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The Study of the Dynamics of Innovative Development of Economy on the Endogenous Growth Through Multi-sector Extension of the Solow Model

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The article considers the global model of economic growth based on a number of national economies, containing endogenous indicators that reflect the status of scientific-technical progress. It is proved that technological development includes simulation stage, which is the borrowing of advanced technology and innovation, which dramatically increases the role of own research and development. In the work on the basis of economic-mathematical methods is the modeling of the dynamics of the economy like Russia in the framework of the theory of endogenous growth based on multi-sector extension of the Solow model with constant saving rate. The main mechanism that determines the dynamics of growth is the flow of investment from one sector to another. The study of the dynamics of the model is carried out both analytically and by numerical simulation of special cases that illustrate different effects. On the basis of application of modern methodological approaches and principles developed by the regulators of innovative development of economy in the conditions of intensification of extraction of natural resources.

Key words: economic growth, the Solow model, innovation, resource sector, high-tech products, scientific and technological progress, competitive selection, capitulationist labour theory of imitation and innovation, endogenous growth, efficiency, imitations and innovations.

Ensuring a high rate of economic growth and making it stable character is the most urgent task today, facing the economy of any country. Different constraints associated with the problem of improving the competitiveness of companies, the low level of development of labour market, imperfection of the legislative base reduce the economic growth of countries. Intensity of innovative activity determines the level of economical development. Today the assimilation of high techniques and manufacturing of science - consuming products is the key factors of steady economical growth for most industry-developed countries. The analysis of economical development shows us that last 300 years the most profitable branches and enterprises are that which are orientated towards producing of high- tech goods (Kartushina and Firsova, 2005). On-going trends of post-industrialization, softization, servicization of economy sharply increased value of knowledge and other factors have a significant quantitative and qualitative impact on the structure formation

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and behavior of economic systems (Firsova *et al*., 2014).

Among the factors that contributes to a positive trend of economic growth, should include effective use of manpower, and the use of central funds and recourses of the economy. This particularly applies to areas of the economy, actively improve the production structure, where a significant increase in total consumer demand is on average more than 10% per year since 2010.

The main danger is that export-oriented extractive industries still account for a significant share of the growth in industrial production, while the growth of domestic demand is compensated by import supply (Bikchantaeva, 2005)

Analysis of these trends is very important to study the dynamics of innovation development in relation to the economy of Russia. A positive trend in the growth of the Russian economy is associated primarily with increased revenue from exports of the commodity sector. The consumer focuses on the potential change in the value of natural resources. So, when the economic slowdown, falling GDP growth rates. The rapid unwinding of the fuel and energy complex industry abstracts capital resources from other sectors of the economy, thereby constraining the implementation of structural reforms and the formation of preconditions for further growth.

Researchers Aghion and Howitt formulated the theory of Schumpeterian growth of the economy. They argue that countries lagging performance from advanced technological powers, much more profitable to engage in the process of modernization, in other words, copy of modern technology (Demin, 2011).

And that simply investing in the purchase of modern technology is the most easiest way to solve this issue. However, only true for the Russian economy modernization is creating and shaping the conditions, methods and mechanisms of economic development.

There are other scientific views about the future development of the Russian economy. Thus, in the researches of V.M. Polterovich discusses the need for implementation of strategies for catch-up development. But the scientist concludes that the implementation of these strategies on the basis of large-scale technological borrowing base will be depleted in about 20 years. Then go on the path of innovative economic development (Polterovich, 2013).

There are a large number of works devoted to the innovative development of the economy of both developed and developing countries and countries with economies in transition.

In the framework of the theory innovations are classified as local (within one country) and global (on the world market), product and process, large and small. The contrast between imitations (pure borrowings of technologies abroad) and innovations (own R&D) is also very important.

A thorough analysis of innovations in developed economies is done in the paper (Morck and Yeung, 2000). It is stressed that the main type of competition in modern knowledge economy is not competition in price but competition in innovation speed. As the company, which has made an innovation the first, becomes a (temporary) monopoly, the economy cannot more be described as a pure competitive economy. Hence, the innovation process should be modeled in the frameworks of monopolistic competition or oligopoly. For the developing and transition countries the similar analysis is done in the work of (Carlin and Seabright, 2003).

One of the key features of innovation analysis is spillover effect: a company does not g*et al*l the profit from its R&D, as other companies will also get the access to the new technology (maybe, with a time lag). By that reason, many firms are prone to underinvest in their R&D. The spillover effect is the basic argument for the subsidies for companies-innovators. Besides, in the economy exists the cash-effect, the effect of the presence of big amounts of cash money in big monopolistic companies, what makes easier for them to finance both imitations and innovations.

A very important part of the innovation theory is the theory of connections between innovations and competition, which is described in (Asemoglu *et al*., 2002). From one side, competition makes firms to innovate more, but, on the other side, in condition of strong competition, the stimuli to innovate become less strong, as a firm does not expect a long-run profitability from its innovation projects due to spillover (Shumpeterian effect). In the work (Carlin *et al* , 2000) the importance of Shumpeterian effect is also

outlined, but it is stressed, that the growth of the competition can give a positive effect of the diminishing of the time period needed for innovation projects. In the paper it is also mentioned the competition escaping effect: due to competition a company starts to do more innovations to establish its share on the market more firmly.

METHODS

The main result of all papers devoted to the interrelations between competition and innovations is the firmly established inverse U-shape dependence of innovation rate on competition. The essence of this dependence is that the influence of the increase in competition on productivity (and innovation) is not monotonic: at the beginning it is positive, but starting from a certain level of competition the pressing on a company is too high, and the reverse tendency goes into force. This allows a possible explanation that on a market with a small number of players the competition in quality takes place (what is a favorable factor for innovations) and on markets with many players the competition in prices is dominant.

The theory of the inverse U-shape relation between innovations and competition has the best applications for the analysis of particular markets. Nevertheless, this theory is insufficient for modeling the innovation development in the whole economy, as it does not take into account the fact that different branches of an economy have different levels of development and the structure of every economy is not uniform. However, the relation between innovations and competition is a good starting point for further analysis. This relation is studied with taking into account the absence of uniformity of the economy (for the case of developing countries, where companies can differ significantly in structure and in level of development inside one economy). Hence, competition not only increases the productivity of all firms, but also makes feasible the selection of the most efficient structures. This selection and its efficiency depend on the quality and type of the institutes. In case of not «sufficiently competitive» environment the effect of competition increase on innovation is rather weak. The work also analyses the effect of scale and innovation costs, including spending on R&D. The main conclusion is that what poor countries really need is not an increase in R&D spending, but more investment, which simplifies the imitation of a completely ready foreign technology from developed markets. This affirmation coincides well with the main conclusion of the theory, which considers technical progress as the consequence of imitations and innovations.

The theory of imitations and innovations is a good tool for the technological development analysis in the framework of endogenous growth theory and it suits well for the analysis of innovations in developing and transition economies. In recent years it was thoroughly developed and verified empirically. The main assumption of the theory is the conjecture that the economic growth consists of two stages: imitation and innovation stages. Companies can do both imitations (direct borrowings) of the high-end technologies and their own R&D. The fundamental model in the work of Acemoglu, Aghion, Zilibotti describes this two-stage growth. At the first stage (when a country is far from technological frontier) the optimal strategy is to increase the total amount of investment in existing firms and the main type of development is imitation. At the second stage (as the country approaches the technological frontier) the role of the amount of the investment becomes less important and competitive selection and adaptive capabilities of the market become the most important factors. The main obstacles on the way of growth and achieving the technological frontier level are underinvestment and overinvestment traps (Nickell *et al.*, 1997). The first trap appears when the economy attempts to jump to the innovation stage too early and stops supporting the increase in investment in traditional sectors. The overinvestment trap appears when industries of the whole economy are ready to transform to the innovation stage, but the economic policy still is more appropriate to the previous, investment and imitation, stage (tax relaxation for the strongest industries, competition restrictions, excessive concentration on the investment to traditional enterprises). The proofs of the existence of such traps are based on two effects: the effect of the insufficient profitability of the investment in innovations and rent-shield

effect (a big amount of resources in the possession of insiders protects them from outside competitors). The first effect leads to the underinvestment trap (the majority of firms do not want to carry out big investment projects as they are not as profitable as they should be) 0nd the second effect leads to the overinvestment trap (the companies-insiders stay firmly in the market and they prefer not to have high-risk innovation projects).

The paper (Tonis, 2003) also develops the two-stage growth theory of Acemoglu, Aghion, Zilibotti. In this endogenous growth model innovations are subdivided into the categories of global and local innovations, and the assertion that companies borrow the technologies only from the frontier level is rejected. In difference with here are three regimes of growth: imitation regime (characteristic for poor countries), innovation regime (characteristic for the most developed countries) and mixed regime which contains both imitation and innovation components. Improving the quality of institutes the country can go from the pure imitation strategy to innovation strategy through mixed regime. The work also contains the empirical subdivision of the countries based on the type of the growth. Also the authors discuss the hypothesis that a significant amount of R&D money is spent on local innovations.

As in the development of the economy different traps are possible, the state influence during some periods of time seems reasonable. (Some measures of state influence can be avoided by appropriate institutional reforms.) This issue is studied in paper. There are some models of endogenous innovation growth, which involve ideas and mechanisms, similar to the outlined above. Underdevelopment trap (due to spillover effect) can be a negative result of economy development without state influence. The one-sector model proposed in the work focuses on the choice between the necessity of partial subsidizing of the R&D and the distortions of the economy caused by the excessive subsidies The second, especially actual for Russia, model represents an economy consisting of two sectors: traditional sector and innovation sector. As in the previous model, the aim of the research is to find the optimal subsidy which will assure that the country will escape the underdevelopment trap. The «new industry» argument supposes that the high-tech enterprises should receive R&D subsidies. The necessity of the subsidies is motivated by spillover effect. On the other side, the amount of subsidies should be seriously restricted, as in the case of generous subsidies the companies' main target becomes additional amount of transfers and they will seek opportunities to increase their influence on the state (rent-seeking argument) rather than to augment the profitability. The main conclusion of the work is that the size of subsidies to high-tech sector should increase with the growth of the profitability of the sector.

A number of researchers believe that the process of modernization should provide free consumer market through diversification of domestic production and innovation orientation.

The problems of technological modernization research of many scientists (Chelnokova O.Yu., Gritsak L.Y., 2013). Thus, in researches reasoned the following:

a) Successful countries, first went on the path of modernization, actively adopted the latest technology, gradually moving on the path of innovative development;
b) It is not possible to first improve institutions, and only after run economic growth;
c) Successful growth strategies may be developed only on the basis of the relationship between business and government.

However, the process of modernization should not limit itself to only the implementation of the production base, all this will not bring significant results.

Regarding to the modernization of the commodity sector, there should not talk about catching up or accelerate the development process, and application modernization, taking into account the comparative advantages of the Russian economy in relation to the related fuel and energy and petrochemical industries (Gamaunov *et al*, 2014).

In addition, for greater effect, the process of application modernization should apply to the entire manufacturing range: starting from production to processing raw materials. It thus laid the prospects for economic growth, as well as the prerequisites for the introduction of new

technologies (Chvetkov, 2011)

RESULTS

1. Consider the global model of economic growth, which consists of a number of national economies, and is formed by endogenous indicators reflecting the state of the world's progress in general. Thus, the indicator X_t at each time t depends on the state of the world's progress in each country (Borisov, 2007).

$$X_t=Y(X_t^i,...,X_t^J)$$

where:

J - is the number of countries that make up the world economy;

X_t^i - is the state of the world progress in the country i at the moment of time t;

Y - is a function that for any value of Y > 0 and it corresponds to the equality Y (X, ..., X) = X. For example, instead of Y, we can take the arithmetic mean value, showing the state of the world's progress in each country [5]:

$$Y(X_t^i,\ldots,X_t^J)=\sum_{i=1}^{J}\frac{X_t^i}{J}$$

If we consider the dynamics of global progress, for each individual country it is s*et al*most the same proportions:

$$X_{t+1}^i=Z^i(K_t^i/R^i k^i,X_t)$$

where:

K_t^i – is the amount of fixed capital in each country i at time t;

R^i – is a constant amount of labor in each country i ($L^i > 0$);

k^i – is exogenous factors;

Z^i – is a function that is homogeneous of the first degree.

Suppose that in each country i the saving rate s^i is constant. Let denote D_t^i as issue the gross national product in each country i in time period t. Let us write the ratio, which together with the already marked formulas fully specify the dynamics of the model of economic growth:

$$D_t^i=F^i(K_t^i,X_t^iR^i),K_{t+1}^i=(1-\mu^i)K_t^i+Y^i$$

where:

F^i – is neoclassical derivative function;

μ^i – is the yield coefficient of the capital of each country i.

As is known, the number of countries in the world is quite large, global progress for all countries is exogenously given, for all that, in a global economy, it is an endogenous (Derunova and Semenov, 2013).

All of the above became the basis for the models of endogenous economic growth for the recourse sector with a constant saving and a complete lack of external investment. When building the model, we also used the Solow model. However, applied it to multi-sector economy with regard to the reallocation of factors of production.

In this model, we have shown that the high cost of natural resources can lead to technological backwardness of the country. In this sense, the "Dutch disease" may have a negative impact on the volume of production, and increase technological efficiency of the economy.

The Solow model allows linking the growth of GDP volume savings (assuming that all savings go into investment). However, in the basic model there is no concept, as such, technological progress, and the economy is a homogeneous mechanism, consisting of a single sector.

The main result of the model is the evidence that there is a stationary state of growth, which strive economy. The growth rate in the steady state equals the rate of natural population increase. The structure of the economy in the steady state effect on savings rates, production functions and rates of population growth.

As practice shows, the Solow model is far from perfect. It does not take into account many important factors. So, in the world meets the uniform convergence of the main parameters of the economy to General average to the values predicted by the model. In fact the convergence is observed for different values across different groups of countries (Eastern Europe, European Union, Arab oil producers, "newly industrialized countries" of Southeast Asia and so on).

Empirical analysis of the Solow model showed that economic growth cannot be interpreted only by population growth and capital provision. This is due to the fact that in a regression of growth on the growth of labour and capital is detected incremental component – "remainder Solow", which, in turn, generates additional economic growth.

Small modification of the Solow model gives the possibility to enter in the country's

economy, technical progress, with a steadily increasing tempo. Assuming fixed rate of economic growth, it is equal to the sum of the rate of technical progress and the growth rate of the population. That gives the opportunity to identify differences in growth rates between different groups of countries, as R&D intensity in different regions of the world is quite different.

The Solow model with the world's technological progress does not consider the endogeneity of technological progress and its relationship with the current level of development of the country, i.e. the distance of the country from the world technological frontier.

As previously stated, the Solow model Solow considers a closed one-sector economic system, which is one universal product can be consumed or invested) (Solov'ev, 2006).

Thus, the level state of the economy at a certain time t is determined by the following indicators:

X_t – is gross domestic product;
K_t – is the basic production assets;
L_t – is the number of people employed in the manufacturing sector;
I_t – is an investment;
C_t – is funds non-productive consumption $
v – is the annual growth of employment.
Hence, the differential equation is as follows:

$$L_t v = \frac{L_t d}{td}$$

Presumably during the year eliminated part of the basic production assets ¼, in this case, q is the rate of accumulation. Annual GDP depends linearly homogeneous neo-classical derivative function:

$$X = F(K, L)$$

Consequently, the rate of accumulation and elimination are:

$$\mu K_t N I_t = qX_t = qF(K_t, L_t)$$

Growth funds are as follows:

$$dK_t = -\mu K_t dt + I_t dt$$

Since the production function $F(K_t, L_t)$ in nature is linearly homogeneous, differential equation for the assets is as follows:

$$dK_t = [-(\mu+\nu) k_t + qF(k_t, 1)]dt$$

Enter additional values $\alpha = \mu + v$; $f(k_t, 1) = F(k_t, 1) = Ak^a_t$, we obtain the deterministic Solow model in relative terms (Solov'ev, 2006):

$$\begin{cases} dk_t = [\alpha k_t + qf(k_t)]dt \\ k_0 = \frac{K_0}{L_0}, \alpha = \mu + v \\ x_t = f(k_t), i_t = qf(k_t), c_t = (1-q)f(k_t) \end{cases}$$

In the framework of the developed model we will consider the achievements of each country's technological progress in the presence of an extractive sectors with exogenous world prices. Attention is drawn to a constant rate of savings (all this is consistent with the Solow model), as well as the absence of external capital inflows. The main mechanism for the following models - reallocation of investment funds between sectors, as well as the transition of the capital in one of the most profitable sectors.

This model assumes the type of economy, which includes manufacturing sector and the natural resource sector. It is assumed quite large stock of natural resources in the model, but the production of each unit of resource generates a loss of utility (due to the fact that this resource is no longer applicable in the future).

The model is characterized by discrete and multi-period factors. All equations of this model represent the dynamics of the transition from a particular time period t to a certain time t+1.

The economy of this type is open to trade relations. The manufacturing sector produces product X and the extracting product Y. Product X and Y can be both external and internal markets. The cost of the product Z has a constant value equal to 1, and the value of Q affects the global environment, its value is Pt at a certain time t.

Factor of production model is the only capital. The idea is that the working-age population in the country's economy is permanent, and the mobility of labour between sectors is completely absent. In other words, a small number of workers in the extractive sectors compared to other sectors.

It should also be noted that the institutional and political risk in the described model is very large. In this regard, all investments come from domestic savings. For the Russian economy, due to the low volume of the strategic foreign investment, it is quite realistic.

DISCUSSION

The economy is based on free market principles. The agents are manufacturing sector firms and natural resource extraction firms. The price of capital is endogenous and equals *1+r* (The capital lives one period and its owner should get back the initial capital cost plus the interest rate after the end of the period).

Let Y_t be the total production (in terms of money), and K_t be the total amount of capital. The outputs in each sector are denoted as $Y_{R,t}$,$Y_{M,t}$ (in terms of money) and $Q_{R,t}$, $Q_{M,t}$ (in terms of real amounts of output). The quantities of capital in each sector are denoted as $K_{R,t}$,$KM_{,t}$.

The utility of the manufacturing sector equals to its profit $Q_{M,t} - (1+r) K_{M,t} = Y_{M,t} - (1+r(K_{M,t}$ and the utility of resource extraction sector equals $(p_t - \beta) Q_{R,t} - (1+r) K_{R,t} = Y_{R,t} - \beta Q_{R,t} - (1+r) K_{R,t}$,, i.e. its modified profit which takes into account the loss of the quantity of the resource which was extracted at the moment *t*: nonzero coefficient β denotes the loss in utility from the fact that a unit quantity of the resource, extracted at *t*, cannot be extracted at any future period of time. Large values of correspond to the case when the owner of the resource «takes care about the future» i.e. considers the possibility of the exhaustion of the resource in defining the current amount of extraction. In the model it is also assumed that, i.e. in spite of fluctuations the world resource price is always higher than the minimal level , starting from which the extraction becomes profitable.

$$Y_{M,t} = Q_{M,t} = A_t \sqrt{K_{M,t}}$$

$$Y_{R,t} = p_t Q_{R,t} = p_t B \sqrt{K_{R,t}}$$

The production functions of the sectors *M* and *R* are:

Here A_t is the multiplier corresponding to the technological level of the manufacturing sector, which changes from period to period, *B* is the constant parameter of production in the resource extraction sector (for example, the quality of deposits). The following type of production functions allows solving the model analytically.
This model indicates that the problem of the negative effects of high volume commodity sector on the economic growth rates really exist (Derunova and Semenov, 2013).

CONCLUSION

We have considered various factors influencing the development of the commodity sector, have tried to determine what impact the natural resource sector on the phenomena of economic, political and social nature, describe appropriate mechanisms of the negative impact of resource abundance. We relied on a statistical model, and also used correlation and factor analysis.

Namely, we attempted to determine the factors of the direct negative impact of the commodity sector to the GDP growth rate, i.e. the factors that characterize the peculiarity of the formation of the commodity sector. Such factors are, first, the deterioration of the resource base, and secondly, low rate of scientific and technological progress and, thirdly, considerable volatility value on natural resources and the heterogeneity of the processes of capital investment.

These factors contribute to the generally low rate of growth in the commodity sector. Undoubtedly, the impact of these factors on economic growth will be reflected in a high share of commodity sector in the economy.

In the analysis we have discovered two fundamental lines to reduce the negative impact of the commodity sector:

1. The decline of this sector on the basis of economic diversification. However, this line requires a relatively long implementation period (for the Russian economy it is 15-20 years).
2. The application of various mitigation and compensation solutions, which, of course, is unlikely to cover all possible compensatory measures, but they can be supplemented in the future.

The main decision in the matter of the compensation of the negative effects of variability of the value of natural resources can serve as the improvement of the taxation system in the direction of considering the differential of mining rent, as well as the formation of the most flexible system of

export duties. All this can lead to a levelling of economic operating conditions bowels of the earth, slightly lowering the investment attractiveness of the given field (Peshkov, 2008).

In addition, due to this can be solved many other problems. So, for example, will decrease the dependence of the growth rate from fluctuating commodity market conditions. The mining sector will focus not on the search for natural rent, and the planned increase in production through involvement in the development of deposits with gradually deteriorating quality characteristics.

Competitive advantages in the study of fields with complex mining situation will allow you to use the latest technological advances that will stimulate the search for intellectual rent.

Finally, will be blocked by a variety of indirect factors affecting the development of the economy. We are talking about "Dutch disease", rent seeking about reducing corruption, etc. But to date there is still no necessary methods fair valuation differential of mining rent on microeconomics level. For the development of such methods will require major efforts by the researchers.

It will be necessary also develop a phased program of reform of the economic system, which would cover all spheres of production and would rely on the existing institutional structure of the economy. The duration and depth of reforms at the initial stage of transformation involves a significant export of raw materials, followed by its substitution products with the highest added value.

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