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FISCAL OR MONETARY STIMULUS? EVOLUTIONARY ARGUMENTS FOR TAX REFORMS

ABSTRACT. The article deals with the problem of substantiation of the emergent economies development regulatory measures (fiscal and / or monetary), using the evolutionary modelling methods. For this purpose, the mathematical model was constructed that simulates the co-evolution process of the advanced and developing countries, linked by global value chains. In this model, each country is characterized by its original structure of economic entities, defined by the ratio of the egoistic enterprises (predisposed to conservative behaviour) to the altruistic enterprises (predisposed to innovation), as well as by specific population and demographic processes. The results of the computational experiments have shown that the success of economic regulation fundamentally depends on the peculiarities of the initial state of the institutional environment. In the institutional environment with the «transparent» long behaviour and, accordingly, a long economic planning horizon, the best result in the form of average annual production growth rate of the emergent economies is provided by the cheap money policy combined with the high European taxes. A different situation is observed in more realistic short behaviour and, accordingly, short (under 5 years) economic planning horizon. In this case, any tax policy (neither low nor high taxes) together with any money (neither cheap nor expensive), to a certain extent loses its significance, as the initially backward innovative system does not allow to quickly get good results, and the long-term benefits of the potential economic growth are not taken into consideration. However, low taxes and cheap money are important as they create better conditions for survival of the altruistic enterprises, facilitating their investment activities, which can multiply increase their technical performance and economic efficiency. Still, in the context of the evolutionary economics and following the conducted computational experiments, the fiscal policy in terms of emerging markets retains its regulatory capacity, and therefore requires further reforms in the context of the «new reality» based on the global value chains.

KEYWORDS. Fiscal policy; monetary policy; taxes; evolutionary economics; co-evolution; institutional environment; mathematical model; enterprises; investment; economic growth.

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НАЛОГОВОЕ ИЛИ МОНЕТАРНОЕ СТИМУЛИРОВАНИЕ? ЭВОЛЮЦИОННЫЕ АРГУМЕНТЫ В ПОЛЬЗУ НАЛОГОВЫХ РЕФОРМ

АННОТАЦИЯ. Статья посвящена исследованию проблемы обоснования мер регулирования развития эмерджентной экономики — фискальных и (или) монетарных, с использованием методов эволюционного моделирования. Для этого была построена экономико-математическая модель, имитирующая процессы коэволюции развитой и развивающейся стран, связанных через глобальные цепочки создания стоимости. В этой модели каждая из стран характеризуется собственной исходной структурой экономических субъектов, определяемой соотношением предприятий-эгоистов (предрасположенных к консервативному поведению) и предприятий-альтруистов (предрасположенных к инновационному поведению), а также специфическим населением и демографическими процессами. Результаты вычислительных экспериментов показали, что успех того или иного способа экономического регулирования принципиально зависит от особенностей исходного состояния институциональной среды хозяйствования. В институциональной среде с «прозрачными» длинными правилами игры и, соответственно, длинным горизонтом хозяйственного планирования наилучший результат в виде высоких темпов роста производства в эмерджентной экономике дает политика дешевых денег в сочетании с высокими «европейскими» налогами. Иная ситуация наблюдается в более реалистичной ситуации с короткими правилами игры и, соответственно, коротким (не более 5 лет) горизонтом хозяйственного планирования. В этом случае любая налоговая политика (низкие или высокие налоги) в сочетании любыми деньгами (дешевыми или дорогими), в определенном смысле теряет значение, поскольку изначально отсталая инновационная система не позволяет быстро получать высокие результаты, а преимущества экономического роста в отделенном будущем не принимаются во внимание. Вместе с тем, для постепенного формирования лучшей инновационной системы низкие налоги и дешевые деньги имеют важное значение, поскольку создают лучшие условия для выживания предприятий-альтруистов, облегчая им инвестиционную деятельность, способную принести многократный прирост технической производительности и экономической эффективности. В любом случае, в контексте эволюционной экономической теории, исходя из проведенных вычислительных экспериментов, налоговая политика в условиях эмерджентных рынков сохраняет свой регуляторный потенциал, и, таким образом, требует дальнейшего реформирования в контексте «новой реальности», основанной на глобальных цепочках создания стоимости.

КЛЮЧЕВЫЕ СЛОВА. Фискальная политика; монетарная политика; налоги; эволюционная экономика; коэволюция; институциональная среда; математическая модель; предприятия инвестиции; экономический рост.

Introduction

To overcome the consequences of the global financial and economic crisis the world's leading countries are widely using the monetary policy (mainly the quantitative easing), as the fiscal policy receded into the background and was largely limited to the procyclical budget austerity measures.

The active actions of the G7 central banks did indeed stabilized the situation. However, fundamentally the global issue of the transition to the sustainable economic growth has not been solved. As it is noted in «The Economist»: «Despite central banks' efforts, recoveries are still weak and inflation is low. Faith in monetary policy is wavering. As often as they inspire confidence, central bankers sow fear. Negative interest rates in Europe and Japan make investors worry about bank earnings, sending share prices lower. Quantitative easing (QE, the printing of money to buy bonds) has led to a build-up of emerging-market debt that is now threatening to unwind. For all the cheap money, the growth in bank credit has been dismal»[1].

Such circumstances revive the natural interest in more active use of the alternative fiscal policies aimed at promoting the structural reforms in the real sector of economy. In particular, J. Stiglitz and H. Rashid believe that: «…large increases in public investment in infrastructure, education, and technology will also be needed. These will have to be financed, at least in part, by the imposition of environ-

[1] Out of ammo? Economist.com, 2016. URL: http://www.economist.com/news/leaders/21693204-central-bankers-are-running-down-their-arsenal-other-options-exist-stimulate.

mental taxes, including carbon taxes, and taxes on the monopoly and other rents that have become pervasive in the market economy — and contribute enormously to inequality and slow growth» [1]. M. Feldstein notes that «…there is no alternative to fiscal policy if we want to reverse the current downturn» [2]. The IMF experts concluded that: «Infrastructure investment is needed across a range of countries and should be attractive in a setting of very low real interest rates. Countries with fiscal space should not wait to take advantage of it. …Tax reform, even when budget neutral, can create demand if well targeted, while simultaneously improving labour force participation and enhancing social cohesion»[2]. At the «Communiqué G20 Finance Ministers and Central Bank Governors Meeting» it was stated that: «Our fiscal strategies aim to support the economy and we will use fiscal policy flexibly to strengthen growth, job creation and confidence, while enhancing resilience and ensuring debt as a share of GDP is on a sustainable path. We are also making tax policy and public expenditure more growth-friendly, including by prioritizing high-quality investment»[3].

That is one way to look at it. While on the other hand, the arguments against the active countercyclical fiscal policy remain very serious. Its introduction is usually associated with high political costs, time delays required to change the fiscal programs, the weak reaction of the economic agents to the temporary tax cuts. Besides, in the present circumstances, when the economies of many countries are close to full employment, the government funding can crowd out private investment, reducing the potential productivity growth and standards of living, and budget deficits automatically increase government debt and require higher future taxes to pay the interest on that debt, which in turn distorts the economic incentives, etc. [2; 3].

Therefore, much depends on how well under the specific economic conditions of and considering the stated circumstances, the fiscal incentives can be transformed into the growth of the real modern goods and services production, which is the accelerator of the sustainable economic growth[4]. Recent researches showed that «…in advanced economies, stronger planned fiscal consolidation has been associated with lower growth than expected, with the relation being particularly strong, both statistically and economically, early in the crisis. A natural interpretation is that fiscal multipliers were substantially higher than implicitly assumed by forecasters» [4]. However, this conclusion, even if it is a completely fair one, cannot be automatically referred to the emerging markets, including Russia, where the production potential is limited by conventional technologies, the lack of modern equipment, STEM-staff and others, and many businesses are integrated into the Global Value Chains (GVCs) as a raw materials supplier or the low processed. In such conditions, the selection of the best tools of overcoming the recession is deeply contested [5].

The fundamental part of the solution of this problem is the fact, that due to the «past dependence» the GVCs are often built so that their innovative science-intensive and, at the same time, environmentally friendly links are located on some territories, while the resource-intensive links (environmentally unfriendly) are located somewhere else [6]. For example, the relative environmental and economical prosperity of the modern Western European car producing countries is traditionally connected to the low personal income and environmental problems in other countries, which produce coal, ore and smelt metal used for the production of these cars. In fact this is the coevolution, i.e. a historically joint and interdependent development of differentiated communities,

[2] International Monetary Fund. World Economic Outlook: Too Slow for Too Long. Washington, April, 2016.

[3] Ministry of Finance of the People's Republic of China (2016). Communiqué G20 Finance Ministers and Central Bank Governors Meeting. Available at: http://wjb.mof.gov.cn/pindaoliebiao/gongzuodongtai/201604/t20160416_1952794.htm.

[4] http://www.unido.org/fileadmin/user_media_upgrade/Who_we_are/Structure/Policy-making_Organs/Lima_Declaration_RU_web.pdf

which are further referred to as economic and ecological populations, acting within their territories, possessing different process technologies, environmental conditions, labour and natural resources, and directed by different institutes, etc.

On the basis thereof, the purpose of this study is to prove what measures of national economies development regulation — fiscal and/or monetary and in what combination — are better to use in order to change the current unfavourable situation for many developing countries involved in GVCs as auxiliary links.

In this regard, it was required to solve the following tasks:

– to develop and verify a basic model the coevolution of two differentiated populations, linked by GVCs in the «*Emerging market – Developed market*» complex («*E — D*»);

– to apply fiscal and monetary regulators to the basic model and, basing on the computational experiments, to prove what measures of coevolution regulation — fiscal and / or monetary — could improve the present tendencies.

The economic literature presents a number of the economic system evolution models: e.g. R. Nelson [7], T. Wiedmann [8], J. Van den Bergh [9; 10]. As to the coevolution mathematical models, they are much fewer in number. The review by M. Gual [11] and G. Kallis [12] showed that causal models of coevolution are used more often economically than mathematically.

Considering all the above stated this article proposes the model of the coevolution of different economic and ecological populations that uses and develops the following ideas of the predecessors:

– economic evolutionists — that the economic development is determined by the stochastic interaction between the economic agents using the mechanisms of variability, heredity, and selection;

– financial economists — that the effectiveness of fiscal and monetary regulations depends on the extent and stage of development of manufacturing technologies and economic institutions[5].

[5] An important work in this respect is the monograph by C. Perez [13].

Development and verification of a basic model. Cognitive properties of a basic model

There are two territories linked by the goods supply chains, each of which contains the interaction of two subpopulations: economic subpopulation (represented by enterprises) and ecological subpopulation (represented by human population). Together, they constitute the overall economic and ecological population of the given territory. Thus, we understand the economic and ecological population as a set of economic entities (enterprises) and human population, located and operating in a separate territory.

Organizational routines of the population's enterprises form their behaviour patterns, i.e. the predisposition to act in a certain way in a certain kind of situation [14]. It is assumed that such patterns can be of two types: innovative altruistic pattern and egoistic conservative pattern, so hereafter we will relatively divide the enterprises on egoists and altruists.

Both altruists and egoists seek to maximize their welfare (with due regard to the limitations on available resources, the monetary and fiscal stimuli and restrictions, the established institutions, etc.). But the egoists do not consult social interests, and altruists consider them important. That is, the altruists are, in this case, the enterprises engaged in risky development of new production technologies, taking into account the social costs incidental to the environmental pollution, and therefore seek every possible way to improve the cleaning system of the emitted pollution, marshalling their own resources on these matters. In turn, the egoists are the enterprises, which prefer not to engage in the development of new production technologies, do not take into account the social costs incidental to the environmental pollution, and do not seek to improve the emitted pollution cleaning systems[6].

[6] It is assumed that the egoists, even in case of tighter penalties for environmental pollution, will not invest into new eco-technologies, and prefer to decrease their costs, for example, by bribing inspectors, or withdraw from business.

Economic subpopulation produces goods and emits pollution (which is partially removed by the cleaning). Ecological subpopulation consumes a part of the goods and pollution, and in return supplies the economic subpopulation with labour (Fig. 1).

The Figure 1 shows that populations are different from one another.

The first one is located in the Territory *D* and specializes on producing final science-intensive products with high added value and low pollution level. The orientation towards innovation development and low environmental polluting is prevailing.

The second one, located on the Territory *E*, specializes on producing intermediate resource-intensive products with high level of environmental pollution emitting. The orientation towards conservative behaviour and indifference to environmental pollution is prevailing.

There is a link between the economic subpopulations of the territories — the intermediate products of the Territory *E* are the input for the final products of the Territory *D*. Both Territories *D* and *E* consume these products. The ecological populations of the Territories *D* and *E* do not interact (e.g. they do not share borders, or there is an emigration control in Territory *D*).

Pollution, emitted in one territory, does not affect the other one (i.e. cannot be spread by wind, water, etc.).

Mathematical description of the model Economic subpopulation

Production unit. In each of the territories the production output of the enterprise *i* in the period of *t* (Q_t^i) is determined by the following production function

$$Q_t^i = \frac{Q_t^i}{F_t^i}\frac{F_t^i}{Lq_t^i}Lq_t^i = A_t^i f_t^i Lq_t^i, \qquad (1)$$

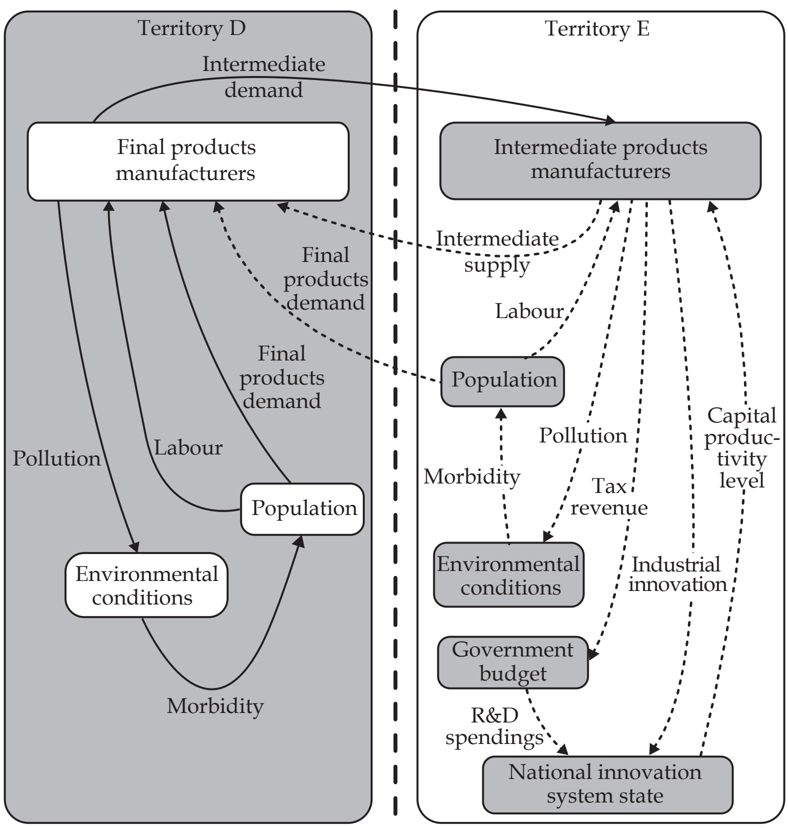

Figure 1. Cognitive model of the interaction between economic and ecological populations, linked by the goods supply chains

where F_t^i is the fixed production assets value of the enterprise i in the period of t; A_t^i is the capital productivity; f_t^i is the capital-labour ratio ($f_t^i = const$); Lq_t^i is the time worked; i is the location number; t is the period number.

In addition to the output of products, every enterprise is engaged in disposing the contamination, associated with this output, or, figuratively speaking, in «cleanness production»:

$$^{+}Qa_t^i = \frac{Qa_t^i}{Fe_t^i}\frac{Fe_t^i}{Le_t^i}Le_t^i = Aa_t^i fe_t^i Le_t^i, \quad (2)$$

$$^{+}Qw_t^i = Aw_t^i fe_t^i Le_t^i, \quad (3)$$

$$^{+}Ql_t^i = Al_t^i fe_t^i Le_t^i, \quad (4)$$

where $^{+}Qa_t^i$, $^{+}Qw_t^i$, $^{+}Ql_t^i$ are the disposal volumes of the air and water emissions, and production waste, respectively, in the period of t; Fe_t^i is the fixed environmental protection assets value of the enterprise i in the period t; Aa_t^i, Aw_t^i, Al_t^i are the capital productivity of fixed environmental protection assets; fe_t^i is the capital-labour ratio (for fixed environmental protection assets $fe_t^i = const$); Le_t^i is the amount of time worked in the environmental protection activities.

The supply of the products made by the enterprise i during the period of t is determined from the following formula:

$$\widehat{Q}_t^i = Q_t^i + Z_{t-1}^i, \quad (5)$$

where Z_{t-1}^i is the unsold product in the period of (t – 1):

$$Z_{t-1}^i = \begin{cases} \widehat{Q}_{t-1}^i - Qr_{t-1}^i, & \widehat{Q}_{t-1}^i > Qr_{t-1}^i \\ 0, & \widehat{Q}_{t-1}^i \le Qr_{t-1}^i \end{cases}, \quad (6)$$

where Qr_{t-1}^i is the volume of products sold in the period of (t – 1).

The companies are assumed to operate in a competitive market, i.e. the final product pricing is set exogenously (determined by the volume of aggregative supply and demand, not by the enterprises themselves). Therefore, the enterprise's profit (P_t^i) is equal to the difference between the value of products sold and production costs (C_t^i) taking into account the tax payments (τ_t)

$$P_t^i = (Qr_t^i - C_t^i)(1 - \tau_t). \quad (7)$$

To determine C_t^i it is proposed to use the following production function

$$C_t^i = \delta(Fe_t^i + F_t^i)^{\psi}(Q_t^i)^{v}k^{\eta} + \\ +(^{-}Qa_t^i)\tau^a + (^{-}Qw_t^i)\tau^w + (^{-}Ql_t^i)\tau^l, \quad (8)$$

where $^{-}Qa_t^i$, $^{-}Qw_t^i$, $^{-}Ql_t^i$ — the environmental contamination by air emissions, water emissions and production waste, respectively, in the period of t; τ^a, τ^w, τ^l are the environmental tax rates; k is the credit interest rate; δ, ψ, ν, τ are the function parameters.

The Figure 2 shows the procedure of distribution of the profit remaining at the enterprise's disposal.

The profit is expected to be fully directed to the production and environmental protection. But the egoists are just simulating the available environmental technologies, when the altruists are involved in the development of new green technologies.

The number of egoists and altruists within the economic subpopulation changes over time as a result of natural selection, which alters the subpopulation structure.

The condition of their reproduction is defined by the following formula:

$$R_t^i = \frac{P_t^i}{C_t^i} \ge Rn, \quad (9)$$

where Rn is the standard level of profitability.

The economic sense of this formula is that if the strategy of the economic entity (whether it is altruist or egoist) leads to the increasing business activity effectiveness, then it reproduces enterprises of its own kind, which will use the same behaviour patterns. If not, then the reproduction does not occur.

At the same time, each territory has its historically formed level of profitability, which is relevant to the specific features of its institutional environment.

If $F_t^i \le Fn$ (where Fn is the standard fixed assets value) or the enterprise has been standing the losses for the previous 3 periods ($P_t^i < 0$), then the entity fails (removes itself from the subpopulation).

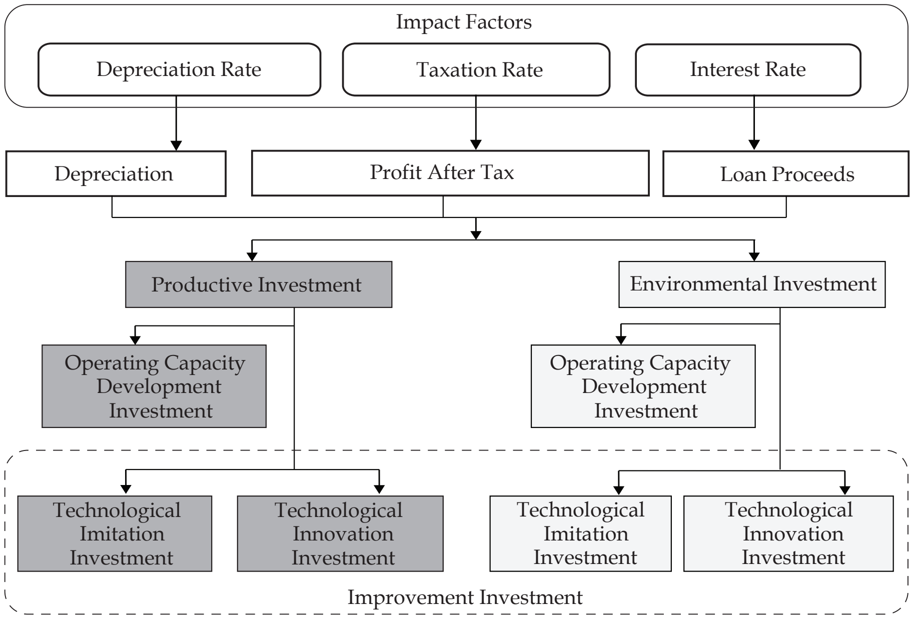

Figure 2. The scheme of formation and distribution of industrial enterprise investment

Thus, the structure of economic subpopulation is dynamic and may change due to the comparative advantages of the altruistic or egoistic behaviour.

Both egoists and altruists can direct their profits into expanding the existing facilities and / or their modernization (through simulating the known technologies or developing new ones). They engage in the enterprise modernization only if the current profitability rate ($R_t^i = P_t^i / C_t^i$) is lower than a threshold figure (which is sufficient to maintain the business activity).

The development of the investments in expanding the existing capacities causes an increase in fixed assets value:

$$F_t^i = \begin{cases} F_{t-1}^i - NA \cdot F_{t-1}^i + I_t^i = \\ = F_0^i - \int_0^T D_t^i dt + \int_0^T I_t^i dt, \quad P_t^i > 0 \\ F_{t-1}^i - NA \cdot F_{t-1}^i = \\ = F_0^i - \int_0^T D_t^i dt, \quad P_t^i \le 0 \end{cases} \tag{10}$$

where NA is the amortization rate; D_t^i is the amortization payment; T is the total number of periods.

The amount of investment (I_t^i) (see Fig. 2) is determined as follows:

$$I_t^i = f^I(P_t, D_t^i, K_t),$$

where K_t is the loan proceeds amount ($K_t = f^k(k_t)$), k_t is the average credit rate.

The facilities modernization and the research-and-development (R&D) process, associated with it, are logically proposed in seminal work by R. Nelson and S. Winter [7]. The R&D generates new capital productivity values using the two-stage stochastic process.

The first stage is characterized by independent random variables dm and dn, which can be equal to either 0 or 1. According to the values of these random variables enterprise begins (or not) the modernization process.

At the second stage, the probability of investment success is estimated:

$$\Pr(dm=1) = \frac{K\_rm_t^i - K\_rm_t^{\min}}{K\_rm_t^{\max} - K\_rm_t^{\min}};$$
$$\Pr(dn=1) = \frac{K\_rn_t^i - K\_rn_t^{\min}}{K\_rn_t^{\max} - K\_rn_t^{\min}}, \tag{11}$$

where $K\_rm_t^{\max}, K\_rm_t^{\min}$ are, correspondingly, the maximum and minimum costs for the simulation of known technologies by the enterprises of the sector in the period of t; $K\_rn_t^{\max}, K\_rn_t^{\min}$ are, correspondingly, the maximum and minimum– costs for the new technologies development by the enterprises of the sector in the period of t.

Investments, as Figure 2 shows, may be directed to the technologies imitation and / or technological innovations.

If the enterprise gets an imitation, then it should find and imitate the best practice in the industry. If the enterprise gets an innovation, then it selects a technology, proceeding from the technological capabilities distribution in the industry An_t:

$$An_t = f^n(d_t^{Ind},\ d_t^{VVP}), \qquad (12)$$

where d_t^{Ind} is the industrial contribution to GDP; d_t^{VVP} is the R&D spending from the government budget.

The latter, in turn, is defined as follows:

$$d_t^{VVP} = f^d(\tau_t, k_t).$$

The economic sense of this formula is that the raising enterprise taxes reduces the resources of the enterprises, but increases the government revenues, which are directed to the R&D funding among other things.

The capital productivity value for the enterprises, which got both simulation and innovation, is defined by the following expression:

$$A_{t+1}^i = \max(A_t^i, \tilde{A}_t, An_t), \qquad (13)$$

where $\tilde{A}_t$ is the highest (corresponding to the best practice) productivity level in the sector.

If the enterprise does not get neither simulation nor innovation, then the capital productivity remains the same[7].

As the enterprise evolves, F_t^i and Fe_t^i also change, and therefore in the assumption $f_t^i = f_0^i = const$ changes the total amount of labour used $L_t^i = Lq_t^i + Le_t^i$.

[7] Enterprises do not know a priori, whether their attempts to become innovators (simulators) will be justified or not, and specifically what level of R&D expenditure they may need. For any of them, the answer to this question depends on choices made by other enterprises.

The enterprise's composite demand for labour $\tilde{\Lambda}_t^i$ is

$$\tilde{\Lambda}_t^i = \frac{F_t^i}{f_t^i} + \frac{Fe_t^i}{fe_t^i} = \tilde{\Lambda}q_t^i + \tilde{\Lambda}e_t^i. \qquad (14)$$

The enterprise's total filled demand for labour (Lf_t^i) is defined by the labour market offers in the territory ($\widehat{L}_t^i$):

$$L_t^i = \begin{cases} \tilde{\Lambda}_t^i, & \widehat{L}_t^i \ge \sum\limits_{i=1}^{n} \tilde{\Lambda}_t^i \\ \dfrac{\tilde{\Lambda}_t^i}{\sum\limits_{i=1}^{n} \tilde{\Lambda}_t^i} \widehat{L}_t^i, & \widehat{L}_t^i < \sum\limits_{i=1}^{n} \tilde{\Lambda}_t^i \end{cases}, \qquad (15)$$

where n is the number of enterprises (entities) in the territory.

In turn, the enterprise's demand for production labour is determined by the formula

$$Lq_t^i = \begin{cases} \tilde{\Lambda}q_t^i, & \tilde{\Lambda}q_t^i = L_t^i \\ \dfrac{\tilde{\Lambda}q_t^i}{\tilde{\Lambda}_t^i} L_t^i \end{cases}. \qquad (16)$$

The filled demand for environmental activity labour is calculated as follows:

$$Le_t^i = \begin{cases} \tilde{\Lambda}e_t^i, & \tilde{\Lambda}_t^i = \widehat{L}_t^i, \\ \left(1 - \dfrac{\tilde{\Lambda}q_t^i}{\tilde{\Lambda}_t^i}\right) \widehat{L}_t^i \end{cases}. \qquad (17)$$

Environmental protection. The cleanness production results in environmental pollution reduction. The pollution balance is defined as follows:

$$\begin{cases} {}^{-}Qa_t^i = {}^{-}Qa_0^i + \int\limits_0^T {}^{-}Atm_t^i dt - \int\limits_0^T {}^{+}Qa_t^i dt \\ {}^{-}Qw_t^i = {}^{-}Qw_0^i + \int\limits_0^T {}^{-}Wat_t^i dt - \int\limits_0^T {}^{+}Qw_t^i dt, \\ {}^{-}Ql_t^i = {}^{-}Ql_0^i + \int\limits_0^T {}^{-}Lan_t^i dt - \int\limits_0^T {}^{+}Ql_t^i dt \end{cases} \qquad (18)$$

where ${}^{-}Qa_t^i$, ${}^{-}Qw_t^i$, ${}^{-}Ql_t^i$ are the balances of pollution by air emissions, water emissions and the waste disposal, respectively, in the period of t; ${}^{-}Atm_t^i$, ${}^{-}Wat_t^i$, ${}^{-}Lan_t^i$ are the amounts of pollution by air emissions, water emissions and the waste disposal, respectively, in the period of t.

The calculation of the volumes of pollution by air emissions, water emissions and the waste disposal in the period of *t*, is carried out according to the following formulas:

$$\begin{cases} {}^{-}Atm_t^i = f^{Atm-}(Q_t^i) \\ {}^{-}Wat_t^i = f^{Wat-}(Q_t^i) \\ {}^{-}Lan_t^i = f^{Lan-}(Q_t^i) \end{cases}, \quad (19)$$

where f^{Atm-}, f^{Wat-}, f^{Lan-} are the pollution functions.

It is assumed that enterprises only utilize their own pollution.

Ecological subpopulation. As noted above, the ecological subpopulation is represented by the human population living in a given territory (*E* or *D*), which is divided into four age groups (0–14, 15–24, 25–64 and over 64 years).

The human population size in dynamics is defined by the formula:

$$PL_t^v = PL_{t-1}^v + Rb_t^v - Rd_t^v + Rs_t^{v-1} - Rs_t^v,$$

where PL_t^v is the population in the group of ν; Rb_t^v is the birth rate for the group of ν, $Rb_t^v = const$; Rd_t^v is the mortality rate for the group of ν; Rs_t^{v-1}, Rs_t^v is the rate of the transition from one age group to the other.

The mortality rate for the relevant group of population depends on the aggregated environmental pollution:

$$Rd_t^v = f^{Rd}({}^{-}AQ_t^i, {}^{-}WQ_t^i, {}^{-}LQ_t^i).$$

The labour market offers of each territory ($\widehat{L}_t^i$):

$$\widehat{L}_t^i = f^l(PL_t^2 + PL_t^3), \quad (20)$$

where PL_t^v is the population size in the 2d and 3d groups.

The interaction between populations. The interaction of populations, operating within the Territories *E* and *D*, goes in the following directions.

First, the population of the Territory *E* and *D* determine the amount of demand for the products of the Territory *D*:

$$\sum_{i=1}^{n} \tilde{Q}E_t^i = f^Q(PLE_t^v, PLY_t^v),$$

where PLE_t^v, PLY_t^v are the population size in the 2–4 age groups in the Territory *D* and *E*, respectively.

Secondly, the production volume of enterprises in the Territory *D* depends on the production of the enterprises in the Territory *E*. To account this dependence, the production of the enterprises in the Territory *D* is adjusted by a factor of (η), which is defined by the following logistic function:

$$\eta = \frac{1}{\alpha\beta^{QY_t} + \gamma},$$

where QY_t is the total output in the Territory *E*; β, α, γ are the function's parameters, 0 < β < 1, α > 0, γ > 0.

With proper selection of the function's parameters, the growth of total output in the Territory *E* will provide the value, approximately equal to 1. At the same time, the total output reduction will cause a decrease of the rate to 0.

Third, the total output in the Territory *D* determines the demand for products manufactured in the Territory *E*:

$$\tilde{Q}Y_t = f_Q(\tilde{Q}E_t). \quad (21)$$

The implementation of the model, its parameterization and verification

The model of populations' coevolution has been implemented in the development environment AnyLogic 6.0[8], which supports agent based and system dynamics simulation (Fig. 3).

Two countries, which may be considered typical representation of the Territories *D* and *E*, have been chosen as objects for the model's parameterization: Germany (the advanced economy with innovative production technologies and institutions, promoting environmentally-friendly behaviour), and Ukraine (the emerging economy with traditional manufacturing technologies and institutions promoting environmentally-unfriendly behaviour).

Each object is characterized by the structure of its economic subpopulation — altruists-egoists ratio (ψ).

During parameterization for each object, these ratios have been chosen so that

[8] URL: http://www.anylogic.com/.

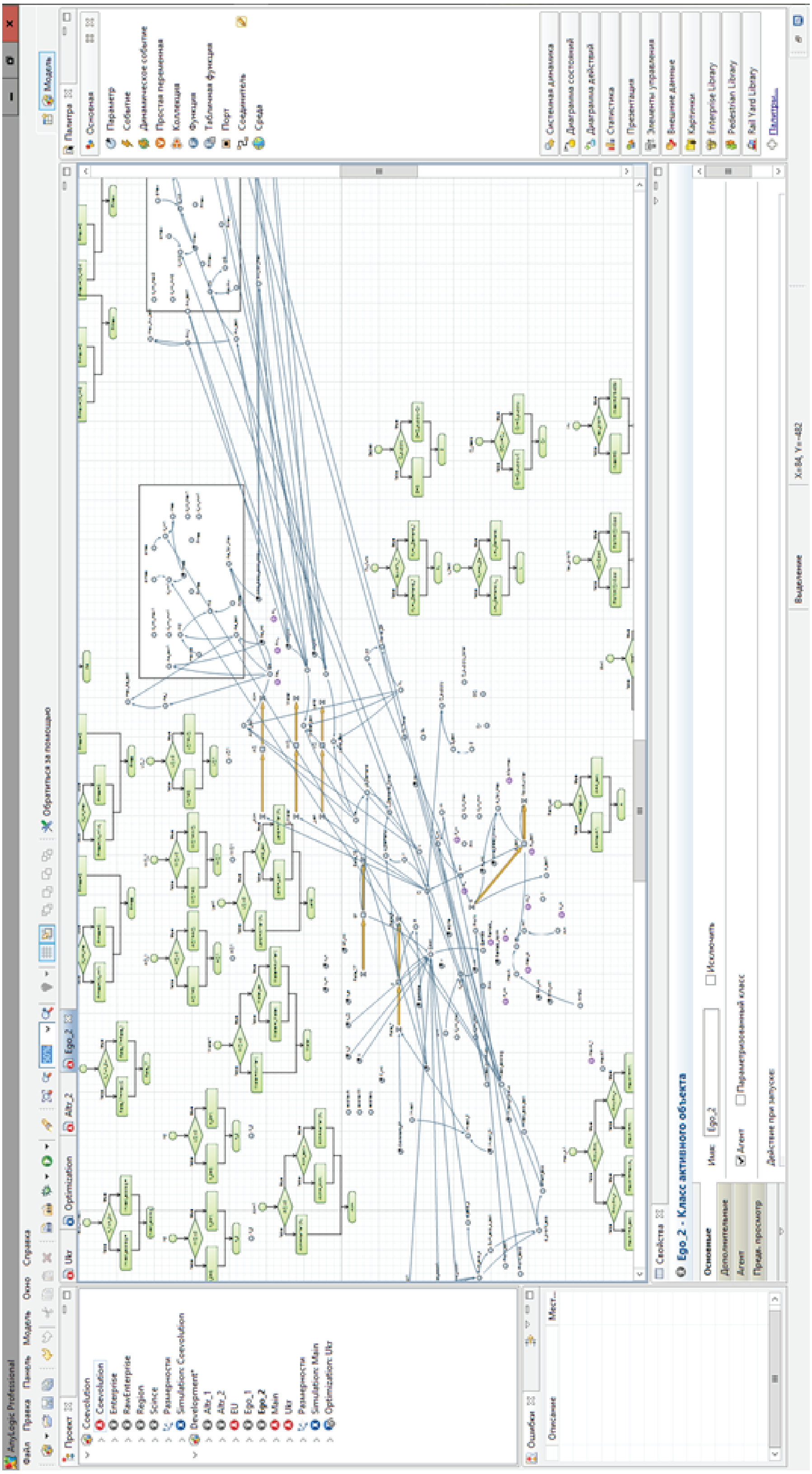

Figure 3. A detail of the mathematical model of populations' coevolution, implemented in AnyLogic 6.0 development environment

the dynamics and values of the populations' developments, determined by the behaviour peculiarities of the altruists and egoists, respond actual observed trends during the entire period of the approximation (2008–2013) (Table).

Parameterized and verified basic model enables the computational experiments, designed to determine the patterns of interdependent development of two populations of economic subjects with different levels of production, innovation and environmental activities.

For this purpose, the following computational experiments were carried out:

– A_1 — the coevolution continuing current trends, when economic populations of the Territories *D* and *E* rely on their own production technologies;

– A_2 — the European type of coevolution, when the economic population of the Territory *E* gets the access to the technologies developed in the Territory *D*.

Experiment A_1 is the coevolution, continuing current trends; the economic populations of the Territories D and E rely on their own production technologies

In the assumption on the independent development of the production technology, the indicators dynamics, characterizing the situation in the Territories *E* and *D*, have different trends.

The Territory *D* has been showing steadily increasing production output (average annual growth rate of +2,0 %) (Fig. 4) and decreasing total resident population size, which is not related to the environmental pollution (–0,06 %) (Fig. 5), and the gradual reduction of anthropogenic impact on the environment (Fig. 7). It comes from the fact that in the Territory *D* the enterprises with advanced production technologies and altruistic (innovative) behaviour type (ψ = 0,55), which are accustomed to the permanent production modernization (which positively reflecting on the capital productivity dynamics — Fig. 6), and also take into account social costs related to the environmental pollution and therefore seek to improve the ways of emitted pollution cleaning, are prevailing.

The Territory *E* has also been showing the decreasing total resident population size at the rate of (–0,15 %) during the simulated period, but it can be explained by increasing anthropogenic impact on the environment — the average annual pollution growth rate (as opposed to the Territory *D*) is positive. This in turn causes the decrease in the working-age population and labour shortages, which results in the long-term decrease in production output. In addition to the stated factor and general low production technology level, the reason is the prevailing in the Territory *E* is egoistic enterprises with conservative behaviour, which seek quick results to the detriment of innovative future, and do not take into account the environmental pollution spillovers.

Model's verification results (mean values for 2008–2013)

Parameter	Unit	Ukraine			Germany		
		Actual	Estimated	Deviation	Actual	Estimated	Deviation
Resident population size	%	100,0	98,9	–1,1	100,0	99,6	–0,4
Industrial output	%	100,0	102,8	+2,8	100,0	91,9	–8,1
Stationary air pollution	%	100,0	91,8	–8,2	100,0	100,0	0,0
Water body pollution	%	100,0	105,6	+5,6	100,0	105,7	+5,7
Industrial pollution	%	100,0	106,8	+6,8	100,0	89,6	–10,4
Mean absolute deviation	pp	–	–	**4,9**	–	–	**4,9**

The statistical data (population size, production output, research and development expenditures, environmental pollution level, etc.) used for the model parameterization is obtained from the websites: URL: http://www.ukrstat.gov.ua; URL: http://data.un.org; http://www.oecd-ilibrary.org; URL: http://epp.eurostat.ec.europa.eu; http://apps.who.int.

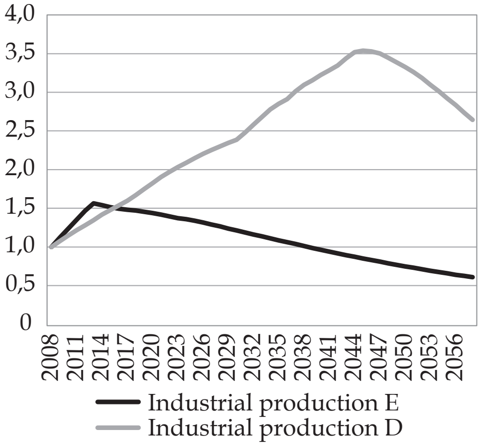

Figure 4. Experiment A_1. Expected production output dynamics (base index)

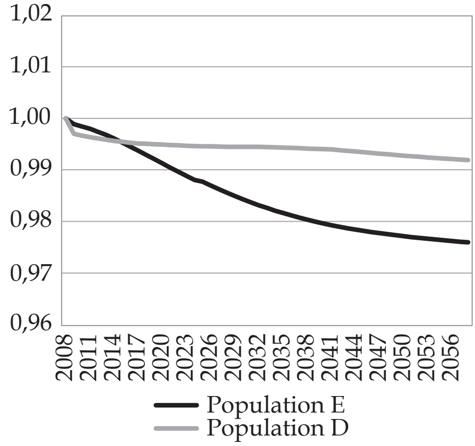

Figure 5. Experiment A_1. Expected resident population dynamics (chain index)

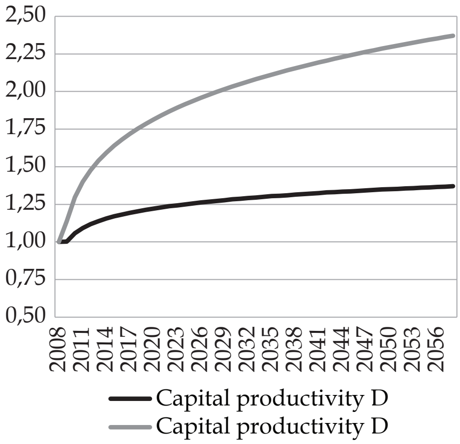

Figure 6. Experiment A_1. Expected capital productivity dynamics (base index)

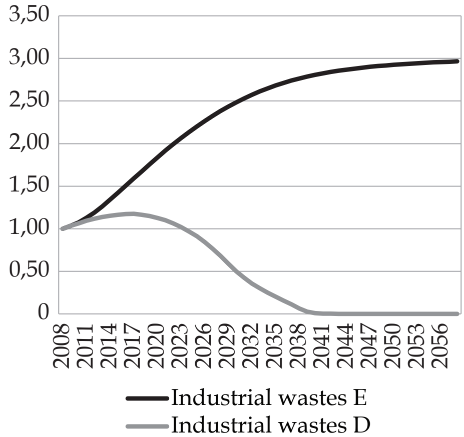

Figure 7. Experiment A_1. Expected industrial waste dynamics (base index)

Experiment A_2 — the European type of coevolution; the economic population of the Territory E gets the access to the technologies developed in the Territory D

If the economic population *E* gets the access to the advanced foreign technologies, then the territorial development parameters change drastically. Now, the economic population (the industrial enterprises of the Territory *E*) has the ability to occasionally copy, and then after a while to replicate massively these technologies, which results in productivity growth of the production and environmental activity, the increase in production output (Fig. 8), and better cleaning of emitted environmental pollution. As a result, the ecological population situation improves, which reflects positively on the resident population size dynamics of the Territory *E* (Fig. 9).

However, it should be noted that the results obtained in the experiment A_2 are rather a demonstration of the capacity of the European development vector, than real policy for the Territory *E*.

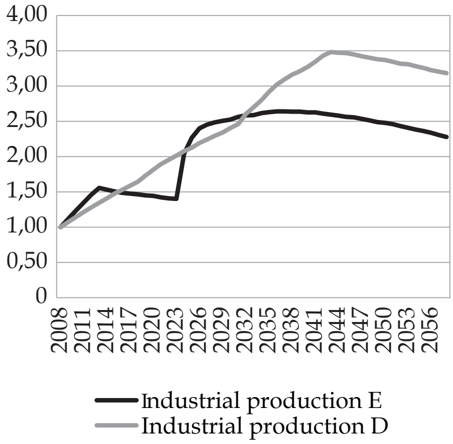

Figure 8. Experiment A_2. Expected production output dynamics (base index)

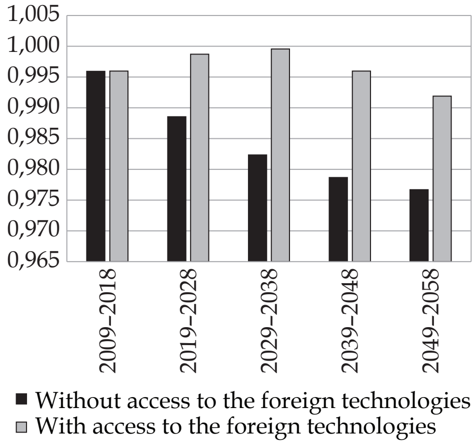

Figure 9. Experiment A_2. Average population decrease rate in the Territory E (chain indexes)

In order to simulate technologies successfully (and especially to create them), the appropriate scientific and technological potential is required (a rather high level of scientific and technological culture, qualified personnel, innovation traditions, etc.), which enables the country to open the window of opportunities in using technological experience of more advanced countries. The dynamics of all these processes is well described in the well-known monograph by C. Perez [13]. The common principle is that the ability to copy and mass-replicate new technologies depends on the recipient's scientific and technical development, which, in turn, is determined by the cumulative (for many years) R&D expenditures of the government and enterprises. As noted by V. Dementyev [15], there is a certain threshold of initial scientific and technical knowledge, failing which they raise the marginal costs infinitely large. And conversely, the higher initial knowledge is the easier it gets to acquire additional knowledge [15, p. 37].

As is known, the total R&D level in the emergent countries is substantially lower than in advanced countries. But several post-Soviet economies retained the national scientific and technical potential (especially in the military-industrial complex). It is obvious that the capacity development through expansionary economic policy will improve both the generation of its own scientific and technological development and, more importantly for the emergent markets, enhance the ability of economic agents to adopt foreign technology (reducing the time required for learning to use and further mass replicate by the formulas 10–13).

Using the model to choose the adjustment policy: fiscal and/or monetary tools

The government of the Territory *E* has two main tools of stimulation the innovative economic development of the population: fiscal and monetary policy, the impact of which we will analyse further.

Within the model, they function the following way.

Fiscal policy reduces the total tax rate[9] (τ↓):

– τ1↓ — increasing enterprises' earnings — increasing intramural technology development costs;

– τ2↓ — changing amounts of tax payments — changing government R&D financing.

[9] It this paper to determine the tax impact on economic processes we use the total tax rate indicator, introduced by the experts from PwC and World Bank Group (2015, p. 126), which describes the taxes and other mandatory contributions of the enterprise as a share of its profit.

There is no unambiguous prior answer on how the change in tax rate will affect the tax payments, whether they will increase or decrease. This is a specific question, which relates to the Laffer problematics (the tax base elasticity by the tax rate). The same applies to changes in the R&D government financing by the changes in tax revenues. Typically, for various reasons this dependence is absent, as far as additional revenues can, technically, be directed anywhere (within the law). Therefore, our simulation is based on a neutral hypothesis of unit elasticity:

– the x % increase in tax leads to a proportional x % increase in the tax base;

– the x % income change leads to a proportional x % change in each type of government expenditures, including x % change in R&D expenditures.

Monetary policy reduces mean interest rate ($k\downarrow$):

– $k1\downarrow$ — increasing enterprises' profit by interest savings — increasing intramural technology development costs — increasing tax payment amounts (for a given tax rate) — increasing government R&D financing;

– $k2\downarrow$ — increasing investment, financed by credits loans — increasing enterprises' profit — increasing intramural technology development costs — increasing tax payment amounts (for a given tax rate) — increasing government R&D financing;

– $k3\downarrow$ — increasing inflation — decreasing government R&D financing (real terms).

As the case of tax reduction, the interest rate reduction has an ambiguous impact on the volume of the government R&D financing, because, on the one hand, they may be increased due to revenue and thus the enterprise's tax payments growth and, on the other hand, they may be decreased in real terms due to the fact that the reduction of the official discount rate in the Territory E which determines the interest rates is related to the increasing inflation risks. Generally, it is a paraphrase of the aforementioned Laffer problematics, but only on the dependence of tax base on the interest rate. In this case, the sign and degree of this dependence are determined by the analysis of data for past periods.

Using this logic, further the simulation of the impact of τ and k on the coevolution of the economic and ecological populations in terms of long and short planning horizons (long and short behaviour) is carried out:

– B_1 is the fiscal and monetary regulations of the coevolution in terms of long term planning horizon;

– B_2 is the fiscal and monetary regulations of the coevolution in terms of short term planning horizon.

Experiment B_1 — fiscal and monetary regulations of the coevolution in terms of long term planning horizon

The calculations start with a social discount rate equal to zero. With such rate, the present value of its future revenue is equal to that of the present. This means that, following the population approach he performed calculations allow to take into account the long-term effects of the regulation of economic and ecological populations coevolution, and to serve the interests of future generations. At the same time, the planning horizons of economic entities coincide with the duration of calculation period (50 years).

Basing on these assumptions, the purpose of this experiment is to find those values of the variables (τ and k) at which the objective function (discounted production output) tends to the maximum under the following variables restrictions[10]:

[10] The following values of variables were used in calculation: (1) T_N = 0,01 (2) R&D spending — from 0,76 % GDP (Ukraine, average for 2005–2014) to 2,10 % GDP (The euro region, average for 2005–2014); source: The World Bank. World Development Indicators & Global Development Finance; (3) interest rates — from 17 % (Ukraine, average for 2005–2014) to 5 % (data on Italy for 2005–2014, recent data on other countries is unavailable, but before the financial crisis of 2008–2009, Germany and France had the same rates); source: The World Bank. World Development Indicators & Global Development Finance; (4) total tax rates — from 52,2 % of profit (Ukraine 2015) to 40,6 % of profit (the UN 2015, the rates for other years were similar); source: PwC, World Bank Group, Paying Taxes.

$$\begin{cases} \tau_{\min} < \tau < \tau_{\max} \\ k_{\min} < k < k_{\max} \\ \dfrac{\sum_{i=1}^{N} \dfrac{\widehat{Q}_t^i}{(1+b)^t}}{\sum_{i=1}^{N} \dfrac{\widehat{Q}_{t-1}^i}{(1+b)^{t-1}}} \geq T_N \end{cases}, \tag{22}$$

$$\sum_{t=1}^{T} \sum_{i=1}^{N} \frac{\widehat{Q}_t^i}{(1+b)^t} \to \max, \tag{23}$$

where b is the discounting rate; T_N — is minimal required compound annual growth rate of the production output.

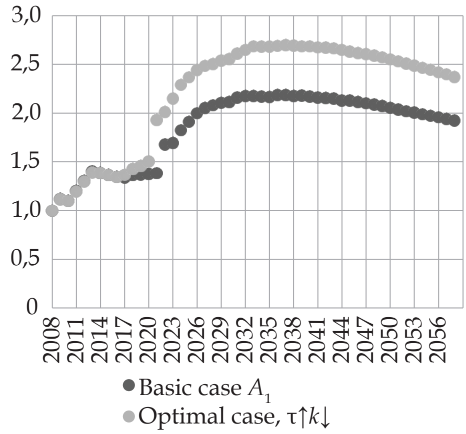

Figure 10. Experiment B_2. Comparative dynamics of production outputs (base index) in the Territory E under «long behaviour»

The results of the optimization calculations on the assumption of «long behaviour» showed that the policy, promoting the economical growth best (Fig. 10), is the cheap money policy, which gives the economic population the best investment access to savings, and high European taxation, which provides the government with the ability to consistently build and maintain a high level of R&D expenditures, thereby contributing into accelerating the development and localization of imported technologies. In fact, such conclusion may be considered expected. After all, in order to achieve high economic growth rates, catching up the advanced economies, it is necessary to gradually build up an innovation friendly institutional environment, which, along with other features, is characterized by cheap money and relatively high taxes, by which the advanced economies maintain their high development level of health care, education, science, culture, etc.

Experiment B_2 — fiscal and monetary regulations of the coevolution in terms of short term planning horizon

In this computational experiment the discounting rate is b = 0,3. With such discounting rate ≈ 80 % of the discounted cost results (Pareto distribution) fall on the first five years of accounting period, and ≈ 20 % only fall on all the other years. This means that, in practice, for the decision-makers, only the first 5 years of the activity do really matter. The planning horizon for economic entities of the given population is limited by the period, usually coinciding with the normal duration of the presidential term. Basically, it is a political (not economic) planning horizon, well reflecting current public life reality in Ukraine, where each central regime change causes a radical change in the strategic course of the state and the dominant rules of «the game». Therefore, nothing, happening beyond this horizon, is so important for making important decisions.

The results of the optimization calculations on the assumption of «short behaviour» showed that there are no optimal values of the variables τ and k exist. That is, any combination of monetary and fiscal policy τ↓k↓; τ↓k↑; τ↑k↓; τ↑k↑ does not provide the increase (compared to the base A_2) in minimum required annual economic growth (T_N ≥ 1 %). Therefore, under such conditions, the potential of the state economic regulation is levelled off by the politically motivated business investment «myopia», which results, regardless of the government actions, in no hope for acceleration of the innovation economic growth in the Territory E.

However, this does not mean that the developed model has nothing to offer in the situation, well corresponding to the current institutional reality in Ukraine. In this context it is worth recalling that, in this paper, we proceed not from the usual neo-classical presentation, but from the evolutionary (population) paradigm that links the achieved results to the activity of the entities, generating those results.

If the population of enterprises is viable, then there will be some results, and if the population of enterprises is gradually dying out, sooner or later, the results will disappear too. It follows that the neoclassical entity utility maximization is insufficient (even taking into account the usual constraints on resources, rationality, institutions, etc.). This is just the presupposition of the behaviour of a single entity (person) to model the population.

But in the long-term evolutionary context, the entity itself is not important, but the growing (at least relatively) population of entities is, which also gives the chance to survive to those who adhere to innovation (altruistic, cooperative) behaviour. After all, according to the theory of multilevel (group) selection, the frequency of altruists in a structured population is determined by two factors: the individual selection within subpopulations (groups), which is unfavourable for altruists-cooperators, and the group selection, which is cooperative subpopulations «friendly». Consequently: «Selfishness beats altruism within groups. Altruistic groups beat selfish groups» [16, p. 335].

The computational experiments showed that in terms of the short planning horizon of economic entities, the policy, that is most conducive to the growth of their population, involves a combination of cheap money and low taxes $\tau\downarrow k\downarrow$ (Fig. 11).

However, it is important to point out that such a policy can only be a first step in the long-term economic growth-focused national strategy. In the future, to ensure accelerated development of the Territory *E* through the windows of opportunities, which open for the localization of the European process technologies, it will be necessary to introduce the higher European taxes, only by gradually replacing the short political planning horizon with the long economic one. That is the raise in taxation should follow the formation of new institutional environment, based on the following: the stable rules of economic relations, long enough for the creation and commercialization of new technologies; the high costs of the rent-seeking behaviour and corruption; the government's ability to be a «technocratic» one and to direct the social revenue growth to the healthcare, education, R&D and not to their own needs, to serve the community at large, rather than the officials running the economy or rent-seeking businessmen.

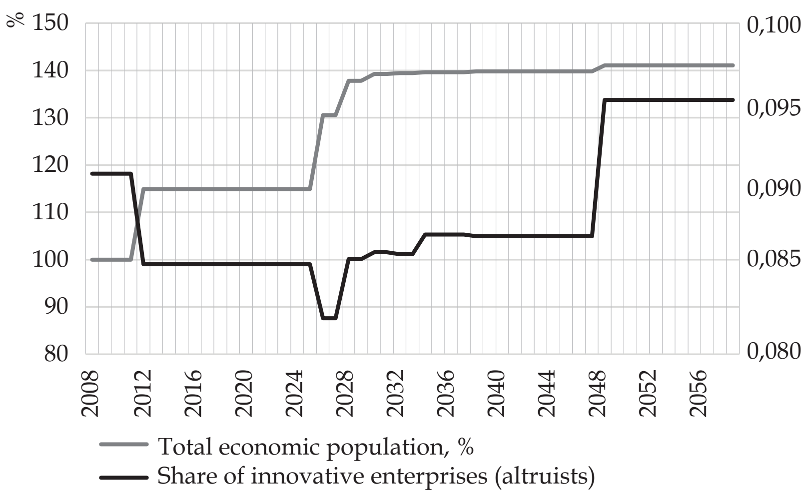

Figure 11. Experiment B_2. The dynamics and structure of the economic population of the Territory E under «short behaviour» with cheap money and low taxes

Conclusions

1. To overcome the consequences of the global financial and economic crisis and to shift to the sustainable economic growth, the developed nations mostly use the monetary policy tools. However, the achieved results, which are far from being great, put a more active use of the alternative fiscal policy tools on the agenda. The developing countries also face the challenge of such a choice, but it is even more difficult, because in the process of interaction with the developed economies, many of them entrenched in the global value chains as auxiliary units specialized in the production of raw materials and low processing degree products. And this, in its turn, imposes additional restrictions on the ability of the successfully solving the economic growth issues.

Therefore, in view of the indicated circumstances, to justify the choice of the best methods of economic processes regulation, which can change for the better the situation between interconnected and interdependent economies, this paper did not use the usual neoclassical methodology, but the evolutionary methodology based on the idea of studying the patterns of co-development (coevolution) of the differentiated economic and ecological populations, which function within the separate territories, under specific labour and natural resources, production technologies and environmental conditions, are lead by special institutions resulting from the «path dependence», etc.

2. It was suggested to present the development patterns of the economic and ecological populations, using the agent based and system dynamics modelling, which simulates the processes of their coevolution. In this model each population is characterized by its original structure of economic entities, defined by the relation of the egoistic enterprises (predisposed to conservative behaviour) to the altruistic enterprises (predisposed to innovation), as well as by specific population and demographic processes. Moreover, the population, specializing in the production of final products with low environmental costs, is characterized by high proportion of altruistic enterprises, when the population, which specializes in the production of intermediate products with high environmental costs, has a high proportion of egoistic enterprises.

It is important to mention that this model is not designed to describe the quantitative economic growth only, but to analyse its evolutionary processes in the form of changes in the initial structure of economic entities (egoistic and altruistic enterprises) which, in turn, determines the change of the population's dominant institutions.

3. The simulation of the coevolution processes of two differentiated economic and ecological populations, connected through GVCs in the production complex «Emerging market — Developed market» («*E* — *D*»), has shown that their spontaneous development can have hard negative impact on the entire system, which is determined by the fact, that the problems of the less developed territory through the supply chains, extend to the other members of the GVC, placed in the safe territory. To avoid such unfavourable developments, fraught with increasing global instability, the two types of regulatory tools — fiscal and monetary tools, which are used at the same time by the government in the Territory *E*, have been considered.

In particular, the following tools were considered:

– fiscal policy — the total tax rate reduction;

– monetary policy — the mean credit rate reduction.

Both tools influence (through different transmission mechanisms) the enterprises' profits, investments, taxes, amounts of government R&D funding and, eventually, the economic growth.

4. The results of the computational experiments have shown that the success of economic regulation fundamentally depends on the peculiarities of the initial state of the institutional management environment.

In the institutional environment with the «transparent» long behaviour and, accordingly, a long economic planning horizon (at zero social discount rate), the best result in the form of average annual production growth rates of the emergent economies is provided by the cheap money policy (low credit interest rates) combined with the high European taxes. With such planning horizon, the taxation burden reduction is not as important, from the national standpoint, as the provision of high tax revenues, directed to the advanced development of the R&D sector.

In other words, in terms of initially backward innovation system, the enterprises' investment in the production modernization provide lower returns than government R&D investment, allowing the accelerated development and localization of advanced foreign technologies.

A different situation is observed in more realistic short behaviour and, accordingly, short (under 5 years) economic planning horizon (with politically motivated discount rate). In this case, any tax policy (neither low nor high taxes) together with any money (neither cheap nor expensive), to a certain extent loses its significance, as the initially backward innovative system does not allow to quickly get good results, and the long-term benefits of the potential economic growth are not taken into consideration.

5. However, the low taxes (except for the tax on negative externality) and cheap money are important for the gradual development of better innovation system, because, all other things being equal, they create better conditions for the altruistic enterprises, facilitating their investment activities and increasing the probability of meeting the innovative «black swan» [17], which can multiply increase their technical performance and economic efficiency. This will result in the improving economic population's structure by growing share of the economic entities adhering to innovation (altruistic, cooperative) behaviour, and in the increased population's viability. And that, finally, along with the favourable institutional environment of economic activity is essential for the sustainable economic and social development.

Anyway, in the context of the evolutionary economics and following the conducted computational experiments, the fiscal policy in terms of emergent markets retains its regulatory capacity, and therefore requires further reforms in the context of the «new reality» based on the global value chains. However, due to the relatively unbalanced economic populations' structures, the large-scale fast results should not be expected from such actions.

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