Simulation of the controlled processes of real sector working capital reproduction

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Abstract[1]

The research results delivered in the article lie in the field of macroeconomic system behaviour simulation, and in particular working capital reproduction. The article includes the description of the developed cognitive model, the main features of the process formation, functional scheme of the dynamic models, results of the experimental research; it also concerns the control influence of the monetary policy instruments through the money market and goods market mechanisms regarding the influence of the market conditions uncertainty.

1. Introduction

In contemporary conditions of the global economic crisis, the problems of working capital control are of utmost importance. The problems concern export and domestic demand decrease that cause income decrease, final commodities in store increase, lack of payments, price increase on import inventory materials, more expensive and decreased external borrowing. These factors in turn lead to decrease of capital turnover rate, lack of working capital, liquidity crisis and working capital borrowing risks [1, 2].

The research of the problems of dynamics of nonequilibrium reproduction processes on macroeconomic level is held in Ufa State Aviation Technical University. The cognitive and dynamic models of working capital reproduction are developed.

2. Cognitive model of working capital reproduction on the macroeconomic level

Cognitive model of working capital reproduction on the macroeconomic level is based on the cognitive model of macroeconomic system functioning in market conditions [3-5] and includes extended macroeconomic agents and relationships between them.

Cognitive model of working capital reproduction on the macroeconomic level is based on the following principles.

1. The process of working capital reproduction on the macroeconomic level is concerned. The process takes place in macroeconomic system that functions in market conditions and includes repeated and connected processes that are gross domestic product formation, gross domestic product distribution by income of the macroeconomic agents, labor expenses and gross income formation, consumption and real economy income formation; savings and investments formation; investment in working capital of available accumulated funds.
2. Working capital reproduction process on the macroeconomic level is researched in the context of the macroeconomic system functioning and is concerned as a part of the main system circuit “production-consumption” of the macroeconomic financial flows turnover concerning economic sectors stocks.
3. Working capital reproduction process on the macroeconomic level is not only a part of the entire macroeconomic system reproduction process, but in turn includes the completed reproduction cycle of working capital.

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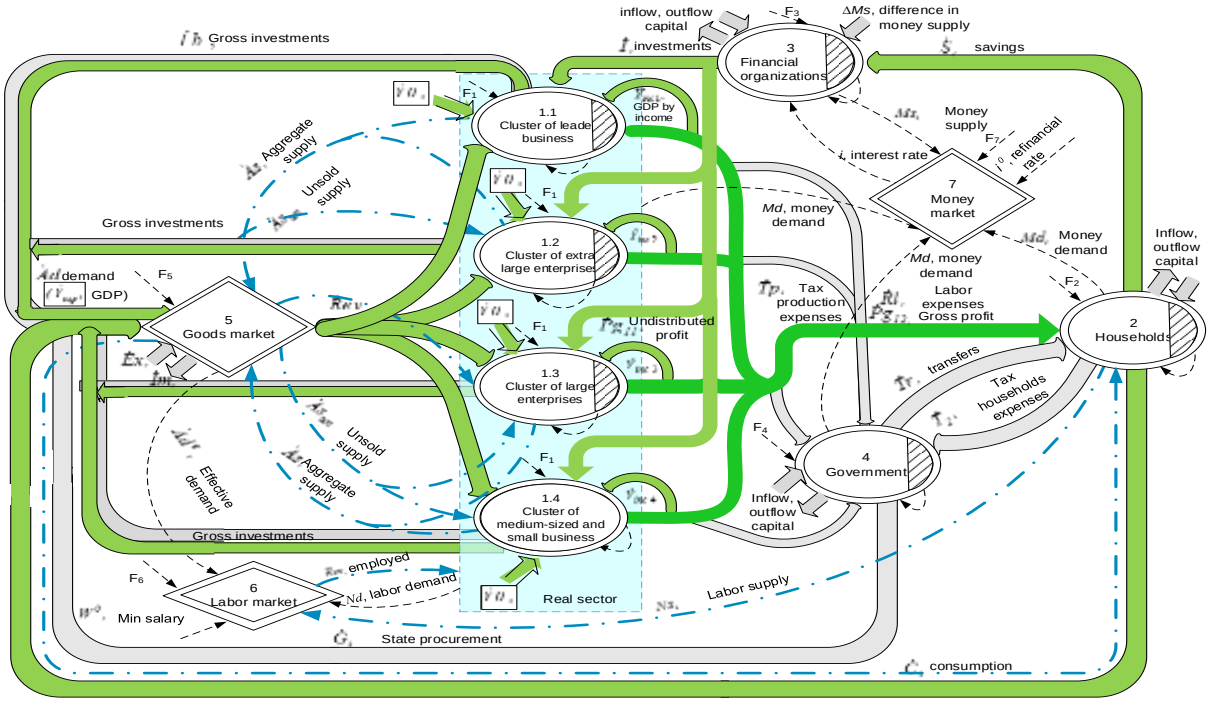

Fig. 1. Cognitive model of working capital reproduction on the macroeconomic leve

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4. Nonequilibrium behaviour of working capital reproduction process is concerned. The behavior is caused by different disturbances from domestic and external market that are characterized by high variability and uncertainty that cause nonequilibrium of income and expenses of economic sectors and of demand and supply in macroeconomic markets.

5. Control of working capital reproduction in macroeconomic system is held both on the level of macroeconomic agents (economic sectors) and on the level of market self-control mechanisms, and on the level of government control. Government control includes mechanisms of monetary policy, financial policy in the terms of government finance of investments, and mechanisms of structural policy that are important from the point of reproduction proportions correction on the level of real sector clusters.

Dynamic models of working capital reproduction in macroeconomic system is based on the dynamic models of working capital reproduction in macroeconomic system developed earlier in two directions.

Firstly, real sector is decomposed on several clusters regarding the results of intellectual data analysis of 100 big enterprises and regarding the information about GDP structural proportions formed by business leaders, medium-sized enterprises and small business.

Secondly, development of each of the clusters' dynamic models is based on the decomposition the investment flow on two flows such as investments in capital assets and investments in working capital.

Four clusters are developed as a result of the intellectual analysis. The first is the cluster of enterprises that are the leaders which form the significant flow in GDP. According to the intellectual analysis results and statistics of Russian Federation 12 business leaders produce 10% of GDP. The second cluster is the cluster of large enterprises that consists of 88 enterprises which produce 20% of GDP. The third cluster is the cluster of large enterprises the balances of which were not considered in intellectual analysis and which produce 50% of GDP according to [10, 14, 15, 17]. The fourth cluster is the cluster of medium-sized enterprises and small business that produce 20% of GDP.

The cognitive model of working capital reproduction on macroeconomic level (figure 1) other economic sectors are included:

- households which realize the processes of consumption $\dot{C}$, saving $\dot{S}$ and tax payments $\dot{T}_H$;
- financial institutions which accumulate households financial resources $\dot{S}$, form financial resources stocks in the form of different funds, form the investments and gives credits to enterprise $\dot{I}_i$;
- government which forms income of the state budget on the basis of tax and nontax payments $\dot{T}p$

of the real sector and households $\dot{T}_H$, forms expenses $\dot{G}$ in the form of public procurement including public investment;

- macroeconomic goods, labor and money markets.

Sectors of the macroeconomic system (macroeconomic agents) as the elements of the cognitive model realize the following functional processes:

- producing sectors realize the processes of manufacturing, product value is the sectors' gross output $\dot{Y}_i$. Gross output $\dot{Y}_i$ is the sum of intermediate consumption $\dot{I}c_i$ and gross value added $\dot{Y}_{gac_i}$: $\dot{Y}_i = \dot{Y}_{gac_i} + \dot{I}c_i$. The sum of three sectors' gross values added is the gross domestic product that is calculated by production method. Producing sectors realize the processes of labor expenses $\dot{R}l_i$, tax expenses $\dot{T}p_i$ and sectors' gross income $\dot{P}g_i$.

According to the developed methodology each of the macroeconomic agents (sector) realizes the following processes:

- has financial and material stocks including capital stocks and working capital including inventories (shaded region);
- makes decisions on correction of planned expensing rates of financial resources on the basis of analysis results;
- realizes controlled functioning that correspond to the exact activity type of the macroeconomic agent and connected with the financial resources expenses;
- receives financial recourses from the other agents;
- receives material recourses in the form of satisfied demand.

Four described real economy clusters are shown on the functional model of the dynamic model of the macroeconomic system.

The feature of the developed cognitive model of working capital reproduction on the macroeconomic level is that it includes not only financial circuits, but also entire closed circuits of materials.

The circuits concerning financial aspect of working capital reproduction on the macroeconomic level include:

- "production-consumption" circuit;
- "investment-savings" circuit.

The circuits concerning material aspect of working capital reproduction on the macroeconomic level include:

- "product-labor resources" circuit;
- "aggregate supply-unsold supply-inventories".

The aim of working capital reproduction process control is to provide equilibrium financial flows of income, consumption, savings and investment and material flows of goods concerning stocks of capital funds and working capital that provides planned rates of GDP increase in conditions of demanded reproduction proportions.

Real sector functioning description in the form of four connected enterprise clusters allows showing the features of capital funds and working capital stocks formation in enterprises of different scale and analyzing the influence of structure scale on the GDP production in different macroeconomic situations

The functional scheme of the dynamic model of macroeconomic system working capital reproduction is developed on the basis of the cognitive model of working capital reproduction on the macroeconomic level and includes nine connected dynamic models (figure 2).

The four models describe production sectors' functioning: model *A11* concerns leaders, model *A12* concerns extra large enterprises, model *A13* concerns large enterprises, model *A14* concerns medium-sized and small enterprises and goods market *A6*, model *A2* concerns households, model *A3* concerns financial organizations, model *A4* concerns government organizations, model *A5* concerns money market. Connections are financial flows (solid line), information connections (dash line) and material connections (dash-dotted line). Colors show financial and material circuits: production-consumption, investment-savings, tax-public procurement.

Sectors' models (*A11, A12, A13, A14, AH, AG, AB*) include dynamic models of functional processes controlled regarding the feedback coupling and connected by the adaptation circuit of the planned rates of resources expenses regarding the information about the stocks. Dynamic models of the macroeconomic system sectors are based on the system principles described above on simulation of the controlled behavior of the macroeconomic agents. The activity of each sector is controlled and concerns function realization according to the role in reproduction process of the macroeconomic system.

Models *A11-A14* describe the sectors' functioning: leaders, extra large enterprises, large enterprises, medium-sized and small enterprises. Each of the production sectors realizes the following functional processes: gross production with the rate $\dot{Y}_i$ based on the planned flow rate $\dot{Y}^0{}_i$; capital accommodation K_i based on the gross investments implementation $\dot{I}b_i$ and receipt of investments from capital funds market;

capital consumption K_i by amortization expenses Am_i with the amortization rate δ_i; intermediate consumption $\dot{I}c_i$ and intermediate demand $\dot{I}d_{ij}$ for production of the j sector; gross value added $\dot{Y}_{gac_i}$ formation, distribution of gross value added to the flow of labor expenses $\dot{R}l_i$, tax $\dot{T}p_i$ on production and import, gross income $\dot{P}g_i$ formation (including retained income $\dot{P}g_{i1}$ which is the source of gross stocks capital and income $\dot{P}g_{i2}$ that is the income of the owners of production factors); aggregate supply $\dot{A}s_i$ formation regarding planned rates of inventories expenses $\dot{Y}^0{}_{inv\,i}$; current investment expenses $\dot{I}b_i$ formation on the basis of proprietory investments with the planned rate $\dot{I}b_{ii}^0$ and borrowings with the rate $\dot{I}_i$; income $\dot{R}ev_i$ formation as a result of product realization on the i goods market and acquiring inventories with the rate $\dot{A}s_{uni}$ in conditions of excessive supply.

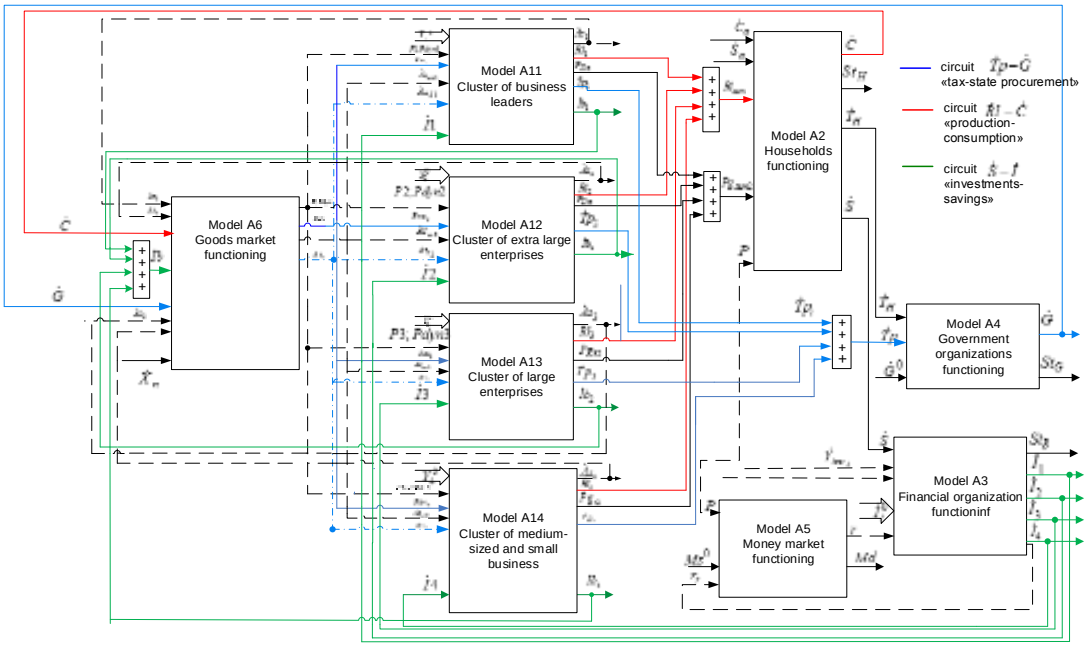

Fig. 2. Functional scheme of the dynamic model of macroeconomic system working capital reproduction

The main function for the model of goods market is to provide connection in time of aggregate demand (the sum of intermediate and final demand): $\dot{A}d_i = \dot{I}d_i + \dot{F}d_i$ as the input financial flow and aggregate supply $\dot{A}s_i$ as the input material flow. The result of this connection is the price level P_i for the product *i*.

Intermediate demand is formed by all sectors of the production subsystem for product i for intermediate consumption and is determined as $\dot{I}d_i = \sum_j Id_{ji}$.

Final demand for i product is formd by households in the form of consumption rate $\dot{C}$, by government in the form of public procurement $\dot{G}$, foreign sector in the form of net export $\dot{X}n$, by production sectors in the form of gross savings rate as a part of demand on capital funds on investments market. So, final demand for production of the first and the third sectors is determined as $\dot{F}d_i = k_{Ci} \cdot C + k_{Gi} \cdot G + k_{Xni} \cdot Xn$, $i = \overline{1,3}$, for the second sector as

$$\dot{F}d_2 = k_{C2} \cdot C + k_{G2} \cdot G + k_{Xn2} \cdot Xn + \sum_i \dot{I}b_i \,, i = \overline{1,3}\,.$$

The feature of the goods market is the connection with the sector "External World" in the form of net export $\dot{X}n_i$ that is regarded as external connection. Net export rate is formed as the difference between export rate $\dot{E}x_i$ and import rate $\dot{I}m_i$ and can be negative for the sectors in case of excess of export by import: $\dot{X}n_i = \dot{E}x_i - \dot{I}m_i$.

The additional function of the market is the formation of manufacturers income $\dot{R}ev_i$ that correspond to the satisfied demand $\dot{A}s_{uni}$ as the output financial flow and unrealized product that is inventories and provides additional information about the character of

nonequilibrium state of the market as the output material flow.

Model *AH* describes the households functioning. The sector realizes the following functional processes: gets income in the form of summarized rates of *A11-A14* labor expenses $\sum_i \dot{R}l_i$ and part of net profit $\sum_i \dot{P}g_{i2}$; forms tax expenses $\dot{T}_H$; on the basis of sum of income forms consumption $\dot{C}$ and savings $\dot{S}$.

Plans on expenses formation are determined according to Keynesians concept on the basis of planned rates of: autonomous consumption $\dot{C}^0$ and autonomous savings $\dot{S}^0$. Plans on consumption expenses $\dot{C}^0$ are additionally corrected according to the information about the dynamic part of the price $P_{dyn.average}$, real consumption expenses rates are corrected with the coefficient k_{ad}.

Model *AB* describes the financial organizations functioning. The sector realizes the following functional processes: accumulates savings $\dot{S}$ of the macroeconomic system sectors; transfers savings into investment borrowings; forms the interest rate r_i for credits regarding information on money interest rate; forms investments $\dot{I}_i$ regarding information on planned autonomous investments $\dot{I}_i^0$ for each credit type.

The feature of the model *AB* is concidering of the influence of the current gross value added of the sectors $\dot{Y}_{gac_i}$ and current interest rate *r* when forming the credit interest rate on investment credits $\dot{I}_i$ for production sectors.

Model *AG* describes the government organizations functioning that form income in the form of sum of tax and nontax incomes from production sectors $\sum_i \dot{T}p_i$ and households $\dot{T}_H$ and the expenses in the form of state procurement $\dot{G}$ regarding investment expenses.

Model *AMM* describes the money market functioning on the basis of information about the current money supply *Ms* and price level *P* and income $\dot{Y}_{inc.total}$ that determines the demand for money. Current interest rate formation *r* is directed on possible differences in refinancing rate r^0 and dynamic part r_{dyn}.

The money market determines the demand for money *Md* from all macroeconomic system sectors and integrates in the single dependency. This is accumulating function of the market. The money market also forms the special price for money – market interest rate *r* that is based on the connection of the demand for money *Md* and money supply *Ms* in dynamically nonequilibrium conditions. Regulating function of the market is that it has the influence on the situation of the money market on the behavior of the macroeconomic system sectors in the process of demand for money and investment demand formation.

Dynamic models of the production sectors functioning forming investment expenses are invariant to the type of product and therefore are presented in the common form for production sector *i*.

Dynamic models of the production sectors functioning are developed according to the methodology of development of sectors functioning models that are controlled on the basis of stocks.

Model *A10* of accumulation and consumption of the capital is developed on the basis of the Solow dynamic model. The model describes, firstly, dynamics of difference in the current rates $\dot{K}$ and cost values of the sectors' capital funds *K*; and, secondly, accounts investment lag.

Model *A11* of production planning describes the process of gross production rate planning on the basis of the potential production values that is determined by production function; plans correction based on the information about the market price level and nonprice determinants of the aggregate demand.

Model *A12* is presented in the form of controlled subsystem developed on the basis of the combination control principle and describes the production process as the functional process of the production sector.

Model *A13* describes the process of sector *i* formation of gross value added rates. Gross value added is the field's factor expenses that mean the produced cost distributing to the labor income and business income (profit).

The process of spending and formation of inventories in the form of unsold stocks is presented as the model controlled regarding of stocks. The feature of the resources expenditure flow is that it describes the material flow.

The process of capital funds and working capital planning is presented by the model, where accumulation of capital funds and working capital is divided into two flows. Capital funds are considered using Solow model. The model, firstly, describes the dynamics of the difference of the current rates $\dot{K}$ and value of the sector's capital funds *K*; and, secondly, regards investments lag.

The input parameter for the model is the rate of inventories flow from the sold supply $\dot{A}s_I$ as the output flow of the investment market model. The model

parameters are the capital amortization δ and investment lag τ_i^0.

The developed dynamic models of the production sectors show the dynamics of the processes unsteady in time: sectors' investments expenses regarding the accumulated stocks; accumulation and consumption of the capital funds and working capital that influence on the gross production formation rates; added value and intermediate consumption formation that connects financial and material flows between the sectors. The decomposition of the real sector enterprises is held and the balance between capital funds and working capital is determined. The influence of the working capital on the entire reproduction process of the macroeconomic system is determined.

On the basis of the developed dynamic model experimental research was held. The experiments concern the research of the working capital reproduction dynamics in different situations.

Uncontrolled scenarios showed the decrease of the GDP production rate in crisis conditions caused by the decrease of the net export. The chosen tough monetary politics in the form of money supply targeting by interest rate increase does not cause investments increase. In such conditions, control of inflation takes place, however gross income of the real sector decreases due to the misbalance in the mechanism of extended reproduction of the working capital. The most important economy sector becomes illiquid borrower, which is not capable to increase the working capital for manufacture development. The structure of the real sector of the Russian economy shows that the cluster of the extra large enterprises increased the profit, but the rest clusters, in particular medium-sized and small business, significantly decreased the profit.

Controlled scenarios showed the possibility to increase GDP in negative conditions of export decrease for resource-oriented economics in transfer conditions from tough monetary policy to mild monetary policy. The decisions aimed to provide flexibility of money supply fulfilling the manufacturers' demand in working capital take place in such situations. Additional decisions in the form of interest rate decrease and providing cheap credits for the cluster of medium-sized and small business that is most sensitive to the lack of working capital lead to the secondary wave of GDP increase.

3. Conclusion

Therefore, the cognitive and dynamic models of the macroeconomic system that describe the main circuits of the material and financial flows of the reproduction process are developed. The models describe the features of working capital formation and concerns the control influence of the monetary policy instruments through the money market and goods market mechanisms regarding the influence of the market conditions uncertainty. The simulations made showed the possibility to increase GDP in negative conditions of export decrease for resource-oriented economy by making decisions aimed to provide flexibility of the money supply and interest rate which leads to working capital increase in economy.

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