ISSN 1648-9098
Ekonomika ir vadyba: aktualijos ir perspektyvos. 2010. 2 (18). 104–114

INVESTMENTS MODEL DEVELOPMENT WITH THE SYSTEM DYNAMIC METHOD

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Abstract

In the paper the model of macroeconomic turnover and its possibilities for investments modelling are shown.

The model consists of four blocks: in the first the theoretical model is described. In the second the model is reflected in accordance with the requirements of system dynamics method, there are shown included influences, intercommunications and equalizations. The third block examines demand and supply model for capital and investments. The fourth part complements previous parts, describes additional indexes.

The method is offered for using both in forecasting and in teaching.

Keywords: investment, aggregated demand, macroeconomics, simulation model, system dynamics.

Introduction

Research problem, novelty and relevance

Research problem. Development of economy of any country depends not only on GDP, consumption, export, but also on investments. In Latvia in 2009 investment decrease was near 40%. One of the possible reasons for decrease may be related to investment boom in Latvia in 2007-2008. In stable development situation it is possible to use for investment forecasting statistics-based forecasting methods, but in changes these methods do not work. In changeable situation is necessary to use for forecasting more powerful forecasting methods.

Research novelty. In reality macroeconomic forecasting models in system dynamics created by economists are very rare. Mostly papers of this type are written by specialists of mathematics; therefore they are not very popular among economists. The first global model was developed by Forrester, but it was not economic model, but World dynamics model. Now better macroeconomic models are developed by Kaoru Yamaguchi (Japan), David Wheat (Norway). The general part of Yamaguchi model is related to financial markets and their place in macroeconomic turnover. Wheat model is developed in theoretical form, for teaching. Each model is related with its author and is unique. Each author developed the model for specific condition or proceeding from personal understanding of a problem. Novelty of this paper is related to special role of investment in macroeconomic turnover. Investments determine development of economy not only for current moment, but also for years to come.

Research relevance. Effective forecasting methods include the creating of macroeconomic environment model and its uses for different indexes simulation, including investments. Traditional approach to macroeconomic model development is based on econometric method. But in very changeable condition this method does not work either. This happens because the method uses defined statistical relation between indexes, but in boom or crisis time, it changes, too. System dynamics method is rarely used, new method for investments forecasting and modelling. Its advantage is in possibility to use it in non-stable, rapidly changing economic conditions, when forecasting with traditional quantitative methods is problematic. System dynamics method does not use statistical relation, but uses analytical or logical relations system, which shows excellent forecasting results in any condition.

Research subject

Research subject is macroeconomic and investment modelling system dynamics model.

Research aim

Research aim is to show macroeconomic and investment modelling system dynamics model.

Research objectives

Research objectives are to explain system dynamics method and it terminology, show income and goods circulation flow theoretical model, extend it to system dynamics model, specify investments role in macroeconomic system dynamics model, show additional parameters needed for functioning of the model, analyze the model and method possibilities in teaching economic theory.

Research methods

The paper shows use of system dynamics method for macroeconomic and investment forecasting. This method is chosen for problem solving because it has advantages in comparison with traditional methods. In changes, boom and crisis time traditional methods do not serve the purpose. But system dynamics method is intended for long time forecasting in changing, indefinite conditions.

Theoretical basis of system dynamics method and it use for macro process forecasting

System dynamics (systems approach, systems thinking) is an approach to understanding the behaviour of complex systems over time. It deals with internal feedback loops and time delays that affect the behaviour of the entire system. In economics, system dynamics deals with the economic impact on the set of economic relationships among objects of study. Predicting economic behaviour of the object, the main task in the model is to reflect the real world analytically as correctly as possible; it is a challenge to any economist. Commonly used econometric methods are based on a statistically determined relationship/correlation, but system dynamics reflects analytically defined correlation results, and ultimately it could act in circumstances with changing statistical value of indicators. In other words, system dynamics answer the question of what the development should be, taking into account relations in the model.

System dynamics approach was created in the last century (in the end of 70s – beginning of 80s) and developed by Forrester. Economic forecasting models in system dynamics created by economists are very rare, books of this type are written mostly by mathematics specialists, therefore they are not very popular among economists (Turnovsky, 2000; Sargent, 1987). Development of each method depends on strong personalities who use this method. For traditional sciences its development can depend on number of it users (adopters). But in system dynamics we cannot tell that there are many adopters, now in the World, in system dynamics society there are less than a thousand members, and nearly ¾ of them are economists (others use this method in physics, engineering, etc.). In small countries, such as the Baltic States, this method is not known very much, for example, in Latvia there are only two scientists who use this method, one physicist and one economist. In Germany there are nearly 60 specialists in system dynamics (including students), which is very little for developed, knowledge-based country. With small number of scientists, amount of researches and publications on system dynamics is limited, but each of them has good response. Figure 1 shows scientists' response (citations) to basic system dynamics publications.

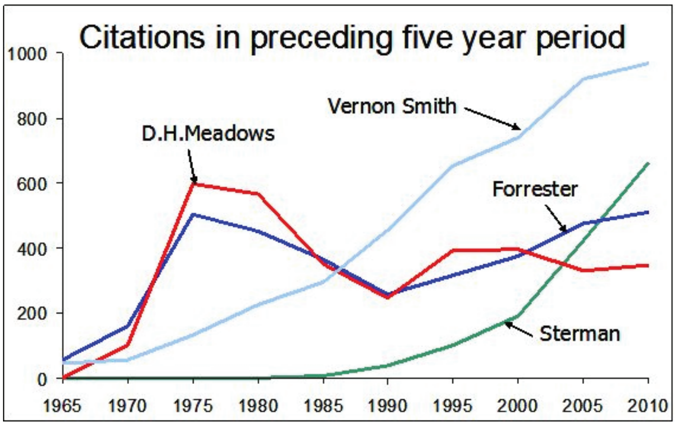

Fig. 1. Citations in system dynamics in preceding five year periods (Moxnes, 2009)

Peak in citations of Forrester and Meadows (first – author of *Limits to Growth, 1972*) was after the publications of *World Dynamics, 1971* and *Limits to Growth, 1972*. Sterman's career started later and citations of his works show stronger growth than of Forrester and Meadows. They are three better authors in system dynamics. It is interesting to compare Sterman's citations to citations of 2002 Nobel Prize laureate in economics Vernon Smith. Sterman's citations in 2009 are very close to Smith's citations in 2000. This means that for specialists their works may be equal. Currently the best book on system dynamics is by Sterman (Sterman, 2000). Unfortunately this book describes system dynamics approach at the business level or at the micro level. At the macro level there are not many publications, but different countries (Japan, Norway and Latvia) are preparing for publication some macroeconomic model in system dynamics. Now better macroeconomic models are developed by Yamaguchi (Japan), Wheat (Norway). General part of Yamaguchi model is related to financial markets and their place in macroeconomic turnover. Wheat model is developed in theoretical form, for teaching. The lack of research in economics with system dynamics method gives unlimited possibilities for theory development.

In Latvia, system dynamics method has shown the best results in the construction sector, which reveals that the construction boom has no economic basis, but there are speculative reasons (Skribans, 2002). This method has also been used to estimate the credit burden potential of Latvian population (Skribans, 2008a), study the labour and wage market in relation to migration from Latvia (Skribans, 2009a), model the mobile phone market development in Latvia (Skribans, 2008b), etc. The method has great potential in economic forecasting, however in Latvia its development is hindered by, firstly, high start-up costs of adoption (system dynamics software is rather expensive, 10 thousand. USD per license is not the upper limit). And, secondly, there are almost no lecturers in Latvia who are willing to teach courses on system dynamics. Positive side of the method's development is that Latvian firms already see its advantages and order researches with this approach at Riga Technical University. Therefore, with the aim of reflecting the opportunities and advantages of the method in investment modelling, the paper sets the task to explain the nature of the method, what is done in this section.

This section describes the basic elements of system dynamics mentioned in Sterman's book and further an investment forecasting model is created on the basis of these elements. It is important to note that the elements described below are widely used, but they could be somewhat different in books by other authors or other recently published books. This is related to changes over time, technology development or alternative computer applications.

Graphical objects of system dynamics consist of the following elements: stocks, physical (material) flows, non-material and information flows, flow regulators and converters. They are reflected in Figure 2.

⟹	material flows;	☁	external environment;
→	non-material and information flows;	**A**	stock "A";
<C>	converter or stock "C" from the related sub models;	B	converter "B".
⧗	material flow regulator.		

Fig. 2. System dynamics elements

The elements consist of the following: collected stocks materials, money, people, reflected stock of material, stock raising and using opportunities. Stock can be entered and exited by material flows (cash, buildings, people, etc.). Physical inflows and/or outflows determine the stock increase and/or decrease. Stock is characterized by initial level and maximum capacity; all other stages of stock are forecasting objects. Material flows can enter/exit stocks and/or external environment. Amount of physical flow can be constant or variable over time, it is set by regulators. Information and transmission of regularities is done by converters and information flows. Information flows transfer the information and/or operation from stocks, material flows, regulators and converters to the material flows, regulators and converters. In this case, converters process the action or information. Converters can not only process information, transmit it, but also store it. The external environment is an artificial object that can both supply and consume everything. Figure 3 reflects an example of dynamics model which combines all the above-mentioned elements.

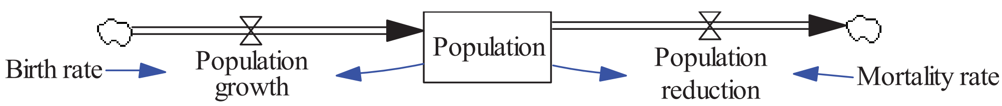

Fig. 3. Example system dynamics model for Latvian population growth

Graphic images in dynamics modelling are usually duplicated by mathematical formulas.

Population = INTEGRAL (Population growth - Population reduction, 2261294)
*Population growth = Population * Birth rates* (1)
*Population reduction = Population * Mortality rate*
Birth rate = 1.4 / 1000
Mortality rate = 13.7 / 1000

Formula (1) reflects the data from model in Figure 3. This is a simple model and it serves as an example of system dynamics model. In the model one stock shows population. Two material flows with their regulators indicate growth and decrease. Population growth and decrease depend on the population and corresponding coefficients, as shown by the information flows in Figure 3. The image only reflects that one element is connected with another, but the formulas specify relationship among elements. The model also has two converters: the birth and mortality rates. Simple formulas are enclosed in these ratios, but they could also include variables complex.

Using of dynamics modelling techniques presented in this section can create any degree of complexity of forecasting models, testing with it various economic theories and assumptions. The offered investments forecasting model is shown below.

Macroeconomic system dynamics model general scheme

The development of macroeconomic or sector model is an ongoing scientific work, which could not be done instantaneously, without careful preparation. Also, this paper presents a model produced in different years. The first preparatory phase of the model was completed in 2008. The author of this paper, together with Dr.habil.oec. Počs, conducted a research project on Latvian business competitiveness. The research analyzed Latvian economy in subsectors, and, by combining them and adding some sub-blocks, system dynamics model for business competitiveness was designed (Skribans, 2010). At the beginning of 2009, considering the rapid change in the national economy as well as tax policy changes, the model was adapted for tax revenue and state budget forecasting. The model has good forecasting quality, but taking into account that the model brings together all sectors of the economy, further use of the model requires significant work, updating and maintaining of databases. In addition, the model of mutual correlations is so diverse and wide that the model adoption also takes some time. Therefore the model is used by narrow circle of specialists. At the beginning of 2009 the author of this paper made the first attempt to develop a model that would be easy and comprehensive for all economists (Skribans, 2009b). Unfortunately, this model was not published, but this paper slightly talks about its performance. Since that time the model was significantly revised, it contains more correlations, and is more detailed. But compared to the model of 2008, it is no longer possible to estimate the development of individual economic sectors. A general scheme of the model is shown in Figure 4.

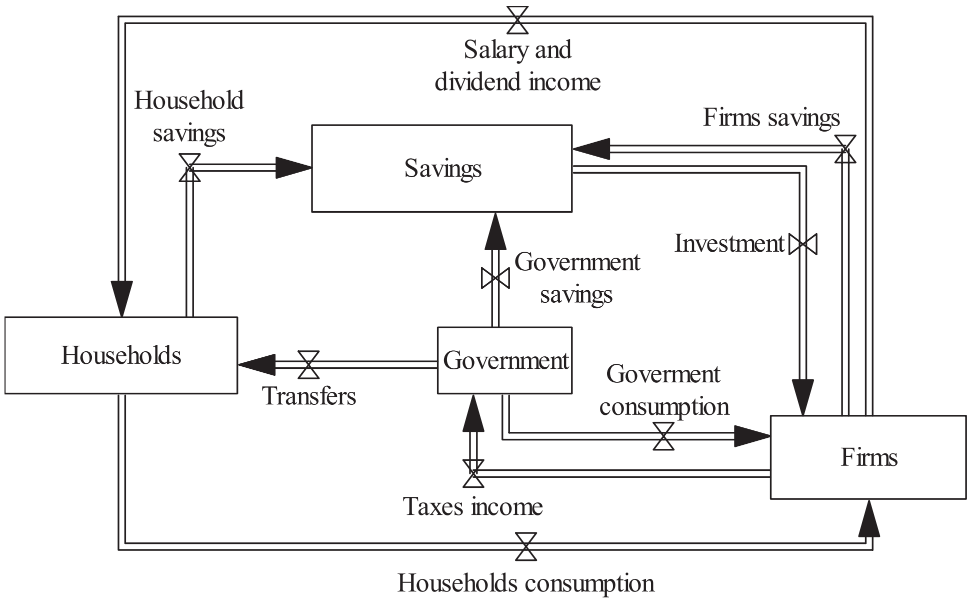

Fig. 4. General scheme of macroeconomic system dynamics model

Figure 4 shows that the system dynamics model is based on the model of macroeconomic flows. The base of the model consists of households and firms. Households own all the resources. They supply labour force, material and other resources. Households create demand and consumption of consumer goods and services. In the model household demand is described as *Households consumption*, i.e., the sum that firms receive from households in exchange for manufactured products. Households pay for the goods at the expense of income received from firms for use of labour, land and other production factors. One of the specific types of income is dividends that households receive from firms for the use of the business factors. All households revenues obtained from firms are summed up into one flow, which is marked as *Salary and dividend income*, there is underlined the importance of wage income to households, and importance of dividends to the firms.

Not only households and firms, but also the savings are reflected in the common framework. Households could spend a part of their income on consumption, and another part could be saved. Also they could spend more than they receive from firms, paying the difference with credits. It is a negative form of savings. In the general model both household savings and household loans are reflected in one flow, which is designated as the *Households savings*. Household savings together with firms' and government savings form total savings, in the model denoted as *Savings*. Unlike households', firms' savings and their use are reflected in two flows, i.e., *Firms savings* and *Investment*. According to economic theory, the amount of total investment should comply with amount of total savings. The proposed model allows realizing this principle. It is also possible to add external environment block, through which it is possible to increase both the amount of investment in economy, and household consumption. This paragraph also refers to the government savings. In the model it is the total balance of government savings and loans. Government savings, the same as household and business savings, impact total savings. Considering government's special role in the macroeconomic turnover model, government's action is discussed separately.

The government is another subject in the macroeconomic turnover model. Its role is to stabilise the economic situation and fulfil general social interests. The government carries out its tasks by collecting taxes, paying transfers to citizens and commissioning various products and services to firms. In the best case, the amount of collected taxes should match the amount of transfers and public procurement, in such a case the government has no loans and no savings. If spending exceeds the income, government has to borrow money, or make savings. Government related flows in the model are referred to as *Transfers* – net transfers paid to households, Government savings, Government consumption and Taxes income.

From economist's point of view, this description is not a novelty; it can be seen in different books on economics (Долан and Лидсей, 1994). The element of novelty is related to the creation of mathematical formulas in the system dynamics model. Analyzed correlations are very complicated for traditional economic forecasting. There are many reflective connections that are not possible to describe using linear or similar equations. The described turnover in the system dynamics model goes from theoretical to real economic forecasting circles. A more detailed description of these equations is made in the following section.

Advanced macroeconomic system dynamics model

The model discussed in the previous chapters is supplemented with influencing parameters and equations, and is reflected in Figure 5.

Figure 5 shows that the practical realization of the system dynamics model is repeating Figure 4 stock and flows. The aim of this section is to describe and explain the model forming relationships. It is important to note that Figure 5 is supplemented with stock – *Inventories*, its forming flows, *GDP*, *Aggregate demand*; and households stock is supplemented with flow – *Cash withdrawals*. This is discussed further in the article.

The first stage to explain Figure 5 and its forming equations is a description of stocks. The equations show that volume of stocks is calculated from the initial volume, integral from incoming and outgoing flow difference. Actions of stocks and flows were generally described in the previous section; therefore here are reflected only previously not described stocks and flows. First of all, the flow – cash withdrawals from households – has been established to display the amount of money that households withdraw from economical flow. It complements the household savings flow. The household savings flow is made savings, which later could be used for investment or other purposes, but the cash withdrawals create household savings that do not participate in the turnover, but this money could be used if households get in financial difficulties.

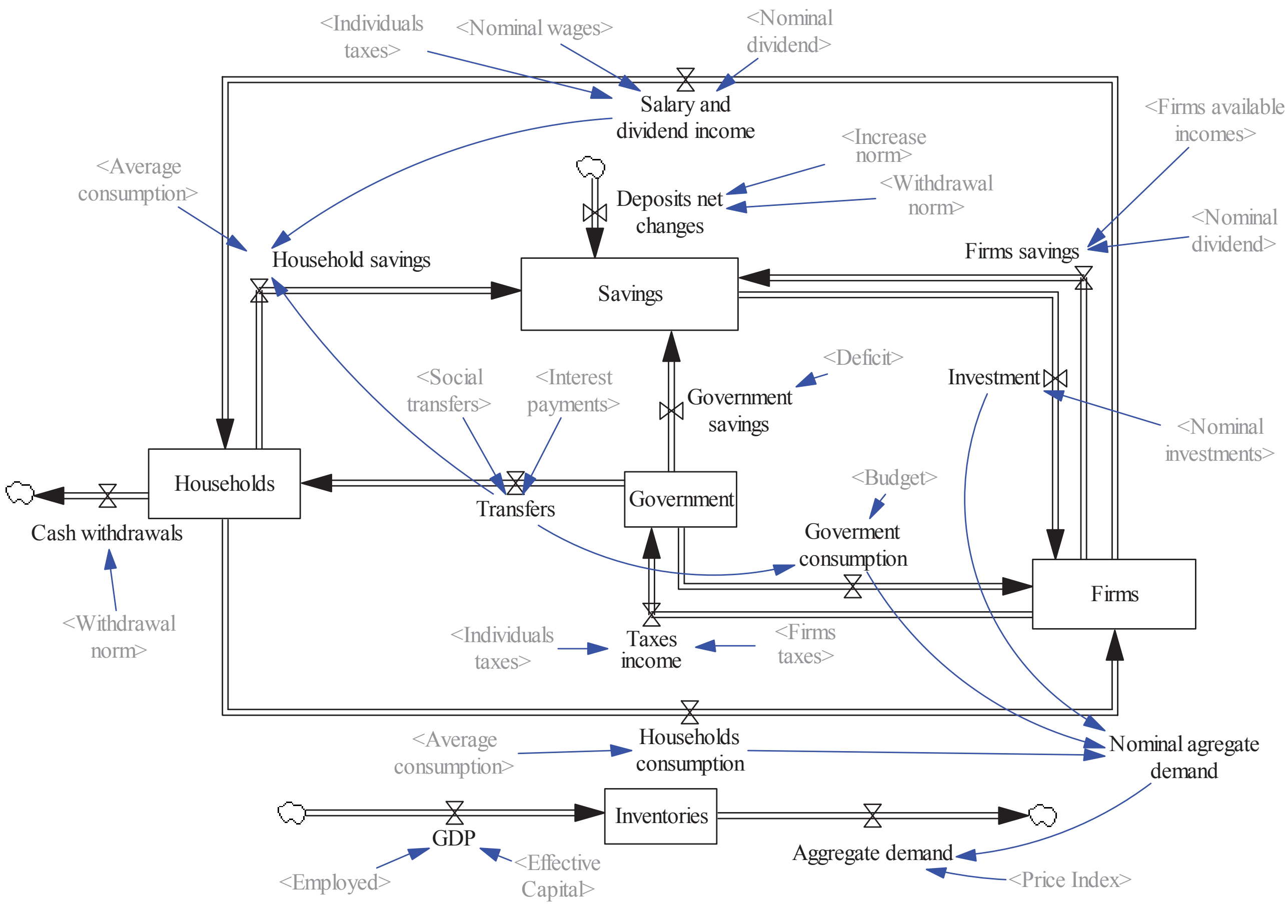

Fig. 5. Practical realization of the system dynamics model

In accordance with Figure 5, system dynamics formulas are formed.

Households = INTEG (Salary and dividend income + Transfers - Households consumption - Household savings - Cash withdrawals, initial level) (2)

Firms = INTEG (Investment + Households consumption + Government consumption - Salary and dividend income – Taxes income – Firms savings, initial level)

Savings = INTEG (Firms savings + Households savings + Deposits net changes + Government savings – Investments, initial level)

Government = INTEG (Taxes income - Transfers - Government savings - Government consumption, initial level)

Inventories = INTEG (GDP - Aggregate demand, initial level)

*GDP = (Employed ^ Production function coefficient) * (Effective Capital ^ (1 - Production function coefficient))*

Aggregate demand = Nominal aggregate demand / (Price Index / 100)

Nominal aggregate demand = Households consumption + Government consumption + Investment

Salary and dividend income = Nominal wages + Nominal dividend - Individuals taxes

Taxes income = Individuals taxes + Firms taxes

Firms savings = Firms available incomes - Nominal dividend

Households savings = Transfers + Salary and dividend income - Average consumption

Deposits net changes = Increase norm - Withdrawal norm

Transfers = Social transfers + Interest payments

Government consumption = Budget - Transfers

Households consumption = Average consumption

Cash withdrawals = Withdrawal norm

Investments = Nominal investments

Government savings = - Deficit

Where: INTEG (a, b) – the integral from a; in starting point, where it is impossible to calculate the integral, the function adopted b value.

Substantial improvement is associated with the stock – *Inventories*. Firstly, it reflects inventories in system and, secondly, it reflects gross domestic product (*GDP*) from production and expenditure side. In short-term production of goods may not match the consumption, in the given circumstances material stocks are growing or decreasing. Modifications of inventories could be covered with the external environment (international trade). Thus, in the model inventories are complemented by GDP, which is the total value of all goods and services produced in state. GDP model is calculated using Kobb-Douglas production function (see Equations 2). GDP depends on the labour and capital use intensity. In the model, they are shown as *Employed* and *Effective capital*. Variables – employees and effective capital – are not included in the classical macro economic flow, they are not reflected in the basic section of the model, but it is indicated that they are from the related sub-model. Unfortunately, due to the limited number of pages it is not possible to show all sub-models and their variables, so the variables of the related subsections will not be discussed in the paper. Next inventories related flow is aggregated demand; usually it is estimated GDP from expenditure side. In the model the aggregate demand is analyzed considering price changes. The *Price index* from sub-model and *Nominal aggregate demand* form calculation of aggregate demand. Aggregate demand is calculated as nominal aggregate demand divided by the price index (see Equations 2). Nominal aggregate demand, according to the economic theory, consists of household consumption, government consumption and investment; it is calculated in the model in the same way. The model shows closed economic system, and the external environment (or international trade) is not shown in the paper.

Further we will discuss the model forming flows. From the author's point of view, all other equations reflected in the model are simple; it is no longer necessary to explain them. For example, salary and dividend income flow is equal to the sum of nominal wages and nominal dividends minus personal taxes, as shown in Figure 5 and its equations. Problems could arise if the model equations show that some indicator is influenced only by one parameter. For example, households consumption is equal to the average consumption or government savings are equal to the minus government deficit. That is due to the fact that in the present basic model these values are not defined. They are defined in another sub-model; and according to the above mentioned limitation will not be reviewed in the paper.

Taking into account that paper theme is restricted to investments, further in the work investments sub-model is examined.

Investments model

In sub-model creation one important role is to understand the concept of investments. In theoretical macroeconomics they are understood as production of products, which will not be spent, but will be used in the future. Usually it extends in money expression. This definition is clear and needs no explanations, but further it is offered to look at it from another point of view, not from the investment definition point of view, but from that of consumer products. Or answer a question why investments are necessary for production of consumer goods.

So, in order to produce goods, resources are necessary. They can be acquired by using capital. Capital is also necessary in production process. Accordingly, one of the alternative definitions of investments can be the following: investment is production capital increase in the economic system. Accordingly, for estimating of increase in production capital the comprehensive analysis of factors influencing capital actions (increase and decrease) is necessary.

First of all, let us agree that demand expected in the long run is known. In each economic system it can be characterized with the Leontief production function coefficients, which stipulate production resource and output correlations. Having taken capital and output correlations together with the long run expected demand it is possible to estimate amount of capital which allows producing according to demand. Next, by knowing desired and actual capital it is possible to determine lack of capital. It is important to retreat from the above-mentioned idea by the author and it should be explained and reminded that it is necessary to analyse not only needs and actual capital, but also the capital that leaves the system, it can be called a capital decrease. Capital decrease is constrained with limited life time of capital. Investing means each investor plans to get means back. Accordingly with it, in the state, it is possible to calculate the average investment time, or capital average life time. The invested capital leaves system after its average life time. Accordingly, on this sum it is necessary to attract capital, let provide output level. Together with required and actual capital, capital decrease stipulates lack of capital. Also, if we take into account capital decreasing, in future it will allow calculating net capital changes.

Knowing the lack of capital, it is possible to attract capital. In reality, it is not possible to attract capital immediately, but it can be done after some time. Furthermore, capital attraction is possible only if there are savings the system. The described relations are represented in graphical form in Figure 6.

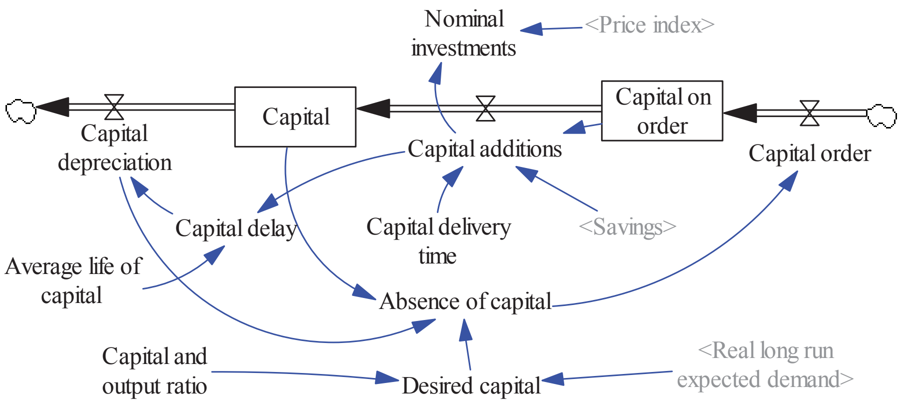

Fig. 6 Investments model

Accordingly with Figure 6, system dynamics formulas are formed.

Capital = INTEG (Capital additions - Capital depreciation, initial level) (3)
Capital depreciation = Capital delay
Capital additions = MAX (0, MIN (Savings, Capital on order / Capital delivery time))
Capital on order = INTEG (Capital order - Capital additions, initial level)
Capital order = Absence of capital
Capital delay = DELAY FIXED (Capital additions, Capital delivery time, Capital / Average life of capital)
Absence of capital = Desired capital + Capital depreciation - Capital
*Desired capital = Real long run expected demand * Capital and output ratio*
*Nominal investments = Capital additions * (Price index / 100)*

Where: MAX (a, b) – logical choice operator, return maximal value of a or b;
MIN (a, b) – logical choice operator, return minimal value of a or b;
DELAY FIXED (a, t, b) – time delay operator, delay a at time t, before it, b is used.

In general, relations represented in Figure 6 were analysed beforehand. Separate indicators, such as *Average life of capital*, *Capital and output ratio*, *Capital delivery time* can be taken as fixed for different states. In a short-run this is in accordance with real life. These indicators theoretically can change in a long-run, but in a short-run their changes are not visible.

It is necessary to explain equalizations in Figure 6. It is evident that for capital increase is applied expression Max (0, (Min (a, b)). First of all, suppose capital increase is positive (maximal in comparison to zero) and, secondly, suppose select a capital increase less from savings (a) and from ordered capital (b). Theoretically, in case of diminishing populations, demand can diminish. In such circumstances use of capital must decrease. But its decrease will occur gradually, taken into account *Average life of capital*. Next argument for necessity of this limitation is that investment cannot be negative. Positive capital increase is provided by operator Max (0, Y). In case of declining demand this model can estimate *Effective capital*, i.e. such capital that corresponds to a new, diminished demand taking into account Leontief production function. Operator Min (a, b) provides logical choice between an investment volume: there is no need to add more capital than is ordered and it is impossible to add any more than are in savings. All other equalizations are simple and do not require additional explanations.

It is necessary to talk about relation of investments sub-block to basic model and other model indicators. From general scheme, analysing Figure 5, conclusion can be drawn that investments are possible only if there are savings in the system. Accordingly, in Figure 6 a variable *Savings* from basic model can be seen. Also, *Price index* was already mentioned in the basic model. Variable *Real long run expected demand* is from expected demand sub-model and it will be examined later.

Expected demand

Determination of expected demand is based on estimation of aggregate demand, material inventories and on expected time of their changes. This model is represented in Figure 7.

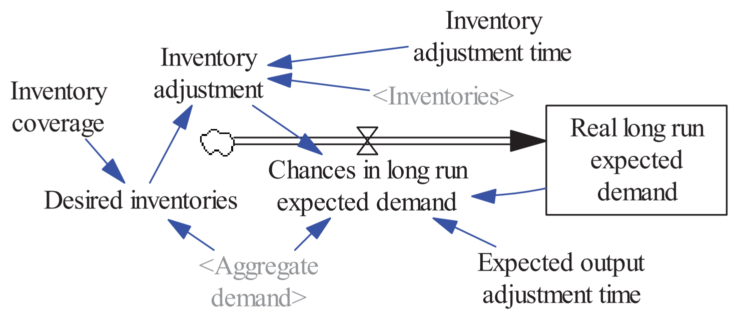

Fig. 7 Expected demand model

Accordingly with Figure 7, system dynamics formulas are formed.

Real long run expected demand = INTEG (Changes in long run expected demand, initial level) (4)
Changes in long run expected demand = (Aggregate demand + Inventory adjustment - Real long run expected demand) / Expected output adjustment time
Inventory adjustment = (Desired inventories - Inventories) / Inventory adjustment time
*Desired inventories = Aggregate demand * Inventory coverage*

The *aggregate demand* and *Inventories*, which are examined beforehand in general model, serve for expected demand model as the start point. Times of changes, also *Material coverage*, are fixed coefficients that can be calculated for each state separately. Coefficient *Material coverage* shows demand correlation between material inventories and aggregate demand. This coefficient very slightly changes over time, therefore for short and middle term forecasting it is taken as fixed. If aggregate demand changes, then according to this coefficient it is possible to calculate desirable materials inventories. From required inventories, taking into account actual inventories and time of their changes, it is possible to calculate the changes of the inventories. Inventories changes, aggregate demand and time of output change in aggregate forms changes in expected demand. Taking into account changes in expected demand and a previous period expected demand, it possible to calculate expected demand.

Alternative application of the model

Use of the model in investment forecasting is not the only way of model application. System dynamics could be used not only in economic forecasting, but also in student teaching, lecturers' qualification raising, etc. Unfortunately, this part of system dynamics is not developed in Latvia. Researches show (Wheat, 2007) that students choose to acquire knowledge of macroeconomics using the system dynamics method rather than traditional methods. This is related to the transparency of the method, students do not study statistics, analytical theoretical methods, but with real data they make sure that the change of one parameter could affect macroeconomic flows throughout the system. Consequently, compared with traditional methods of training, the method based on system dynamics approach yield better results, students show better understanding of the macroeconomic processes (Wheat, 2007). Hopefully the system dynamics model will soon be used in Latvia for both forecasting macroeconomic processes and teaching at higher education institutions.

Conclusions

1. In the paper the system dynamics model of macroeconomic and investment modelling is worked out. The research aim is achieved. All research objectives are reached: system dynamics method and its terminology are explained; the circulation flow model is shown both theoretically and in system dynamics form; investments role and additional parameters are shown separately; possibilities of the model and method in teaching economic theory are analyzed.
2. The represented model is produced only in a theoretical form, it is not possible with it to represent the results of operation of the model. To finish the model it is necessary to do national economy analysis (it is possible to do for any country), calculate separate fixed coefficients. The previously done researches on development of models with a system dynamics method in Latvia in construction sector (Skribans, 2002), in population's potential credit burden estimation (Skribans, 2008a), in mobile phone market analysis (Skribans, 2008b), in migration, labour and wage market research (Skribans, 2009a), and in national business competitiveness study (Skribans, 2010) confirm the conclusion drawn in the paper that in the Baltic States,

for forecasting economic processes, this method is more appropriate than others.

3. The use of the model in investment forecasting is not the only way of model application. System dynamics could be used not only in economic forecasting, but also in student teaching, lecturers' qualification raising.

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Создание модели инвестиций методом системной динамики

Summary

Развитие экономики Латвии, как и любой страны, зависит не только от ВВП, потребления, экспорта, но также и от инвестиций. Инвестиции предопределяют развитие экономики как на текущий момент, так и и на последующие годы. В Латвии после неуклонного в течение более десяти лет прироста в 2009 году объем инвестиций сократился почти вдвое. Об уменьшении инвестиций предупреждали ряд экспертов, но тем не менее качественных прогнозов о времени изменения тенденций и грядущих объемах инвестиций не было предоставлено. Отсутствие действенных концепций о развитии ситуации наряду с важностью проблемы для народного хозяйства в целом обусловливают актуальность прогнозирования объемов инвестиций. Один из возможных методов прогнозирования состоит в создании макроэкономической модели окружающей экономической среды и ее использовании для моделирования различных показателей, в том числе инвестиций. В данной статье для моделирования макроэкономической среды предлагается использовать метод системной динамики, который является новым методом для прогнозирования и моделирования инвестиций. Преимущества данного метода заключаются в возможности его применения в нестабильных, быстро меняющихся экономических условиях, в которых прогнозирование традиционными количественными методами представляется весьма дискуссионным, поскольку они не могут зафиксировать моменты изменения тенденций, а способны только найти и продолжить имеющиеся тренды. В условиях грядущего кризиса результаты традиционных методов статистического прогнозирования идут в разрез с мнением экспертов о том, что, согласно предыдущему опыту, как рост, так и падение не могут длиться бесконечно. Тем не менее эксперты не указывают точного момента изменения тенденций. Метод системной динамики на основе имеющихся взаимосвязей и ограничений показывает пределы роста, и при приближении к ним замедляет темпы основного тренда. В частных случаях метод системной динамики может информировать об изменении тенденций, а также о цикличности развития экономики, инвестиций и т.д.

В статье описан метод системной динамики, этапы его становления и развития, указаны основные признанные на международном уровне специалисты, упомянуты их труды. Метод системной динамики

подразумевает изучение поведения сложных систем в течение времени и оперирует системой показателей, их взаимосвязями и временными задержками. В экономике системная динамика анализирует влияние совокупности экономических отношений и взаимосвязей объектов исследования. При прогнозировании экономического поведения объекта главная задача модели заключается в аналитическом максимально корректном отображении реального мира, что является вызовом для любого экономиста. К сожалению, экономисты считают метод системной динамики не экономическим методом изучения экономических взаимосвязей, а математическим, вследствие чего он среди них не распространен. В странах Балтии данным методом в большей степени интересуются математики, программисты, которые не обладают должным уровнем экономических знаний. Данная статья является одной из первых попыток построить модель макроэкономического равновесия, инвестиций с точки зрения экономиста.

В статье представлена модель макроэкономического оборота ресурсов, товаров и доходов, характеризуются её возможности для моделирования инвестиций. Данная модель состоит из четырех блоков. В первом блоке описан теоретический аспект модели макроэкономического оборота ресурсов, товаров и доходов. Основу модели составляют домохозяйства и фирмы. Домохозяйства формируют внутреннее потребление, предоставляют предприятиям рабочую силу и прочие ресурсы. Фирмы, в свою очередь, производят продукцию, товары и услуги; оплачивают рабочую силу и производственные ресурсы; выплачивают дивиденды домохозяйствам. В общую структуру модели макроэкономического оборота включены сбережения, которые формируются как совокупный баланс сбережений домохозяйств, фирм, государства и инвестиций. Согласно экономической теории, суммарный объем инвестиций должен совпадать с суммарным объемом сбережений. Предложенная нами модель позволяет реализовать данный принцип. Следующим сегментом модели макроэкономического оборота является государство, влияющее посредством налогов, потреблением товаров и услуг, выплатой трансфертов, участием в финансовых рынках, дебиторством или кредитированием. Важную роль в макроэкономическом обороте играет изменение материальных запасов, что отражает следующий блок описываемой модели. В определенных случаях рыночная модель может потерпеть фиаско: вследствие перепроизводства товаров объем производства на некоторое время может упасть до нуля, но не вызвать нестабильности или коллапса всей системы. Наличие материальных запасов способно компенсировать кризис в производстве. Представленная модель отражает закрытую экономическую систему, внешняя среда (или международная торговля) осталась за рамками настоящей статьи. Реализация вышеупомянутой теоретической модели представлена во втором блоке в соответствии с требованиями метода системной динамики, показаны работающие экономические взаимосвязи и их механизмы, рассмотрены формирующие модель потоки.

В третьем блоке исследуется формирование спроса и предложения на капитал и инвестиции, анализируются взаимосвязи подблока инвестиций с основной моделью и остальными ее показателями. В основе определения объема инвестиций лежит сравнение фактически имеющегося и необходимого для производства капитала. Их разность в случае превышения потребностей в капитале показывает объем инвестиций. Необходимый для производства капитал определяется исходя из ожидаемого потребления (спроса). Привлечение необходимого капитала, или инвестиций, происходит с определенной временной задержкой, что вызывает циклические и затухающие колебания в экономике.

Четвертый блок модели дополняет предыдущие, в нем описываются необходимые для их функционирования показатели: формирование ожидаемого потребления, наличие и изменение материальных запасов в системе. Ожидаемое потребление (спрос) определяется исходя из долгосрочного ожидаемого спроса, краткосрочных изменений в материальных запасах, временных задержек, связанных с необходимостью привести выпуск продукции в соответствие со спросом.

Предлагается использовать метод системной динамики не только для прогнозирования макроэкономических показателей, инвестиций, но и для обучения экономической теории. Исследования показывают, что студенты заинтересованы в получении знаний по макроэкономике с использованием метода системной динамики в большей степени, чем с применением традиционных методов. Использование метода системной динамики в процессе обучения повышает уровень усвоения и восприятия экономических знаний.

Ключевые слова: инвестиции, прогнозирование, моделирование макроэкономической среды, метод системной динамики

Straipsnis recenzuotas.
Straipsnis gautas 2010 m. birželio mėn.; straipsnis priimtas 2010 m. rugpjūčio mėn.
The article has been reviewed.
Received in June, 2010; accepted in August, 2010.