J} K_j \cdot n_{5j} = K_3 \cdot n_{53} + K_5 \cdot n_{55} + K_F \cdot n_{5F} + \sum_{j \neq 3,5,F} K_j \cdot n_{5j}, \quad (57)$$

$$K_F = \sum_{j \in J} K_j \cdot n_{Fj} = K_3 \cdot n_{F3} + K_5 \cdot n_{F5} + K_F \cdot n_{FF} + \sum_{j \neq 3,5,F} K_j \cdot n_{Fj}. \quad (58)$$

Let us denote $S_3 = \sum_{j \neq 3,5,F} K_j \cdot n_{3j}$, $S_5 = \sum_{j \neq 3,5,F} K_j \cdot n_{5j}$, $S_F = \sum_{j \neq 3,5,F} K_j \cdot n_{Fj}$; the sums are taken over all j , except 3, 5, and F . Since the variables K_3 , K_5 , and K_F are on both the left and the right-hand sides of the equations, we solve the system (58–60):

$$K_3 = -(S_3 \cdot (1 - n_{55} - n_{FF} + n_{55} \cdot n_{FF} - n_{5F} \cdot n_{F5}) + S_5 \cdot (n_{35} \cdot (1 - n_{FF}) + n_{3F} \cdot n_{F5}) + S_F \cdot (n_{3F} \cdot (1 - n_{55}) + n_{35} \cdot n_{5F})) / H \quad (59)$$

$$K_5 = -(S_5 \cdot (1 - n_{33} - n_{FF} \cdot (1 - n_{33}) - n_{3F} \cdot n_{F3}) + S_3 \cdot (n_{53} \cdot (1 - n_{FF}) + n_{F3} \cdot n_{5F}) + S_F \cdot (n_{5F} \cdot (1 - n_{33}) + n_{53} \cdot n_{3F})) / H \quad (60)$$

$$K_F = -(S_F \cdot (1 - n_{33} - n_{55} \cdot (1 - n_{33}) - n_{35} \cdot n_{53}) + S_3 \cdot (n_{F3} \cdot (1 - n_{55}) + n_{53} \cdot n_{F5}) + S_5 \cdot (n_{F5} \cdot (1 - n_{33}) + n_{35} \cdot n_{F3})) / H \quad (61)$$

$$H = n_{33} \cdot (1 - n_{55} - n_{FF} + n_{55} \cdot n_{FF}) + n_{55} \cdot (1 - n_{FF}) + n_{FF} + n_{3F} \cdot n_{F3} \cdot (1 - n_{55}) + n_{5F} \cdot n_{F5} \cdot (1 - n_{33}) + n_{35} \cdot n_{53} \cdot (1 - n_{FF}) + n_{35} \cdot n_{F3} \cdot n_{5F} + n_{53} \cdot n_{3F} \cdot n_{F5} - 1. \quad (62)$$

Now, we can determine the levels of shade:

$$\theta_j = K_{SMj} / K_j, j = 1, 2, 3, 3_H, 3_N, 4, 5, 5_H, 5_N, 2_D, 2_R, F. \quad (63)$$

To determine the K_j , we used the yet unknown θ_j , so, if in the system of equations (39–65) the number of unknowns equals the number of equations, it can be solved for θ_j . If equations are less, the system is recurrent. However, in both cases, for solving, one can apply an iterative algorithm of the method of successive approximations.

From this, we propose for the lazy: even if the method of solution of any system of equations is known but is hard enough, you can not spend time on it, but it is easy to

implement this iterative algorithm on the computer and get a solution quickly and without errors, which is often encountered in the “manual” solution in the “quadrature”. Even for experienced mathematicians it may be easier to use iteration than 1) to identify the suitability of an appropriate method for this problem (i.e., the test scope) and 2) to use it. If the method is not yet developed, the more so. The convergence process is also easier to identify than to prove.

Of course, the above described version is an ideal in which there is no place for over- or underproduction. However, in reality, a manufacturer does not know this ideal, so the model has an adjustable deviation from this ideal and hence the ability to analyze the results of such deviations. Suppose a company manufactured or imported the **consumption or investment** product in I_{rj} ($j = 1, 2_R, 4, 3_N, 5_N$) times greater than the equilibrium volume. Then it made the full costs of production, import, and distribution of this extra volume. So, there will increase: 1) the salary of employees, 2) the sale of goods for intermediate consumption $5, 3$ and F , the wages and profits in them, but the extra items will not be sold; hence the owners will have losses by the amount of salary increments and material costs, so their purchase of consumer and investment goods will decline. However, employees will buy more consumer goods, thus, incomes in their production will increase also in the production of intermediate goods $3, 5, F$, and so on.

If a company manufactures or imports the **intermediate product** in I_{rj} ($j=3, 5$) times greater than the equilibrium volume (banking services cannot be redundant), there will increase: 1) the salary of employees, 2) the sale of intermediate goods $5, 3$ and F , the wages and profits from them. But the extra items will not be sold; hence, owners will have losses more than salary increase, so the purchase of consumer and investment goods will decline. To this, there will be added changes of income from consumer and investment goods, etc.

Changing the technology, new production

It is assumed that investment for one year reduces specific material or/and labor costs the next year:

$$n_{mjit+1} = n_{jit} / (1 + I_{Fmji} p_{Mit} E_{it}), \quad m = Pr, ST; \quad j = 3, 5, F, \quad (64)$$

where p_{Mit} is part for reducing material costs, E_{it} is the efficiency of investment (in which taken into account is the share of active means in all major means).

Investments in six years create a new production after three years with more prices.

Trivial equations like $D_j = K_j d_j$ are not given.

Thus, a closed full system of causal connections between production (wages, bank services, taxes, etc. are recorded in the cost of production), consumption and accumulation, and investment is obtained.

IV. Capabilities of the model

Thanks to these tools, this simulation model of economic development, including the impact of devaluation and inflation, “works” for any trade balance, for non-equilibrium, and is more appropriate for the real economy. What does indicate the adequacy of this model?

- The dynamics of all economic indicators in various cases is logical;
- traditional hypotheses about the impact on the state’s economy, about monetary policy, rational agents, balance, etc. are particular cases within the model;
- the model was constructed and defined on the Ukrainian data for 2006–2007; the results of calculation for 2008–2013 have coincided with the actual indicators of the Ukraine’s economy by 93–99%.

The model allows optimizing (the algorithm of the multi-criteria compromise (Vasylenko, 1983) strategies of each of the 28 manufacturers or of the state using the major (maximum added value) and supplementary criteria (maximum gross profit, market expansion, foreign exchange earnings, trade balance which in the model is identified with the payment balance, the stability of hryvnia (for exporters and NBU), for employees – that of wages; for all economy – GDP and GDP per unit of intermediate consumption, budget revenue, and many others).

You can set any target function of one or all of the agents to analyze any known hypothesis about their behavior, as well as hypotheses about the impact on the economy of state, monetary policy, equilibrium, etc.

All parameters of the model are variable in each cycle. This provides a possibility to explore not just the interrelations but also their characters, and to determine the borders to which these characters are preserved.

The model predicts and analyses the dynamics under inflation and devaluation of the following nominal and real legal and full (with shadow parts) indices for each goods and in the whole country: cost, gross and net profit, and the amount of wages, value added, output, GDP, the share of wages in the cost, rising unemployment, pensions, tax and social insurance revenues, salaries of public sector employees, emissions, foreign exchange earnings from exports of goods of final and intermediate consumption, the physical volume of exports, the volume, expenditure and currency to import goods of the final investment and intermediate consumption, trade balance, the structure of exports and imports, the share of imports in the final and intermediate consumption, prices, GDP production per unit of intermediate consumption, changes of the contributions of individual goods to the country’s GDP, and so on.

You can change the price, salary, the level and cost structure (the share of wages, import, loan for working capital, etc.) for each product, the level of de- or revaluation, in- and deflation, rate loan, share of conditionally fixed costs, tax and deductions rate;

exchange rate, the degree of influence of rate loan, excess emission, a shortage of working capital on the production; the distribution of excess emission between the social sphere, “short” investments in the production of various goods and banks, the import substitution by domestic products and contrary and so on.

The model can forecast for any year (now for 2021).

The model can be modified for any country. As you see, the Ukrainian economy peculiarities were duly accounted for in this model. However, the model can be easily adjusted to study any other country’s economy.

Y. Forecast and analysis of factors of Ukraine’s development

2014. Option 1. Extrapolation of the data of 2006–2013 and January–May 2014 was used as exogenous parameters and as the inputs. Earlier this year, in the Donetsk and Lugansk regions, the industrial production fell, and this generally refers to the goods of intermediate consumption; therefore, we can assume that in 2014 their underproduction in the whole Ukraine was by 5%. We assume for other goods that overproduction decreased to 4% and exports fell by 5.2% like in the first half-year.

At the first glance, the forecast is equal to the minimum version of the consensus-forecast of the Economy Ministry for 2014 (Ukraine, 2014). However, here the model showed to be systemic in nature – the mutual connections of all exogenous parameters, input data and output indicators together. Reducing the legal real GDP by 2.2% took place against a strong fall of legal exports by 5.2%, while the average version of the consensus-forecast gives the GDP decline by 2.6% while reducing exports by only 4.1%. In fact, if legal exports will be reduced as in the consensus-forecast, the legal GDP will decrease only by 1.5%.

Option 2. More probable is the decline in exports by 7–10%. Then the GDP will decrease by 5.3–7.4%. The model shows not only the legal but also the illegal sectors. We accepted the shadow level of 41% as calculated (Vasylenko, 2008). The complete volumes and their real changes are much larger than legal². In 2013, the full GDP grew by 0.16%, but the legal one decreased by 1.8%.

The full forecast includes such indices which fundamentally are not in the legal sector: the amount of bribes, the export of currency abroad, and others. At a fall of exports by 7.5%, the full real GDP will decline by 5.4%, the total gross capital formation by 38%, the total actual final consumption (at the expense of the predominant falling capital) only 7.8%, the legal budget revenues (state, not consolidated) increase to 348.55 billion UAH, which comprise 22.3% of GDP, and full – up to 367.57 billion UAH (17%).

² According to official data, in 1990–2013 Ukraine’s GDP fell by 30%. But this is only that the legal part of the GDP has decreased. Vasylenko (2008) showed that the total GDP rose to the level of 1990 already by 2005.

The legal and the full import will decrease by 22%; due to this, the legal balance will increase to + \$0.6 billion (full one – up to \$28.8 billion).

The sum of real legal wages decreases by 6% (i.e. at a constant average salary the unemployment increases by 6% or at a lower average salary it will be less), the full wages' volume (with shadow) – by 7.1%, the legal gross income – by 7.9%, full – by 4.4% (because of more falling salary the profits may be higher and vice versa), the legal output is reduced by 15.3%, the full – by 13.2%, the economic efficiency (GDP per unit of intermediate consumption) increases by 11.3%. Bribes nominally are reduced from 27.2 to 26.5 billion UAH and their real purchasing power – by 16.3%; the export of currency decreases from \$6.6 to \$4.8 billion. Imbalance between the consumed and the produced GDP increases from 13.9 to 32.6 billion.

This option³ is the most likely. It will be used as the basis for comparison with other options and predictions for 2015⁴.

Option 3. Let underproduction of goods of intermediate consumption will be not 5% but 3%. The forecast has much improved: the legal real GDP will decrease by only 3.2% (full – by 2.5%), the legal amount of wages by 4.6% (full – by 5.5%), and gross income by 4.6% (1.8%).

The legal foreign trade balance is reduced to \$0.9 billion, but the full one increases to + \$26.8 bn. As you see, *the policy of the National Bank according to the official trade balance must be one (throw currency in the market), but according to the actual balance – the opposite. Thus, the National Bank and the government should base their policy on the full data (including the illegal sector).*

Option 4. On the model, it has been determined that exports play a major role for the Ukrainian economy, and the price more than the volume. Thus, in the last version, if we increase the price index by 10%, the real legal GDP will grow by 4.7%, GDP in exports of consumer goods 4 times, and intermediate goods 5.8 times. If we increase the physical volume by 10% without changing prices, the GDP will grow only by 1.6%, the GDP in exports of consumer goods 3.1 and intermediate goods 4.1 times. *Thus, we recommend: to keep the highest possible prices in foreign currency for any devaluation, but not to reduce them automatically as the standard theory of international trade says⁵.*

³ Because of the limited volume, a table with data is not imagine.

⁴ Now the State Statistics Committee reported that in January–November 2014, exports of goods decreased by 11.3%. If we take the annual decline of exports at this level, the model gives a forecast GDP – 7.37%, which is well consistent with the actual 7.5%. If it turns out that the fall in exports is more, the model will have a more exact figure.

⁵ Vasylenko (2010) has showed that if the export price in foreign currency decreases at devaluation according to the standard theory of international trade, sales grow, revenues from inelastic goods are reduced, from elastic ones are increasing but disadvantageous to exporters – due to increased volumes despite the falling prices. This leads to a drop in their income (standard theory hides it).

Option 6. If in the base case the overproduction of consumer and investment goods is zero, the value added increases by 5.4–18.7% and GDP by 2.2%.

Therefore, we have recommended that manufacturers will decrease in 2014 the production of consumer goods by 6% in physical terms, of non-tradable goods – by 8%, of intermediate – by 24%, investment (without housing) – by 45%, housing – by 35%, consumer goods imports – by 33%, housing imports – by 35%, intermediate imports – by 20%, investment imports – by 18%. There will be no demand for more goods.

Option 7. Domestic prices are very strong deterrent factors. By reducing them in version 2 only by 5% we get a real legal GDP drop only by 1.73% instead of 5.4%. The full GDP will decrease by 0.77%, the amount of legal wages by 3.1% (full – by 4.1), the legal gross income by 9.5% (full – by 4.4%).

Therefore, the Ukrainian government should keep prices by any means, even by non-market ones. This will improve the financial situation of all producers, consumers, and the country as a whole. Only the importers' profit will decrease.

2015. Option 1. Suppose that exports and imports will be the same as in the base case of 2014, but import prices in dollars will increase by 15%. The indices of domestic prices will be slightly lower. The underproduction of intermediate goods remains to be 5%; the overproduction of other goods will be 3%.

The dynamics of full indicators will be stronger than of the legal ones. The full real GDP will decline by 3.5% (legal – by 0.76%) and will be 35% more of the legal one; gross income will decline by 6.8% (legal – by 0.8%) and will exceed the legal one by 71%, the sum of salary – by 0.4% (the legal one increases by 0.76%), gross capital formation – by 0.8%, bribes – by 4.5%, export of currency – by 3%, and the real final consumption will increase by 1.7%.

Option 2. If the exports of goods and services will increase by 5%, and only in quantity, the forecast will be much better: the legal GDP will grow by 1.3%, the full GDP will reduce only by 1.35%, the legal balance will increase to + \$3.9 bn, the full one – up to \$6.7 bn. If prices will increase by the same 5%, the forecast is even better: the legal GDP will grow by 2.9% and the full one by 0.7%.

Option 3. Assume that the overproduction of all goods and excessive imports of consumer goods fall to zero. Then the real legal GDP in option 1 will decrease only by 0.36% (full – by 3.3%), the gross income – by 0.9% (5.7%), the total gross capital formation – by 1.7%, final consumption – by 0.2%, the legal amount of wages – by 0.26% (full – by 0.9%). Nominal bribes will be reduced to 26.7 bn. UAH, really – by 5.2%, currency export – to \$4.66 bn., imbalance between consumed and produced GDP – up to 143 bn. UAH.

Y. Analysis of lending

Terms of analysis: every year since 2007, the author has established a constant volume of loans, deposits, interest thereon, of residential investment of business owners (at the level of 2007), exports; small price indices for Ukraine 1.005–1.09, devaluation of 5%, 2% overproduction. The full real GDP is investigated. GDP fluctuations related to pre-history are ending for the first 6 years, and then a stationary process lasts. Without loans GDP from the 7th till the 15th year is reduced by an average of 0.18% per year. This shows that the provisions of the Keynesian theory of the need to moderate inflation for the development of economy was not confirmed in Ukraine in the long run. In the short term, it has been proven in Vasylenko, Bazhenova (2014).

On loans at the level of 50% of the amount in 2007 (representing 8.5% of GDP 2006), the average GDP decline is 0.35%, at the level of 150% – 0.75%, at 350% – 1.3%. Even if from the 11th year loans will increase by 10% yearly, the GDP, of course, will increase (by 2.3% this year); however, from the 12th year gains become less, and in the 15th year the GDP falls by 0.8% (Fig. 1).

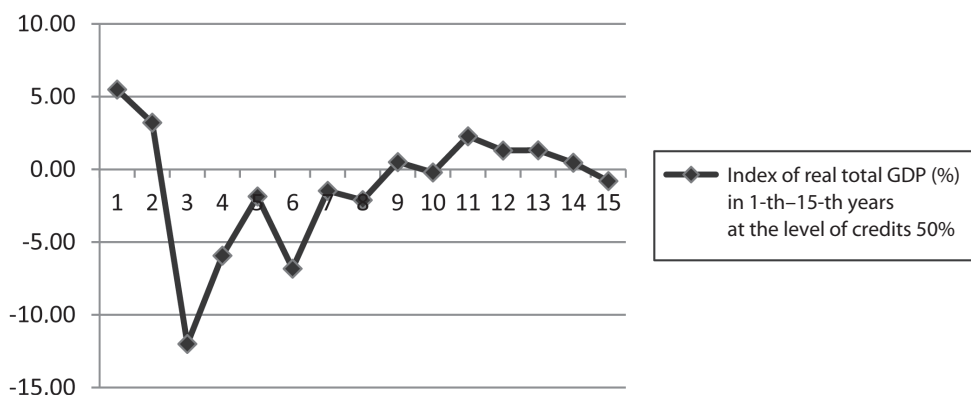


FIG. 1. Index of real full GDP (with illegal sector) in the 1 st – 15th years (the initial level of loans 50% and increases since the 11 year to 10% per year), %

If you turn on dependency loans from banks' income, the oscillatory process develops randomly from 7 to 15 years. The amplitude of the GDP increases with the level of loan (see Fig. 2). At the level of loans 65% the GDP ranges from 0.6% in the 14th year to –0.05% in the 15th and at 100% – from –0.7 to +0.37%.

If in the 15th year the overproduction of housing reaches 30% and residential investment of business owners declines by 50%, the GDP in housing will fall by 42% (without that it grew by 2%) and the total GDP by 3% instead of 0.76%.

Due to the limited space, we have to complete the analysis. The whole next article will be devoted to the analysis.

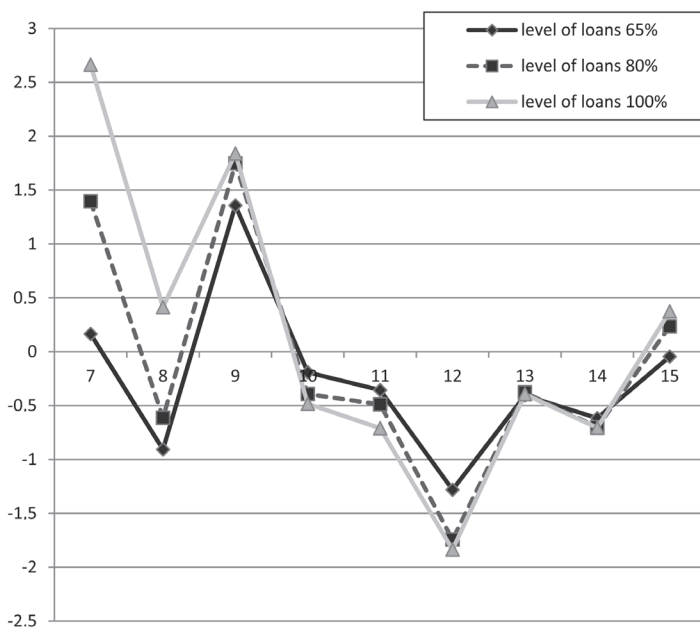


FIG 2. Index of real total GDP (%) in the 7–15 years at the levels of loans 65%, 80%, 100%

VI. Conclusions

1. Retrospective forecasts for 2008–2013 showed a high adequacy of the model. It can be used for a systemic forecast of the development of Ukrainian economy for any years in various situations. The model systemically connects all exogenous and endogenous parameters, input and output data. This is made possible by modeling the full system of economic mechanisms and goods of intermediate consumption.
2. The great advantage of the model is the possibility to consider the shadow sector, what makes it possible to identify changes not only of the legal but also of the full production, GDP, profits, wages, exports, imports, balance, bribes, exportation of currency, etc. The Government and the National Bank are to use exactly the full indices to develop the economic, social, financial, and monetary policies.
3. Forecasts for the years 2014–15, in the fall of exports by 7.5%, show the reduction of the legal GDP by 5.2%⁶ and 2.4% (full – 5.4% and 4.7%).
4. The main factors improving the economy of Ukraine are the maximizing of export prices (if possible) for any elasticity and any devaluation, increase of its volume, minimum deviation of production and imports from the sum of domestic demand, determined on the model containing inflation. Using these factors you can achieve even the GDP growth.

⁶ See footnote 5 on p. 74.

5. By himself, the exchange rate does not fully determine even changes of foreign exchange earnings and expenses for imports and their balance; this is only a minor factor. The basic factors that determine the state of the economy, including exporters, importers and balance, are changes in domestic prices, export / import prices, and elasticity.
6. Loan improves the economic development in the current cycle but worsens in the future.
7. With a monotonous slow change of prices at a constant export and devaluation and with loans, which depend on the income of banks, the oscillatory process develops freely. The amplitude of the GDP increases with higher levels of lending.
8. Due to the nature of the simulation models, a creator of each national model has to revise slightly this model, but he will get a model adequate to the real national economy.

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