Chapter

Using Simulation Modeling for Finding the Limits of Economic Development Lending without a Financial Crisis

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Abstract

The only existing approach to analyze the impact of excessive credit on the economy is based on statistics. Its main drawback is small intervals of changes in countries' indicators, limited by current values. So researchers cannot notice how too much credit causes a financial crisis. To eliminate this and other shortcomings of the statistical approach, the author proposes a different approach: to use for such an analysis an economic model in which one can change credit levels. The most adequate model is a causal simulation model that reflects the main types of legal and shadow economic activity in their relationship. The author has developed such a model. This model showed that the level of loans 25% of output (51.8% of GDP), could create Ukraine's financial crisis. Since loans are mainly used for investment, the author introduced the concept of the technical productivity of investment to link them with the technical progress, and with GDP growth. The technical productivity of investment measures their ability to reduce the rate of material or labor costs. Besides, the introduction of an indicator of technical productivity of investment made it possible to obtain an analytical dependence of the rate of economic growth on the level of loans and technical productivity of investment.

Keywords: financial crisis, limits of secure lending, simulation model, legal and shadow economic activities, technical productivity of investment

1. Introduction

Loans have always been considered the driving force of the economy. Even the financial crisis of 2008–2009 did not change the indisputability of this view in many researchers. For example, Lorenzo Cappiello, Arjan Kadareja, Christoffer Kok Sørensen and Marco Protopapa [1] only regret that "the Financial crisis erupting in mid-2007 which led to the need for banks to deliver their balance sheets and possibly to reduce their loan supply".

Manaresi and Pierri [2] insist that "To grow and thrive, firms need reliable access to external funding".

Sadaf Majeed, Syed Faizan Iftikhar, Zeeshan Atiq found a difference in the effects of loans to household and enterprise in Pakistan: the former does not cause economic growth, while the latter has a positive impact [3].

At the same time, more balanced thoughts emerged. Thus, Dirk Bezemer, Anna Samarina, and Lu Zhang already distinguish the nature of the impact of loans in the short and medium-term: "The impact is positive in the short term and negative in the medium term" [4].

Leading scholars such as Stiglitz, Paul Krugman, and others have pointed to excessive credit as the immediate cause of the 2008–2009 financial crises [5].

After the crisis of 2008–2009, there were works to create early warning systems for the financial crisis [6–8].

All the above-mentioned analytical studies of financial crises and other works are based on a single basis - statistical. The advantage of this approach is the coverage of a wide range of countries or firms. But there are drawbacks. The first is small intervals of changes in countries' indicators, limited by actual values. So researchers cannot notice how too much credit causes a financial crisis. The second drawback is the heterogeneity of the samples for analysis - they mix countries with large differences in institutional characteristics and development levels. The third one is the lack of accurate estimates of the results because the probability distributions of economic indicators are mostly far from normal (Gaussian).

2. Methodology of work

We propose a different approach to analyzing the impact of excessive credit on the economy, free from these shortcomings. We apply the author dynamic model [9], adequate to the Ukrainian economy (see below).

In this model, we simulated Ukraine's economy's smooth development over 5 or 10 years (results were similar) at different lending levels in different economic situations. After that, in the sixth or eleventh year, we stopped lending and watched how much real GDP would fall than the base year. This is a very approximate financial crisis model; however, it gave estimates in the first approximation.

For this approach to work, the adequacy of the model to the real economy of a country or a homogeneous group of countries must be very high. The next section lists the model features that ensure its adequacy.

One uses loans primarily on active investment. So one has to investigate investment more deeply and link them with technical progress, and GDP growth.

Investments in the literature are mostly explored for their payback, which is mainly a microeconomic approach. Nobody analyzed their impact on an economy in general. To assess them on a national scope, one has to characterize investments in macroeconomic terms.

The creators of economic dynamics, Robert Solow, Roy Harrod [10, 11], did not set themselves to create such a characteristic. It is not clear why they did not link investment, on the one hand, with the growth of capital, and on the other hand, with technical progress.

One of the technical progress indicators is reducing material or labor costs due to active investment. But no one measured the ability of an investment to reduce the rate of material or labor costs. This characteristic is the direct technical result of active investment and a direct factor in increasing the enterprise's competitiveness. An economist, having such a characteristic of investment, can quantify the potential of the totality of any investment, regardless of their specific nature. That is, he will be able to move from the microeconomic level to macroeconomic analysis. Moreover, he can no longer derive identity (like in Roy Harrod), but the equation of economic dynamics, which links the GDP growth rate with the endogenous factor of technical progress - investment, a source of which is income.

To fill this gap, move to the macro level, and link investment to GDP growth, we have introduced such an indicator and called it the **technical productivity of**

investment. We accepted that the technical productivity of investment is equal to 1 if the rate of decrease in the rate of expenditure (per unit of output) is equal to the increase of the active part of fixed assets through investment. If technical productivity is 2, then the reduction is twice as much.

These two points are central to our approach.

Else we propose to expand the measurement of investment economic efficiency - to measure it not only in terms of profit but also in all value-added. We believe that this indicator reflects the efficiency for the state, and secondly, the more farsighted interests of the business owner in minimizing the turnover of skilled workers. Therefore, simultaneously with the payback, our model calculates the efficiency of investment by GDP, i.e., the ratio of real GDP growth obtained in one or more subsequent years-cycles to the real amount of investment in one or more previous years-cycles. In some sense, this indicator is the inverse of Roy Harrod's capital ratio [11], but it uses real indicators rather than nominal ones.

Besides, the model considers that if the bank issued loans k times more than it received deposits D; thereby, it created an emission of (k-1) x D. In Ukraine, over the past 15 years, banks issued more loans (for example, in 2005–2008, 2011, and 2013) and less (in 2009, 2010, 2012, and 2014) than they received deposits. We believe, together with monetarists, that prices for all goods will increase accordingly. Rising prices for intermediate goods will increase the cost of all goods, thus reducing gross profit; rising prices of final consumption goods and housing reduce households' purchasing power, higher investment goods' prices reduce real investment. Therefore, the increase in loans has positive and negative results. Let us see which wins lower.

Researchers of the financial crisis, as well as creators of systems of early warning crisis, measured the level of credit as a share of credit in GDP (for example, [6–8]). But GDP is used for purchasing consumer and investment goods only, and loans are taken else to produce intermediate consumption goods included in the output.

We believe that it is methodologically correct to take loans' share, not GDP, but output. GDP is not proportional to output. A more efficient economy produces more GDP per unit of intermediate consumption, a less efficient economy - less.

3. A brief history of economic modeling and an adequate model of economic dynamics of Ukraine

To analyze the impact of excessive credit on the economy by the proposed method, we must have a dynamic model with a very high level of adequacy to the Ukrainian economy.

At that time, when scientists began to build economic science on physics principles, they discuss its nature, roles of mathematic, and the very possibility of such a building. Here is what J. von Neumann and O. Morgenstern wrote in 1944:

> *"To illuminate the concepts that we will apply to economics, we present and will continue to present some illustrations from physics. Many sociologists object to drawing such parallels for 48 different reasons, among which they usually cite the statement that economic theories cannot be modeled on the model of physical ones, since economic theories take into account social, economic phenomena, since they have to take into account psychological factors, etc. Such claims are immature, to say the least. Undoubtedly, it seems reasonable to uncover what led to progress in other sciences and investigate why the application of these principles cannot lead to progress in economics. If there really is a need to apply some other principles to*

> *economics, this can only be revealed in economic theory's actual development. This, in itself, will be a revolution in science. But since, almost certainly, we have not yet reached such a state and it is in no way clear that there is a need to use completely new scientific principles, it would be unreasonable to consider anything other than the interpretation of problems in the way that has already led to the creation of physical science." [12].*

So far, no consistent economic theory based on the principles of physics has been created. Moreover, many economists have spoken of the crisis of economics. Paul Samuelson in 1947 wrote:

> *"The economist comforts himself ... with the thought that he is forging tools that will eventually lead to results. This promise is always for the future; we are like well-trained athletes who do not participate in competitions and therefore lose shape." ([13], p. 4).*

Moreover, the very definition of economics is changing. In the first half of the 19 century, economics was seen as a study of the "nature and causes of the wealth of nations" (Smith), "the laws governing the distribution of what is produced on earth" (Ricardo), and "the laws of the movement of capitalism" (Marx). After 1870, it was believed that the economy analyzed human behavior in different markets. Mark Blaug wittily remarked that many early studies then lost the right to be called economics [14].

As a result of this approach, Paul Krugman has subjected destructive criticism of economic models that cannot predict anything [15].

One of the fathers of economic dynamics, Roy Harrod [11], submitted the fundamental equation of economic dynamics which determines the growth rate: the amount of savings, expressed as a share of net income divided by the capital ratio. The capital ratio is the ratio of net (rather than gross) investment to the increase in output or income over the same period.

Note that the output growth (which stands in the denominator of the Harrod's capital ratio) to its base value - this is the rate of economic growth. Thus, Harrod's fundamental equation of economic dynamics is not an equation - it is nothing more than some identity where the output indicator is determined by itself. If we solve it, we get the known identity: savings equal the capital increase.

Roy Harrod himself understood this perfectly; moreover, he emphasized that this equation is a truism because it is easily deduced from the standard definitions of macroeconomic variables included in this equation.

However, he called this identity an equation. On its varieties - equation of guaranteed and natural growth rate, recommendations were calculated to the governments of different countries to forecast and regulate the rate of economic growth in the 60s of the twentieth century. But only in 6 of the 88 countries where they were used were the expected results obtained [16]. Attempts to predict economic growth based on the Harrod-Domar model have failed. The researchers concluded that the model does not explain the main determinants of economic growth. And how could it explain if it is not an **equation** but **identity**? **The rate of output growth does not follow from this identity.** What the increase in output in the capital ratio we set, the same increase in output we get at the output of the Harrod fundamental equation of economic dynamics.

Robert Solow [10] turned this identity into the equation by replacing the capital ratio with a labor efficiency indicator.

For this he received the Prize behalf of Nobel in 1987. This was, in my opinion, a rather strange decision, because:

1. His labor efficiency was exogenous and not related to investment.

2. It is the Solow exogenousness of economic growth was the object of criticism №1, and less than 10 years later the Ramsey-Cass-Koopmans model appeared, in which the saving rate changed in each period [17, 18], due to which this model became considered endogenous. However, it was later recognized as exogenous because, as in the Solow model, scientific and technological progress in the Ramsey-Kass-Kupmans model is not the result of decision-making by economic agents but is set exogenously [19, 20]. The very problem of determining the norm of conservation F. Ramsey [21] studied in the 20s with differential equations.

   That is, R. Solow took two steps back at once: in time and in terms of abandoning the endogenous nature of economic growth.

3. In choosing the model, R. Solow was behind K. Marx who divided the economy into two sectors: the production of consumer goods and means of production.

4. Solow's model is not his own model, but the Cobb–Douglas model, the adequacy of which to the real economy is in great doubt - deviations of the actual data of the production of the USA manufacturing industry from the Cobb–Douglas function was more than 15 percent, which does not provide sufficient reason to believe this power function adequate the existing economy. And this is for one homogeneous industry, where companies have approximately the same levels of capital intensity. Which will be the mistake for the whole economy, where there are capital-intensive and labor-intensive industries? Mark Blaug ([14], p. 653) expressed a more general idea:

   "In itself, the concept of production function - a set of all known production technologies - is so general that it cannot be called meaningful".

5. So all studies of R. Solow of various modifications of the Cobb–Douglas model (with constant elasticity of substitution (CES), with constant return on a scale, with decreasing return on a scale, etc.) are, in fact, the study of mathematical properties of the power function, but whether this function reflects real economy - a big question.

6. In the Solow model, investments make up a fixed share of production. In fact, all production is not a source of investment. There are three inner investment sources: gross profit, wages, and taxes (in public sector investment), which together account for GDP. The volume of production also contains material costs that are not proportional to GDP: in industries and countries with higher production efficiency, they are smaller, with lower efficiency – higher (this is why it is necessary to take the output as a result indicator of the economy, not GDP). Therefore, an investment cannot be taken as a share of output that includes anything that has nothing to do with investment.

They cannot be taken as a share of GDP because the shares of savings in gross profit, wages, and the share of investment in the budget, formed from taxes, are significantly different. Non-financial corporations in Ukraine direct all gross adjusted disposable income to gross savings. Financial corporations of Ukraine, for example, in 2018–2099.4%. The general government sector directed 8.1% of gross adjusted

disposable income to gross savings. Households are unlikely to use social benefits to save as cash, much less in kind. They save from three sources: gross profit (mixed-income), which amounted to 2018 25.7% of the gross balance of primary incomes, wages of employees (71.9% of the gross balance of primary incomes), and property income (2.5%). The share of gross savings in the gross balance of primary household income was 3.9%. Non-profit institutions serving households directed 8.6% of their gross adjusted disposable income to gross savings [22].

Thus, the average share of gross savings in gross adjusted disposable income in Ukraine of 14.4% does not contain any useful information. This is the average temperature of patients in the hospital, possibly except for the morgue. Because if we determine the optimal share of gross savings in the country's gross adjusted disposable income, and even more so in production, then there is no economic agent who can use it, there is no source of investment from which to take this share. From this optimal share, it is impossible to move to the optimal shares for agents who own or manage investment sources: for households, for non-profit organizations serving households, and for the general government sector.

Note also that to determine the exact optimal share of savings is not simple. As R. Pindyck [23] stated, there is great uncertainty in Nordhaus models' input indicators and the like, particularly regarding the discount factor, small changes of which strongly affect the value of the optimum, and there is no justification for these small differences. W. Nordhaus and E. Moffat [24] themselves note the poor reproducibility of their results.

Modern economists rightly believe that economic development should be carried out at the expense of some endogenous resources. Thus, in the Agion-Howitt model [25], economic growth is a consequence of individuals' decisions, not an exogenously given variable. But for some reason, they focused on the norm of saving and did not study the sources of development, i.e., sources of investment.

In all these and similar models, one of the main determinants of growth is the uninformative **amount of capital,** regardless of its **productivity.** The latter depends on the nature of the investment. Economic growth models did not address either the nature of investment or investment effectiveness. But this needs to be taken into account because the pace of technological progress and economic growth depends on it.

None of the economic dynamics models reflects the shadow economy, although, in many countries, it significantly affects economic dynamics. For Ukraine, we showed this in [26].

This analysis's general conclusion is as follows: **it is impractical to study the economic dynamics on the highly aggregated models, such how mentioned above, where the main determinant of growth is the uninformative amount of capital, regardless of its productivity.** They are inadequate to the real economy, especially in those countries where the shadow economy is significant. Deviations from the real economy are so great that **any economic dynamics in them become indistinguishable**. It is impossible to draw constructive conclusions appropriate for a particular economy or group of similar economies on such models. The conclusions that have been obtained have either already turned out to be wrong (Harrod-Domar model) or will turn out to be such, or they cannot be applied in a particular economy (Solow model).

4. An adequate model of economic dynamics of Ukraine

When creating our model of economic dynamics of Ukraine, we sought **to achieve the greatest adequacy**. We are more inclined to believe Alexander Gray:

"Economic science if this is different from other sciences that there is no imminent transition from least to most credibility, there is no inexorable desire to go all the way, the truth, which, as once revealed, will be true for all time, until the complete eradication of any opposite teaching, "(quoted by [14], p. 3).

Due to the limited scope, we present only the model features that ensure its adequacy and several basic equations of the model (the whole system of equations is given in [9, Chapter 2]).

1. The model is causal. The causal model is better suited to solving various analytical problems than the regression one.

2. The model is imitative. Back in the early 60-s of the XX century, von Bertalanffy wrote: "UTS opens new horizons for us, but its compliance with the empirical data remains scant." Therefore the author tried to stay away from theories and to be closer to life. He simulated real-world economic processes and mechanisms which undoubtedly exist in the economy, not forcing them into the Procrustean bed of theories and macroeconomic hypothesis (hypothesis of monetarists, Keynes, equilibrium) that a priori rigidly predefine the economic behavior and make a model inadequate to the real economy. In the language of control theory, all these hypotheses relate to the economy's management, but not to the economy itself. Introducing them into the model of an object means to mix object and a control system so one cannot analyze the "pure" economy (economy as a system with internal positive feedback is unstable) and synthesize a control system correctly. We used a priori more appropriate path (long known in the theory of control systems, but have never been used in economics): to display only an object of control, but not control actions: the real economy, not the ideas.

   In this respect, it is closer to the ASPEN model [27]; true, the author found out about it in 2018. Of course, our model differs in the specifics of the Ukrainian economy.

3. The model is systemic, i.e., it displays the complete system of essential micro- and macroeconomic mechanisms (formation of prices, cost, producers' and state income, taxes, emission, bank rates, transfers, etc.; for example, most models do not show the interrelation between the increase in salary and taxes and an increase in cost price whereas our model reflects this and all other interconnections.

4. The model reflects seven basic types of shadow economic activities in conjunction with the legal. Any model of economic dynamics (and statics) in the world has no such conjunction, they reflect the shadow economy separately from the legal one (as, for example, in [28–30].

   Significant shadow types machinations that exist in Ukraine:

   In private companies:

   a. In addition to legal exists the shadow production of each product;

   b. Part of the salary is paid illegally; taxes on all illegal amounts are not paid;

   c. One overstates material costs to avoid paying VAT and income tax.

   d. Both private and public companies include the following areas:

e. Prices of public procurement exaggerated;

f. The state returns VAT for sham sales both domestically and for export,

g. VAT is not returned on time or in full;

h. Companies give bribes to officials for not "noticing" shadow machinations. The absolute size of the bribe is proportional to the size of the shadow equipment.

i. We accepted the overall level of the shadow economy for 2018–2027 32%, as determined by the Ministry of Economic Development and Trade of Ukraine. Using the general level of the shadow economy, the model determines the levels of the shadow parts in different goods. They were found to be different and, in some ways, consistent with the data of the Ministry of Economic Development and Trade: the highest level of the shadow is in the financial sector (after exports, in which the Ministry of Economic Development did not evaluate the level of shadow). This confirms the model's adequacy to both the shadow and the legal sectors of the Ukrainian economy.

5. We tried to choose the optimal level of aggregation of goods in this model, in the sense that we abandoned complete aggregation, as in Solow [10] but did not introduce excessive specification by industry, as in V. Leontief [31]. We chose the principle of the system of national accounts (SNA): we formed product groups, manufacturers, and consumers so that they behave equally when devaluation and inflation: final consumption goods, intermediate consumption, investment, exports, and imports. The model reflects the production of raw materials (intermediate goods), lacking in most models. Without this, it is impossible to accurately reflect changes in all goods' cost (including the intermediate goods themselves) and the value-added in its production.

   So, we increased the number of goods from three in the dependent economy model [32] or eight in the ASPEN model [27] to 19, the number of producers to 29 (14 private, 14 state-owned enterprises and the general government sector (GGS)). Each pair companies: private and public, produces one of 14 products:

   a. non-tradable consumer goods and services[1] together with distribution and retail (index *1* in below equations);

   b. Tradable goods of final consumption (only production without distribution and retail) sold domestically (index *2* in below equations);

   c. Tradable goods of intermediate consumption (production together with distribution and retail) sold domestically (index *3*);

   d. Tradable goods of investment consumption (without housing) sold domestically together with distribution and retail (index *3 N*);

   e. Housing sold domestically together with distribution and retail (index *3H*);

[1] Next, we will say "goods", referring to "goods and services".

f. distribution and retail of import of these four goods; we included these services in domestic output and GDP (indexes *4, 5, 5 N, 5H*).

g. Consumer export together with distribution (index *2E*),

h. Intermediate export together with distribution (index *3E*),

i. Consumer goods' distribution (index *2D*),

j. Consumer goods' retail (index *2R*),

k. Financial services (index *F*).

The GGS produces government services (index *DU*).

Imports are, of course, not made in Ukraine, but four types of import (points b-e) increase the number of goods to 19.

In this way, we linked all systemic relations to each other: production (the cost of production reflects material costs (different in each cycle through different investments in previous years), wages, payment for banking services, depreciation (also different due to different investments) and taxes), consumption (products are purchased at the expense of salaries, profits, credits, pensions, and taxes), capital accumulation (at the expense of profits, salaries, taxes, and credits).

6. Based on the availability of 14 types of private and state-owned enterprises which produce 14 types of goods, and GGS, we divided households into 86 groups: 28 aggregated employees of all 14 types of private and 14 state-owned enterprises, which produce the above-mentioned goods; 14 business owners; 14 directors of state-owned enterprises (in Ukraine, they act like owners); pensioners; public servants; 28 aggregated officials, each of whom receives a bribe from one of 28 enterprises.

7. We took output (instead of GDP) as the primary outcome of production. This eliminates a lot of inaccuracies and methodological incommensurability, for example:

a. The neoclassical model of demand for money takes into account only trade agreements that are linked to the GDP, but the sale of intermediate products does not include, and in Ukraine, it is more than 60%;

b. in the traditional regression models, export demand is mainly determined by the GDP of the importing country, but this is true only for end-use products, but the need for exports of intermediate consumption goods, which is in the export of Ukraine 80–90%, depends precisely on the output of the importing country;

c. GDP, which measures only the value-added contained in the goods, sometimes is compared with indicators that measure the full value: exports, imports, consumption, supply, and so on. For example, in the computation of openness of the country to the outside world, this leads to the fact that the two countries with different levels of the cost of producing a unit of output (hence, with varying levels of GDP per unit

of output) for which this indicator has the same value, according to the existing methodology are considered equally open. In contrast, the degree of openness of an economy is more at the country in which the level of GDP per unit of output above. Openness to the outside world should be measured by the ratio of export value to the output. For example, a traditional indicator showed that the degree of openness of Ukraine in 1993 increased from 24 to 26%, whereas, according to our indicator, it dropped from 11 to 10%. In 1996 the opposite was true.

d. The use of GDP as the model output is automatically (though implicitly) introduces the hypothesis of the constancy of economic efficiency (GDP per unit of intermediate consumption), while the simulation of production and costs reflects its changes.

e. When identifying the empirical data model, primary values in the physical dimension may be probabilistically distributed according to the normal (Gaussian) law for which statistical evaluation of the significance and accuracy of the model coefficients is derived. Nonlinear conversion of primary values (multiplication of prices on volumes) changes the normal probability distribution to the other, for which statistical estimates are incorrect.

Besides, the author believes that the hypothesis of a balance between supply and demand (which has never been proved either theoretically or practically) has not been disproved because all models used GDP as a result indicator instead of output. Namely, using output allowed us to detect an imbalance between consumed and produced GDP.

At different levels of efficiency per unit of intermediate consumption, our model produces different amounts of GDP. In particular cases, the hypothesis of equilibrium between supply and demand, between consumed and produced GDP, is performed. Now imagine that the efficiency decreased. Each product unit contains less added value; therefore, the whole output has less GDP. Now households will be able to buy at the new GDP only a part of the goods produced; thus, the balance between supply and demand is broken. It follows that the balance is carried out only for one particular subset of the values of economic efficiency. So, a much more powerful set of unbalanced economy hardly comes into the view of economists. Our model takes them into account.

Our dynamic model is a set of models of successive economic cycles[2]. The model of each cycle is a model of the Ukrainian economy's transition from the previous cycle to the next one under the influence of exogenous and endogenous factors; all three sources of investment: gross income, wages, and taxes, are results of the previous cycle (endogenous factors for it) and input (exogenous) factors for the next cycle.

Each cycle's model is a direct description of the real economic activity of all 28 aggregated enterprises and GGS (**Figure 1**). Each company produces its own product, sends it to the market and receives revenues. From it, the company pays taxes, returns debts with interest, restores spent fixed assets, buys working capital, pays salaries. The owner of the enterprise spends part of the remaining profit on his personal needs, and sends the other part to investments.

[2] For the convenience of applying the existing statistical accounting, it is accepted that one cycle is equal to one year.

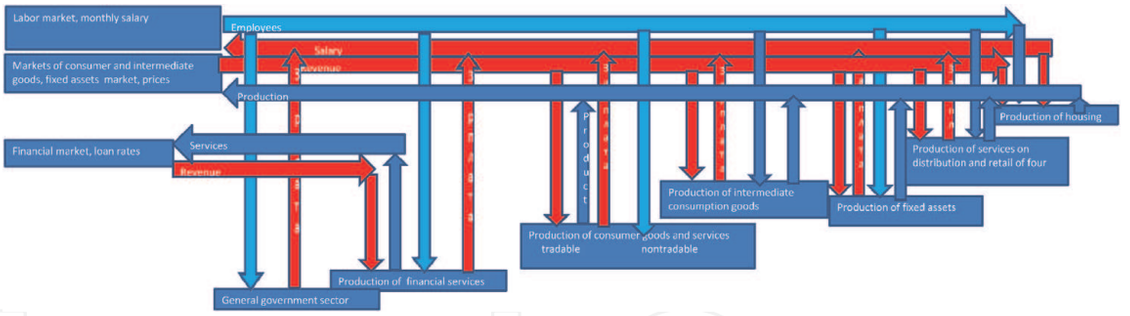

Figure 1.
Block diagram of the model of one economic cycle.

The output of each consumer product is initially equal to the total demand of all 86 of its consumers (listed above), the volume of each intermediate goods (domestic, import, and bank services) - to the total demand for it by all 28 enterprises and the GGS. Afterward one can set any over- or underproduction for any product. Since amounts of intermediate goods' demand also include the demand of the enterprise which produces intermediate goods itself, the systems of Equations [9] are recurrent. We solved them by the sequential approximation method implemented in Excel using the macros developed by the author. In the next economic cycle, enterprises purchase material and labor resources at perhaps new prices and at norms that may have decreased in proportion to investment in previous periods. The aggregated investment enterprise increases (decreases) its production following the increase (decrease) in all enterprises' total gross profit, including this enterprise itself.

Thus, the model calculates each resultative indicator by taking into account all the main direct, feedback, and cross-links, all the main economic mechanisms existing in the economy of Ukraine. Therefore, all known multipliers are determined not once and for all, as traditionally, but for each economic situation newly. For each factor, we make several alternative calculations to ensure the consistency of the regularities found. Therefore, an adequate model is the best justification of conclusions, more conclusive than theoretical considerations, which, at all their correctness, cannot take into account all problem aspects and all factors affecting the development of the economy, especially if the consequences are multiple, opposite, and the outcome depends on which one is stronger.

Here are the basic equations of the model (all equations see in [9]).

The price model consists of non-devaluation I_{nj} and devaluation $a_j \cdot$ *(I-1)* components of inflation. The j-th product owner raises the price more or less than devaluation index I (coefficient a_j and index I_{nj}):

$$I_j = \left(I_{nj} + a_j \cdot (I-1)\right), j = 1, 2, 2_D, 2_R, 2_E, 3, 3_N, 3_H, 3_E, 4, 5, 5_{N,}\, 5_H \qquad (1)$$

The owner has to rise salary under devaluation, but he sets wages (I_{vj}) usually less than price (I_j ($b_j < 1$)):

$$I_{vj} = 1 + b_j\left(I_j - 1\right), j = 1, 2, 2_D, 2_R \qquad (2)$$

Cost of j-th product unit is modeled as a sum of conditionally variable and constant (the last summand) expenses for domestic and imported materials, wages, contributions to pension and social insurance funds with norm c (being changed due to devaluation), amortization am_j and taxes which has been aggregated in groups with homogeneous devaluation behavior of their bases (value added - t_{DWj}, natural resources - t_{Rj}, excise and import duties - t_{IM} and others taxes - t_{INj}):

$$s_j = I_3 \cdot z_{30} \cdot n_{3,j} + I_5 \cdot z_{50} \cdot n_{5,j} + \left(I_{vj} + c\right) \cdot w_{j0} \cdot p_j + am_3 + t_{DWj0} \cdot I_{DWj} - t_{Rj0} - t_{INj0} \cdot I_{Wje1} + S_{jc0} \cdot K_{j0}/K_j, \quad (3)$$

where n_{3j}, n_{5j}, p_j - amount of domestic and imported materials and person-years required for j-th product unit production;

w_{j0} - average annual salary;

Index $_0$ corresponds to base period (before devaluation).

Net profit per unit of product which remains at the disposal of the company's owner depends on prices (1) and cost (3), on tax on profit t_{Dj} and on interest on loans for working capital t_{krj}:

$$d_3 = z_3 - s_3 - t_{FOj0} \cdot I_{vj} - t_{krj} \quad (4)$$

Predesigns on the model have shown that devaluation and inflation **always** reduce real GDP rather more than existing theories showed. To be assured in it, we have entered the best variant into the model: 1) production output is equal to sum of purchases of all consumers; 2) the model does not take into account imbalances in transition process during which the "invisible hand" of Adam Smith balances market, not immediately, but after many underproductions and overproductions of goods that will never find a buyer. This is done to maximize confidence in the negative effect of devaluation. If such "best" model shows a negative effect, in fact it could be only worse, but a positive result may be the same or substantially weakened, or not happen.

Model of j-th good purchase by k-th consumer K_{kj} is oriented on the price (1) and on specific k-th consumer income I_{Vk} (not on average CPI): the consumer demand curve shifts from the nominal price on specified income change (size of shift f_k can be varied).

On the supply side production is limited to the growth of interest on loans for working capital t_{krj} and its shortages, which caused by increasing cost I_{sj} due to devaluation, but supply is growing due to part d_{Kj} of emission EM_3 for the development of production:

$$K_{kj} = l_{kj} \cdot \left(z_k/\left(1 + f_k \cdot (I_{Vk} - 1)\right)\right)^{mk} \cdot \left(1 - h_j \cdot t_{krj}/t_{krj0}\right)/\left(1 + g_j \cdot \left(I_{sj} - 1\right)\right) \cdot \left(1 + d_{EM} \cdot EM_3 \cdot d_{Kj} \cdot ob/S_{j0}\right), \quad (5)$$
$$j = 1, 2_R, 4, k = 1, 2, 2_D, 2_R, 2_E, 3, 3_N, 3_H, 3_E, 4, 5, 5_N, 5_H, BG, PN, BD, DU$$

where ob - velocity of money.

First, we took the sedate demand functions, then - linear. Results were similar.

For tradable goods *2* the effect of substitution of import Im_{40} by output W_{20} in part r_2 is considered:

$$K_{2j}^{IM} = K_{2j} \cdot (1 + r_2 \cdot (1 - K_4/K_{40})) \cdot Im_{40}/W_{20} \quad (6)$$

The production output is made of j-th product sales (5) to all consumers, the whole economy output is made of all products.

Production of intermediate goods *3* and their import *5* are determined by demand of all 11 producers, export - of the outside world. When manufacturer buys his own goods, there is a vicious circle: the volume of purchase depends on his salary, but it – from manufacture volume equal to purchases volume. In the model there are many such recurrent equations' systems. They are solved iteratively: on the first step any values of all unknown variables are substituted in the equations

and the first results are defined. On the second step these first results are substituted in the equations and their second approximations are defined etc. The author did not investigate convergence of recurrent procedure, but already on 5-6th step the error did not exceed 0.001%.

We also have applied the same iterative process to the decision of equations' systems that is not recurrent and difficult for the decision; it has converged to the correct decision.

From this, it follows a proposal for the lazy: even if the method of solution of any system of equations is known but is hard enough, you cannot spend time on it, but easy to implement this iterative algorithm in Excel and get a solution quickly and without errors, that often encountered in the "manual" decision in the "*quadrature*". Even for experienced mathematicians it may be easier to use iteration than 1) to identify the appropriate method's suitability for this problem (i.e., to check the scope of application), and 2) to use it. If a method is not yet developed, the more so. The convergence of the process is also easier to identify every time than to prove it.

CPI is determined not for goods' "basket", but for all consumer goods (difference makes no more than 8–10%):

$$I_{sz} = (I_1 \cdot W_1 + I_2 \cdot W_2 + I_4 \cdot Im_{4I})/(W_1 + W_2 + Im_{4I}) \tag{7}$$

State revenues consist of tax and non-tax revenues and contributions to social insurance funds. Devaluation adds to these a variable part of emission:

$$\begin{aligned} D_{DU} = {} & I_V \cdot T_{FO0} + I_D \cdot T_{D0} + I_{DW} \cdot T_{DW0} + T_{R0} + I_W \cdot \cdot T_{IN0} + I_{IM} \\ & \cdot T_{IM0} + u_D \cdot EM_D + u_2 \cdot EM_2 + EM_{3DU}, \end{aligned} \tag{8}$$

where I_{DW}, I_{ChD}, I_W - indices of added value, net income and production throughout the country;

T_{FO} – income tax;

T_{IM} - excise and import duties.

Whereas inflation has been almost always an occurrence in Ukraine, devaluation happened only sometimes (moreover, a revaluation took place in 2001–2006). Therefore it is expediently to divide total emission on such parts:

1. The first one causes the devaluation *I*:

$$EM_D = (I - 1) \cdot IM_0/ob \tag{9}$$

Devaluation in turn causes inflation:

$$I_{szD} = 1 + EM_D \cdot ob/(W_0 + IM_0 - Ex_0) \tag{10}$$

2. the second one is related to non-devaluation inflation:

$$EM_2 = (I_{sz} - 1) \cdot (W_0 + IM_0 - Ex_0)/ob - EM_D \tag{11}$$

3. and the third one (as a part q_3 of *M2)* which government directs to social sector or to production as "short" investments that allow rapid growth according to a latest factor in (5):

$$EM_3 = q_3 \cdot M_2 \tag{12}$$

Trivial equations like $D_j = K_j \cdot d_j$ or *VVP = (V + D + AM + T)* are not given.

All parameters of the model are made variable. It gives the opportunity to investigate not only dependences, but their characters and also to define ranges of their invariance.

The model allows optimizing strategies of the 14 manufacturers (each or all of them) using major (maximum added value) and supplementary criteria (maximum gross profit, market expansion and many others) by the algorithm of the multi criteria compromise [33].

The model allows to study the devaluation dynamics of nominal and real indices for different goods and across the country: the cost, the gross and net profit, rate and the amount of wages, value added, production output, GDP, the share of wages in the cost, unemployment, pensions, tax and non-tax revenues of budget, salaries of budget employees, foreign exchange earnings from intermediate and consumer exports, physical volume of exports, physical volumes and currency expenses on intermediate and consumer imports, trade balance, the structure of export and import, the share of import in intermediate and final consumption, producer and consumer prices, manufacturing GDP per unit of intermediate consumption, which characterizes the ultimate operational efficiency of economy from the national point of view, efficiency of production of some goods from terms of other economic performers (of production owner - the ratio of gross or net income to capital cost, of employee - salary costs to working time, etc.), changes in the structure of contributions of different types of goods production in GDP and so on.

When modeling, you can change: price, salary and price elasticity of demand and supply for each product, the level of de- or revaluation, in- and deflation and the correlation between them, level and cost structure of each product (the share of wages, intermediate import, credit for working capital, etc.) rate loan, share of conditionally fixed costs, tax and deductions rate; exchange rate in the base period, the ratio between the cost of production, distribution and retail sales, population structure; the degree of influence of rate loan, excess emission, a shortage of working capital on the production; distribution of excess emission between the social sphere, "short" investments in the production of various goods (final or intermediate consumption or exports) and banks, the degree of import substitution of domestic products.

We proved the adequacy of the model by retrospective forecasting of the Ukrainian economy dynamics for 2008–2013: the resultative indicators calculated on the model have coincided with the real indicators with sufficient accuracy: deviations of the calculated legal GDP from the provided by the State Statistics Committee, are in [−0.7; 0.4%], of the gross profit - in [−1.8; 2.6%], of the issue - in [−9; 2.1%], of the salary - in [−2.9; 2%]. Therefore, there is reason to believe that the model calculations' accuracy is sufficient for further analysis and multivariate forecasts. The options below reflect the real-life dynamics of Ukraine's economy rather than the study of the Solow power function's mathematical properties, which is unlikely to reflect the real economy. Therefore, one has reason to trust our calculations.

To make the model suitable for other countries, you need to change its parameters and sometimes some its parts.

5. Analysis of the impact of credit on the economy of Ukraine

So, we are simulating the smooth development of the Ukrainian economy over 5 years at different levels of lending. In the sixth year, we stop lending and look how real GDP falls from the base year. If it falls hard, it will be a model of a financial crisis in a first approximation.

Due to the significant nonlinearity of the economy and our model, the same change of a particular factor in different economic situations (i.e., with varying values of other factors) gives different consequences. Therefore, we will get more accurate results if we study the element's influence in a situation close to real life. Therefore, we will accept the annual devaluation of the hryvnia by 10%, the annual growth of domestic prices for all goods and services 10%, external prices and physical volumes of legal and illegal exports and imports as in 2018. We will leave the distribution of loans between households and the non-financial sector, and their distribution for various purposes (to increase working capital, to invest in reducing material and/or labor costs per unit of traditional products; to invest in creating new varieties of goods that will be in high demand and sold at a higher price, for housing construction, etc.), as in 2018.

Scenario 1. Let the number of loans issued by the aggregate bank to the non-financial sector and households be four times less than the number of deposits placed by them in banks, be the same in all cycles, and is 5% of the 2018 outcome. In the coming years, the outcome will change, so loans share will be different.

Assume that there is no overproduction or underproduction, i.e., the full (including the shadow parts) production of consumer, intermediate, and investment goods and housing and their imports will exactly meet the demand for them.

Under such conditions, Ukraine's total real GDP (legal plus shadow) (TRGDP) will grow by 14.2% in 5 years; its amount will be UAH 16.03 trillion. The number of real wages in five years compared with the base year will increase by 16% (**Table 1**, first column). The latter indicator shows that while maintaining a constant real wage, the number of jobs will increase by 16% (if technological conditions permit).

To test if lending is excessive, that is, if it is not creating a financial bubble, we exclude borrowing in the sixth cycle. Compared to the base cycle, TRGDP not only did not fall but even increased by 3.5%. This means that the lending level of 5% of the issue (10.4% TRGDP) is safe, that is, one that does not create a dangerous financial bubble.

Scenario 2. Now let the number of loans is 10% of the 2018 issue (20.7% of the TRGDP). In the sixth cycle, when we excluded loans, TRGDP decreased by 0.8% compared to the base cycle (**Table 1**, second column). Even if stocks are sharply reduced, as was the case in 2008–2009, for example, by five times, the decrease will be only 0.81%. This is a tiny decrease, so the lending of 10% of output (20.7% of TRGDP) is safe.

Indicators	**Scenarios**				
	1	**2**	**3**	**4**	**5**
The share of loans in total output,%	5,0	10,0	15,0	20,0	25,0
Percentage of loans in TRGDP,%	10,4	20,7	31,1	41,5	51,8
The sum of TRGDP for five years, trillion UAH	16,03	17,37	18,72	20,07	22,98
Growth of TRGDP for five years,%	14,2	21,1	28,0	34,9	25,1
Inflation for five years,%	61	61	61	61	164
Increase in the number of investments for five years,%	6,9	9,9	12,8	15,8	19,8
Increase of the real salary for five years,%	16	23,1	31,8	39,9	11,9
The fall of TRGDP in the 6th cycle compared to the baseline,%	3,5	−0,8	−4,0	−6,3	−23,4

Table 1.
Development of Ukraine's economy at different levels of lending.

Scenario 3. Let the number of loans be 15% of the 2018 issue (31.1% of TRGDP). In the sixth cycle, when we excluded loans, TRGDP decreased by 4% (**Table 1**, third column). This is a small decrease, so the lending rate of 15% of output (31.1% of TRGDP) is also safe.

Scenario 4. If the amount of loans is 20% of the issue (41.5% of TRGDP), then in the sixth cycle TRGDP decreases by 6.3% (**Table 1**, fourth column). This is a considerable decrease but not catastrophic, so the lending of 20% of output (41.5% of TRGDP) can be considered more or less safe.

Scenario 5. If the amount of loans is 25% of the issue (51.8% of TRGDP), it exceeds the aggregate bank's number of deposits by 21.3%. Thus, the bank created an annual emission of 206595 million UAH. Due to the emission prices for all goods will rise. Inflation for five years will be 164%. We will accept the growth of the prices identical to all goods and services. In the first cycle, it will be 12.9%; in the following, it will be slightly lower due to the growth of output (and the volume of emissions remains the same for all cycles).

Due to rising prices, TRGDP will increase by only 25% in 5 years, while scenario four was increased by 35%. The increase in GDP for most goods and services will increase by 10–52%, but for exports of final and intermediate goods, it will decrease by 18.5% and 16.9%, respectively. The sum of real wages will increase by only 12%, while in scenario four they increased by 40% (**Table 1**, first column).

In the sixth cycle, TRGDP will decrease by 23.4% compared to the base cycle (**Table 1**, fifth column). Thus, the level of lending at 25% of output (51.8% of TRGDP) will undoubtedly create a devastating financial crisis. Thus, we can draw two conclusions: 1) the negative results from the increase in loans beat the positive ones, and 2) the negative effect from the price increase due to emission is the largest for export goods.

Scenario 6. Let in scenario 2 deposits become 20% less than loans. This creates an annual emission of UAH 78,377 million, which causes prices to increase by 5.43%. Because of this, inflation for five years will not be 61%, as in scenario 2, but 99%, TRGDP for five years will increase not by 21.1%, but only by 9.2%, the

Indicators	**Scenarios**				
	6	**7**	**8**	**9**	**10**
	Deposits fewer loans by 20%	**The technical productivity of investment is 1**			**The productivity 2**
The share of loans in total output,%	10,0	15,0	10,0	25,0	25,0
Percentage of loans in TRGDP,%	20,7	31,1	20,7	51,8	51,8
The sum of TRGDP for five years, trillion UAH	17,5	20,8	18,39	23,97	25,18
Growth of TRGDP for five years,%	9,2	6,5	31,4	29,5	32,0
Inflation for five years,%	99	224	61	164,3	165,5
Increase in the number of investments for five years	10,0	14,5	10,1	19,9	20,1
Increase of the real salary for five years,%	4,7	−9,7	35,0	16,5	22,3
The fall of TRGDP in the 6th cycle compared to the baseline,%	−12,2	−21,6	9,6	−19,6	−12,9

Table 2.
Development of Ukraine's economy in different economic situations.

number of real wages for five years will grow not by 23.1%, but only at 4.7%. In the sixth cycle, TRGDP will decrease by 12.2% instead of 0.8% compared to the base cycle (**Table 2**, first column).

Scenario 7. Let in scenario 6, the number of loans is 15% of the 2018 issue (31.1% of the TRGDP). Compared to scenario 3, the situation worsened similarly to scenario 6 (**Table 2**, second column). Thus, the price increases due to emission worsen the economic situation more than loans improve. The risk of a financial crisis occurs at lower levels of lending.

These seven scenarios took place at very low technical productivity of investment (0.2) and investment efficiency, typical for Ukraine. The low efficiency of investments in Ukraine is noted by all experts, for example, I. Yu. Egorov: « ... the country from year to year lost the positions in the markets of high-tech goods and services which in the modern world develop most dynamically ... In the total amount of costs for production and sale of industrial products, innovation did not exceed 1.0–1.6% (in 2005–2012). With such volumes of funding, it is almost impossible to expand innovative technological reproduction of industrial production and restructure the economy based on scientific and technical achievements ... Relevant indicators in OECD countries in 2012 were: 3.2% (Germany), 4.5% (South Korea), 5.8% (Canada), 6.7% (Sweden) (Egorov, 2015).

Let us repeat some of the scenarios at the technical productivity of investment 1.

Scenario 8. We repeat Scenario 2. As we can see from **Table 2** (column 3), the situation has improved: in the sixth cycle, after excluding loans, TRGDP increased by 9.6%, so at high the technical productivity of investment, the level of lending 10% of the issue (20.7% of TRGDP) is safe. Note that the efficiency of investment by GDP increased significantly - in the fifth cycle, it reached 15%, while at the efficiency of investment, 0.2 was negative.

Scenario 9. We repeat Scenario 3. The situation has improved again (**Table 2**, fourth column). However, even with the technical productivity of investment 1, the lending level of 15% of the issue (31.1% of TRGDP) cannot be considered safe. The safety requires that the technical productivity of investment be 2 (**Table 2**, fifth column).

Indicators	**Scenarios**	
	10	**11**
	Every year the loan grows by 1%	**In the first year the credit grows by 10.16%**
The share of loans in total output,%	10,0	10,16
Percentage of loans in TRVVP,%	20,7	21,1
The amount of TRVVP for five years, trillion. UAH	17,44	17,42
Growth of TRVVP for five years,%	21,8	21,3
Inflation for five years	61	61
Increase in the number of investments for five years,%	10,0	10,0
Increase of the real salary for five years,%	22,8	22,5
The fall of TRVVP in the 6th cycle compared to the baseline,%	−1,4	−1,2

Table 3.
Development of Ukraine's economy with a gradual and abrupt credit the methods.

Indicators	Scenarios			
	14	15	16	17
	Every year exports grow by 2%		Every year exports fall by 2%	
The share of loans in total output,%	15,0	25,0	20,0	25,0
Percentage of loans in TRVVP,%	31,1	51,8	41,5	51,8
The amount of TRVVP for five years, trillion. UAH	20,2	23,4	18,9	22,39
Growth of TRVVP for five years,%	49,0	31,9	21,9	21,4
Inflation for five years	61,1	163,0	61,1	163
Increase in the number of investments for five years,%	13,1	20,4	15,5	20,1
Increase of the real salary for five years,%	50,5	14,7	23,4	4,3
The fall of TRVVP in the 6th cycle compared to the baseline,%	23,1	−13,3	−16,7	−23,8

Table 4.
Development of Ukraine's economy at different levels of lending with changes in exports.

Scenario 11. We repeat Scenario 3 but the credit increases by 1% for each cycle. TRGDP for five cycles will increase slightly more than in Scenario 3 - by 9.4% but a decrease in the sixth cycle more - by 20.5 and 13% (**Table 3**, first column).

To quickly bring the economy out of the recession, a policy of monetary expansion is used, that is, they rapidly increase the money supply. Let us try to make such an expansion in credit.

Scenario 12. Let the amount of loans in the first cycle is immediately 10.16% of the issue, i.e., up to 10% is added the number of loan increments for five years. In subsequent cycles, the amount of loans is 10% of output. The situation has improved: although the TRGDP increased by only 2.7% in 5 years-cycles, in the sixth cycle, it fell much less - by 11.4 and 9% (**Table 3**, second column). So expansion helps.

In all previous scenarios, exports were unchanged.

Scenarios 13 and 14. Let us repeat scenarios 3 and 5 in conditions when exports grow by 2% every year. As can be seen from **Table 4** (columns 1–2), the situation has significantly improved: the growth of TRGDP and the amount of real wages for five cycles has increased more than in scenarios 3 and 5; in the sixth cycle, when we excluded loans, TRGDP at the lending level of 15% of output did not fall but increased by 23%, and at the lending level of 25% of output increased not by 23.4% but by 13.3%, so the increase in exports allows higher levels of lending without risk of crisis.

Scenarios 15 and 16. Let us repeat Scenarios 4 and 5 in conditions where exports decrease by 2% each year. The situation has significantly deteriorated: the increases in TRGDP and the number of real wages for five cycles have become less than in Scenarios 4 and 5; in the sixth cycle, TRGDP fell more (**Table 4**, columns 3–4), so the decline in exports brings the risk of crisis closer to lower levels of lending.

6. Conclusions

1. The use of the simulation approach has significantly increased our model's adequacy to the Ukrainian economy and significantly expanded its analytical capabilities.

2. The application of the model developed by the author to analyze the impact of excessive credit on the economy made it possible to significantly expand the variety of economic situations and research options, the intervals of changes in factors.

3. The introduction of the concept of technical productivity of investment provided an opportunity to characterize them from a macroeconomic point of view, namely - their ability to reduce the rate of material and/or labor costs, which increases the enterprise's competitiveness. The concept of the technical productivity of investment links it with the technical progress, and with GDP growth.

4. The proposal to measure the efficiency of investments in terms of all added-value provided an opportunity to reflect their effectiveness for the state and reflect the business owner's far-sighted interests in minimizing the turnover of skilled workers.

5. The proposal to measure the level of lending by the share of the loan amount not in GDP but in output increased the analysis's accuracy.

6. For the current state of Ukraine's economy, lending of 20% of output in 2018 (41.5% of TRGDP) is almost dangerous, and 25% of production (51.8% of TRGDP) certainly creates a devastating financial crisis.

7. If the loan amount exceeds the number of deposits received by the aggregated bank, creating emissions. The price increase due to emission is harmful, especially for export goods. The risk of a financial crisis occurs at lower levels of lending.

8. Increasing the technical productivity of investment improves the situation. The risk of a financial crisis occurs at higher levels of lending.

9. Increasing the number of loans in the first cycle gives better results than "stretching" them during all cycles.

10. Increased exports allow the use of higher levels of credit without the risk of crisis. With declining exports, the risk of a crisis occurs at lower levels of credit.

Conflict of interest

The authors declare no conflict of interest.

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