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Research paper

Manufacture Technological Structure Innovation Strategy Development Modeling in Terms of the New Ecological and Economic Doctrine

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Abstract

Economic growth with restrictions on ensuring economic balance implementation and greenhouse gases balance with the efficiency criterion in the form of production construction technological structure sustainable development model using research construction methods is fulfilled in the article. Aggregation procedure method is developed based on original micro-description research and the ecological and economic production function is constructed in explicit analytical form. Gross output modeling is carried out depending on the draw economic and ecological resources amount and technological production structure changes. The obtained results give an opportunity to evaluate any mechanism introduction impact for environmental management on the environment state and industrial enterprises economic development.

Keywords: *economic and mathematical modeling, production technological structure, ecological and economic production function.*

1. Introduction

The Kyoto Protocol, adopted in December 1997, as an annex to the UN Framework Convention on Climate Change, obliged the ratifying countries (192 countries) to develop a system for limiting industrial emissions through quotas. Representatives of 195 states adopted a global climate change agreement in December 2015 in Paris to change the Kyoto Protocol. The Paris climate agreement came into force in November 2016, which aims to prevent a rise in the air temperature on the planet by the end of this century within 2 degrees, and taking into account existing risks up to 1.5 degrees Celsius from the level to the industrial era.
Consequently, in industrial enterprises socio-economic development forecasting and planning system it is necessary to provide natural resources rational usage. As you know, nature is rather inertial and conservative, changes in it occur more slowly than in the economy. Therefore, special attention is given to anthropogenic impact on the environment possible consequences early warning, long-term plans creation and forecasts, where the economic development ecological strategy is determined. Such a plan-forecast envisages, first of all, main directions and scale definition of economic activity impact on environment quality as an important human life condition and sustainable economic development.
Sustainable development ecological and economic strategy should provide natural resources assessment, identify ways of their conservation and rational usage, and include scientifically substantiated recommendations mechanism for the implementation the transition to such development. The main direction is the ensuring environmental protection economic mechanism, which provides nature usage reimbursement, environmental activities preferential lending and taxation, stimulating natural resources conservation, energy conservation, emissions reprocessing and utilization from production and consumption. Solving ecological problems requires systematic and comprehensive research implementation using a program-targeted approach in combination with other methods. The priority direction in this case is the scientific and technical measures substantiation that would ensure an increase in the economic system self-sufficiency level with natural resources, ecologically safe and resource-saving technologies introduction in the industry aimed at anthropogenic impact environment effective protection and reduction on the environment.
Until recently, most of research and construction functions production methods used production maximization as the main economic indicator. However, the task of transforming the economy into sustainable development model requires ecologically adjusted indicators consideration and economic levers entire system transition. Thus, the actual task is to develop an ecological and economic production function (EEPF) that meets the current conditions.
Economics and ecology interaction mathematical modeling task is not new. Many scientists use eco economic modeling during research. In the paper [1], for the first time, information was provided on the economy and the environment interaction, and general equilibrium model study was performed. The book [2] shows how to analyze models using math and software to create dynamics system qualitative description. Work [3] codifies the relationship between energy, resources and the environment economics.
Definitions and methods for evaluating global energy subsidies are presented in [4]. Literature overview on modeling events in ecological macroeconomics and alternative business models study was made in [5]. Ecosystem services conceptualization historical development analysis and their modern practice inclusion in markets and payment schemes are devoted to work [6]. The research in the spatial-temporal dynamics economic growth capital and

pollution model with targeted environmental protection activities is proposed in the article [7].
International environmental agreements formation mechanism is analyzed in [8]. The analytical tool for choosing the optimal rate for demand correction and permit options in the Emissions Trading System (ETS) is developed in [9]. The algorithm for estimating future climate change using the conditional nonlinear optimal perturbation is constructed in the study [10]. A model that uses a repetitive game with linear and quadratic emission reduction functions in a particular country is given in [11]. Dynamic changes limit values calculation in the environment in ecological modeling is used to support decision-making in the work [12]. Ways formation to efficiently transfer calculations results to ecological-economic models to substantiate management strategies is carried out in [13]. The main factors that influence the scheme for trading emission permits in China are found in the paper [14]. A global equilibrium model with many technological constraints has been used to assess emissions permits trade efficiency in a study [15]. The relationship between the environment quality and trade in carbon dioxide (CO_2) emissions is analyzed using quantitative data evaluation in [16]. Relationship between CO_2 emissions, renewable and non-renewable energy consumption and economic growth empirical study is presented in scientific paper [17].
However, despite a significant number of publications on the chosen topic, the task of constructing models economic growth with constraints adequate to the current conditions studying methods remains relevant. Unlike existing analogues, such models allow us to determine ecological-economic system development trajectory explicitly analytical form. Consequently, it is necessary to study methods of constructing economic growth models with constraints on ensuring the economic balance implementation and greenhouse gases balance with efficiency criterion in production technological structure sustainable development form and to construct the EEPF in an explicit analytical form.

2. Constructing economic growth models methods research with given constraints

One of the main economic activity system analysis methodological principles is the ability to adequately determine the input, output and status of each process under study in the production system and their interaction construction schemes. The actual existing production mode is determined by the desire to optimize the use of the technologies involved, as well as the limited ability to provide production factors. These restrictions are connected with the current trends in the development of production, production capacities size, producer's qualification, as well as with the purely economic constraints of such indicators as the payback period of capital investments, products material consumption etc. In essence, particular production mode limitation is determined by two main reasons: changing the composition impossibility and structure of productive resources structure in a short space of time; conditions imposed by the environment.
It is obvious that the organizational and economic aspects that impose restrictions on implementing an optimal production mode possibility play an increasingly important role. Consequently, if production factors quantity and composition, technological methods and organizational and economic constraints are known, then based on these data it is possible to determine issue volume and structure. Along with the environment constraints, the created production structure gives a reflection, which is determined on the set of all possible resources combinations, and aligns to each such set of output products manufactured using them based on this method. Such dependence method model is called the production function, which gives both production process quantitative and qualitative estimation, both at the micro-level and at the macro level. The task of constructing a production function, in particular, the EEPF, was and remains one of the urgent tasks in economic and mathematical modeling.

The model of the EEPF, due to economic and environmental subsystems consideration, as well as their interactions, determines the impact of the introduction of any environmental management mechanism on the state of the natural environment and economic development. Next will be scalar EEPF, which simulate the production of one product. Natural potential usage is reflected explicitly in economic indicators, and also cost savings general requirement is fulfilled. That is, income maximization, as the main objective of the business entity, will also take into account options for optimizing relations with the environment.
It is also necessary to clarify within problem bounds under consideration the ecological resource concept. Among environmental complex total expenditures will be investigated pollution prevention costs, which are financed by the industrial object (source of pollution) in order to reduce pollutant emissions. Examples are the treatment facilities construction, production technologies change, pre-treatment, neutralization, and harmful emissions dilution, in general, the transfer to the appropriate pollutant disposal facilities or environmental tax payment established by the state. Consequently, under the ecological resource, the actual costs incurred by society as a result of environmental pollution, or the additional costs of compensating for these losses, are understood to be expressed in value form.
It is also necessary to take into account environmental quality established standards with implemented environmental measures. It is evident that the standards interconnection with direct control, which is aimed at achieving and maintaining a given environment state. It is this relationship that allows us to investigate the EEPF. Analyzing on its basis taxes on harmful substances emissions various rates, it can be determined the change in the nature state that occurs under these conditions. A real ecological resource adequate assessment is needed in all economy sectors: overall economic efficiency assessment, all types' investment projects selection, in particular environmental protection projects, market economy methods introduction, etc. EEPF model construction in an explicit analytical form will help to build complicated, and sometimes uncertain, factors associated with the problem of decision making into a logical scheme that is necessary for detailed analysis. It will make it possible to determine what data is needed to evaluate the available alternatives and to obtain substantiated conclusions.
When studying production factors group characteristics and manufactured products, one can define grouped, that is, aggregated, ecological and economic technology as a way of converting resource groups into given functional groups finished products. At the aggregates level, the production process result is determined by the aggregated technology, the resource group's size, as well as organizational and economic constraints. By studying the combined aggregate ecological and economic technology and organizational and economic constraints, it is possible to aggregate the output technological micro-description with the help of the EEPF.
Enterprise technical development, connected, in particular, with elementary technologies change, is a continuous process. However, as a rule, upgraded technologies share is small, therefore, the larger economic system and the higher aggregation level indicators, the less this process affects the EEPF. In addition, for the large-scale systems, external organizational and economic conditions and restrictions are more important. In general, it can be concluded that the stability of the EEPF is the greater, the higher aggregation level and the larger the system is analyzed.
The stability of the EEPF is related not only to the stability of the composition and technologies usage intensity, but also to indicators invariance used to measure economic, environmental resources and output. In order to ensure EEPF stability the over a given period of time, it is necessary that the resource and output indicators either remain unchanged or changed in a consistent manner. The highest aggregation indicators level is achieved if the total output is measured by a single volume indicator (for example, the value of marketable products).

3. Ecology and economic production function construction in an explicit analytical form

The economic system in which a set of independent producers in the conditions of perfect competition operates is analyzed. Each of them offers manufactured products on the market of a homogeneous product and is characterized by a plurality of production opportunities, an investment flow I , power M , that is, the maximum possible output per unit time. Production factors will be divided into economic and environmental, it is a homogeneous labor force R , and harmful substances permissible emissions f amount is set Q .

It is believed that the products are manufactured in different technological ways. Each technology is characterized by the following parameters:

- λ – Standard labor cost per product unit per unit time;
- q – Emission factor per output unit per unit of time;
- μ – Power dissipation pace;
- r – Pollution growth rate due to aging technology.

In addition, the time moment is investigated τ new production unit creation, new technology usage $\nu(t)$, that is, the lowest living expenses per output unit, the smallest pollutants emissions $s(t)$ и per material production unit and investments inflow $I(\tau,\nu,s)$. Power, labor norm and pollutant emissions per output unit in a production unit (τ,ν,s) vary in time, they are labeled accordingly $m(t,\tau)$, $\lambda(t,\tau)$ and $q(t,\tau)$. Due to physical wear, the power varies according to the law:

$$\frac{\partial}{\partial t}m(t,\tau)=-\mu m(t,\tau),\ t>\tau,\ m(\tau,\tau)=I(\tau,\nu,s). \tag{1}$$

Received Cauchy problem solution determines the change in power over time:

$$m(t,\tau)=I(\tau,\nu,s)e^{-\mu(t-\tau)},\ t>\tau.$$

Working places quantity per production unit is equal to $\nu I(\tau,\nu,s)$ and does not change in time. Therefore, the following is true:

$$\frac{\partial}{\partial t}(\lambda(t,\tau)m(t,\tau))=0,\ t>\tau,\ \lambda(\tau,\tau)=\nu.$$

From the last conditions and (1) it is written that

$$m(t,\tau)=I(\tau,\nu,s)e^{-\mu(t-\tau)}, \tag{2}$$

$$\lambda(t,\tau)=\nu e^{\mu(t-\tau)},\ t>\tau. \tag{3}$$

It can be stated that production units $m(t,\tau)$ technologically aging, reducing its power in accordance with (2), increasing its labor intensity in accordance with (3) and increasing the contamination according to the exponential law (using the classic hypothesis about worn out equipment the environmental damage):

$$q(t,\tau)=se^{r(t-\tau)}.$$

Based on the obtained equations, it can be noted that the total power is the investment integral value that changes with the pace $\mu\geq 0$ within established resource restrictions limits:

$$M(t,\lambda,q)=\int_{t-\theta(t)}^{t}I(\tau)e^{-\mu(t-\tau)}d\tau, \tag{4}$$

Where function $\theta(t)$ is determined on the following terms:

$$\nu(t-\theta)e^{\mu\theta}=\lambda, \tag{5}$$

$$s(t-\theta)e^{r\theta}=q. \tag{6}$$

Function $\theta(t)$ is a delay argument. Equation (5) and (6) determine the conditions for the production capacity transition to production unit optimal production technologies in terms of the labor cost optimal rate and pollutants emissions, as well as establish operation possible time range $[t-\theta,t]$. At the same time defining for θ is equation (5), and (6) reflects only functions connection equation (5), and (6) reflects only the connection of functions $s(t)$ та $q(t)$ Regarding living labor cost, it is believed that the labor division is taking place, mainly based on the existing economic potential of technology. When work amount and economic system change structure, labor resources demand changes accordingly. Labor resources amount involved in the technological set defines the integral:

$$R(t,\lambda,q)=\int_{t-\theta(t)}^{t}\nu(\tau)I(\tau)d\tau. \tag{7}$$

The ecological resource as pollutants permissible emissions amount is determined administratively. During technological structure changes and innovations introduction the amount caused by the pollutants material production can be changed accordingly. Ecological resource amount involved in this technological set is determined as follows:

$$Q(t,\lambda,q)=\int_{t-\theta(t)}^{t}s(\tau)I(\tau)d\tau. \tag{8}$$

Production technological structure at the time moment t , except for the previously technology capacity allocation allocated function $m(t;\lambda;q)$, can also be described by power normalized distribution continuous function over technologies $h(t;\lambda;q)$. These functions are related to the type relationship which determines power unit distribution at the time moment t .

$$h(t,\lambda,q)=\frac{m(t,\lambda,q)}{M(t)},$$

It is assumed that $m(t;\lambda;q)>0$, $h(t;\lambda;q)>0$ on plural $\nu_1\leq\lambda\leq\nu_2$; $s_1\leq q\leq s_2$, where ν_1 and ν_2 –determines respectively the best and worst technology used in production; S_1 and S_2 – the smallest and largest pollutant emissions amount on a technological set.

Based on made assumptions, EEPF, which describes gross output amount depending on used economic and environmental resources amount, and takes into account the change in the production technological structure, has been constructed. It can be written in an implicit parametric form:

$$Y=M(t)f(t;x_1;x_2),$$

Where power unit distribution at time moment t is determined by the formula

$$x_1=\frac{R}{M(t)},\ x_2=\frac{Q}{M(t)},\ h(t,\lambda,q)=\frac{m(t,\lambda,q)}{M(t)},$$

– Used power total unit used

$$f(t,x_1,x_2)=\int_{\nu(t)}^{\xi}\int_{s(t)}^{\eta}h(t,\lambda,q)d\lambda dq.$$

Then

$$x_1 \equiv \int_{\nu(t)}^{\xi}\int_{s(t)}^{\eta} \lambda h(t,\lambda,q)d\lambda dq\,,\ \ x_2 \equiv \int_{\nu(t)}^{\xi}\int_{s(t)}^{\eta} q h(t,\lambda,q)d\lambda dq\,.$$

However, it is difficult to use such an implicit EEPF. Therefore, a different approach is suggested. Using power dynamics equations

$$\frac{dM}{dt} = I - \mu M$$

and conditions (4), (7), (8) the equation is written:

$$M(t)f(t,x_1,x_2) = \int_{t-\theta}^{t} I(\tau)e^{-\mu(t-\tau)}d\tau\,,\ \ M(t)x_1 = \int_{t-\theta}^{t} \nu(\tau)I(\tau)d\tau\,,$$

$$M(t)x_2 = \int_{t-\theta}^{t} q(\tau)I(\tau)d\tau\,.$$

While

$$M(\tau) = M(t)e^{\left(-\int_{\tau}^{t}\sigma(k)dk + \mu(t-\tau)\right)}$$

— Cauchy task solution $\begin{cases} \dfrac{1}{M}\dfrac{dM}{dt} = \dfrac{I}{M} - \mu, \\ M(t)\big|_{t=\tau} = M(\tau), \end{cases}$

where $\sigma(k) = \dfrac{I(k)}{M(k)}$.

From the obtained relations one can proceed to EEPF implicit parametric representation:

$$f(t,x_1,x_2) = \int_{t-\theta}^{t} \sigma(\tau)e^{-\int_{\tau}^{t}\sigma(k)dk}d\tau\,,$$

$$x_1 \equiv \int_{t-\theta}^{t} \nu(t)\sigma(\tau)e^{\mu(t-\tau)-\int_{\tau}^{t}\sigma(k)dk}d\tau\,,\ \ x_2 \equiv \int_{t-\theta}^{t} s(t)\sigma(\tau)e^{\mu(t-\tau)-\int_{\tau}^{t}\sigma(k)dk}d\tau\,.$$

Obtained relations integration can only be done in individual cases. For example, if labor productivity growth rate is due to technological innovations $-\frac{1}{\nu}\frac{d\nu}{dt}$ proportional to new capacities the share created $I(t)$ in total capacity, like $\frac{1}{\nu}\frac{d\nu}{dt} = -\varepsilon_1\sigma(t)$, $\varepsilon_1 > 0$, and emission reductions pace due to technological innovations $-\frac{1}{s}\frac{ds}{dt}$ also proportional to new capacities proportion created, like $\frac{1}{s}\frac{ds}{dt} = -\varepsilon_2\sigma(t)$, $\varepsilon_2 > 0$.

Then EEPF gets a look:

$$f(t,x_1,x_2) = 1 - e^{-\int_{t-\theta}^{t}\sigma(k)dk}\,,$$

$$(1-\varepsilon_1)x_1 \equiv \mu\nu(t)\int_{t-\theta}^{t} e^{\mu(t-\tau)-\int_{\tau}^{t}\sigma(k)dk}d\tau + {} + \nu(t)\left(1 - e^{\mu\theta-(1-\varepsilon_1)\int_{t-\theta}^{t}\sigma(k)dk}\right),$$

$$(1-\varepsilon_2)x_2 \equiv (\mu+r)s(t)\int_{t-\theta(x_1,x_2)}^{t} e^{(\mu+r)(t-\tau)-\int_{\tau}^{t}\sigma(k)dk}d\tau + {} + s(t)\left(1 - e^{(\mu+r)\theta(x_1,x_2)-(1+\varepsilon_2)\int_{t-\theta(x_1,x_2)}^{t}\sigma(k)dk}\right).$$

From EEPF general representation, expressions for the production function can be obtained in several partial cases. In this case, production function analytical expression $f(t,x_1,x_2)$ is divided into two cases: material output level dependence on labor $f_1(t,x_1)$ and material release level dependence on the established environmental constraints $f_2(t,x_2)$. The connection between them is set as follows

$$f(t,x_1,x_2) = \min\{f_1(t,x_1), f_2(t,x_2)\}.$$

1. If the power does not wear out and pollution growth rate due to aging technology $r = 0$, then

$$f_1(t,x_1) = 1 - \left(1 - \frac{1-\varepsilon_1}{\nu(t)}x_1\right)^{\frac{1}{1-\varepsilon_1}} \text{ while } x_1 \le \frac{\nu(t)}{1-\varepsilon_1};$$

$$f_1(t,x_1) \equiv 1 \text{ while } x_1 > \frac{\nu(t)}{1-\varepsilon_1};$$

$$f_2(t,x_2) = 1 - \left(1 - \frac{1-\varepsilon_2}{s(t)}x_2\right)^{\frac{1}{1-\varepsilon_2}} \text{ while } x_2 \le \frac{s(t)}{1-\varepsilon_2};$$

$$f_2(t,x_2) \equiv 1 \text{ while } x_2 > \frac{s(t)}{1-\varepsilon_2}.$$

2. If investment $I(t)$ make up a steady capacity share $M(t)$, means $\sigma(t) = const$, then:

$$f_1(t,x_1) = 1 - \left(1 - \frac{1-\varepsilon_1-\frac{\mu}{\sigma}}{\nu(t)}x_1\right)^{\frac{1}{1-\varepsilon_1-\frac{\mu}{\sigma}}} \text{ while } x_1 \le \frac{\nu(t)}{1-\varepsilon_1-\frac{\mu}{\sigma}};$$

$$f_1(t,x_1) \equiv 1 \text{ while } x_1 > \frac{\nu(t)}{1-\varepsilon_1-\frac{\mu}{\sigma}};$$

$$f_2(t,x_2) = 1 - \left(1 - \frac{1-\varepsilon_2-\frac{\mu+r}{\sigma}}{s(t)}x_2\right)^{\frac{1}{1-\varepsilon_2-\frac{\mu+r}{\sigma}}} \text{ while } x_2 \le \frac{s(t)}{1+\varepsilon_2-\frac{\mu+r}{\sigma}};$$

$$f_2(t,x_2) \equiv 1 \text{ while } x_2 > \frac{s(t)}{1+\varepsilon_2-\frac{\mu+r}{\sigma}}. \tag{9}$$

3. If $\sigma = const$, and technological innovations are absent ($\varepsilon_1 = 0$, $\varepsilon_2 = 0$), then

$$f_1(t,x_1)=1-\left(1-\frac{1-\frac{\mu+r}{\sigma}}{\nu(t)}x_1\right)^{\frac{1}{1-\frac{\mu+r}{\sigma}}} \text{ while } x_1\le\frac{\nu(t)}{1-\frac{\mu+r}{\sigma}};$$

$$f_1(t,x_1)\equiv 1 \text{ while } x_1>\frac{\nu(t)}{1-\frac{\mu+r}{\sigma}};$$

$$f_2(t,x_2)=1-\left(1-\frac{1-\frac{\mu+r}{\sigma}}{s(t)}x_2\right)^{\frac{1}{1-\frac{\mu+r}{\sigma}}} \text{ while } x_2\le\frac{s(t)}{1-\frac{\mu+r}{\sigma}};$$

$$f(t,x_2)\equiv 1 \text{ while } x_2>\frac{s(t)}{1-\frac{\mu+r}{\sigma}}.$$

The received EEPF presentation partial cases can be used in practice. Based on the proposed model, EEPF implemented numerical calculations on conditional output data. As a basic implementation, the partial case 2 is production function representation (9) when the investment is selected $I(t)$ make up a steady capacities stream $M(t)$ that is the parameter $\sigma(t)=const$. It is assumed that the exogenous variables have the following meanings: technological innovations $\varepsilon_1=0{,}3$, $\varepsilon_2=0{,}1$, amount investment ratio to capacity $\sigma=1{,}3$, depreciation rate $\mu=0{,}1$, Pollution rate as aging technology result $r=0{,}1$.

Besides the entered EEPF dynamics (9) determine labor functions norm costs per output unit per time unit $\nu(t)$ and corresponding ecological resource cost norms $s(t)$. These functions dynamics is given by the equations:

$$\nu(t)=C_1e^{-\varepsilon_1\sigma t},$$
$$s(t)=C_2e^{-\varepsilon_2\sigma t},$$

Where C_1 and C_2 is integration constants.

Dynamics analysis of these functions reflects a reduction in the cost of economic and environmental resources in technological innovations growth in the main and auxiliary industries, which is fully consistent with the general theory. In the introduced parameters, EEPF model (9) is specified as:

$$f_1(t,x_1)=1-\left(1-\frac{1-0{,}3-\frac{0{,}1}{1{,}3}}{0{,}5e^{-0{,}3\cdot 1{,}3t}}x_1\right)^{\frac{1}{1-0{,}3-\frac{0{,}1}{1{,}3}}},$$

$$f_2(t,x_2)=1-\left(1-\frac{1-0{,}1-\frac{0{,}1+0{,}1}{1{,}3}}{0{,}3e^{-0{,}1\cdot 1{,}3t}}x_2\right)^{\frac{1}{1-0{,}1-\frac{0{,}1+0{,}1}{1{,}3}}},$$

Where steady $C_1=0{,}5$ and $C_2=0{,}3$ meet the initial conditions $\nu(0)=0{,}5$ and $s(0)=0{,}3$.

Product output functions trajectories $f_1(t,x_1)$ for $x_1=0{,}1;0{,}3$ and $f_2(t,x_2)$ while $x_2=0{,}2;0{,}4$ given in fig. 1 and 2.

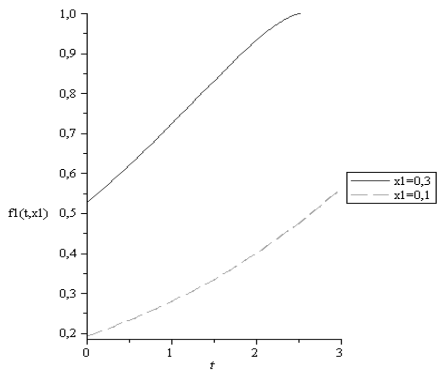

Fig. 1: Production output amount trajectories (function $f_1(t,x_1)$)

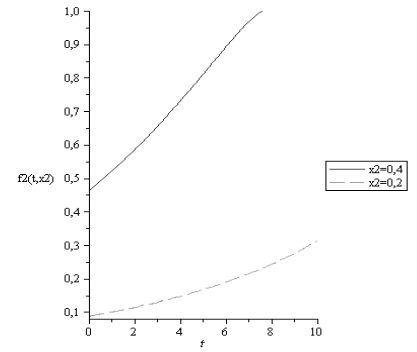

Fig. 2: Production output amount trajectories (function $f_2(t,x_2)$)

Proposed production function model also enables us to determine the dynamics reaction of gross output amount, depending on the parameters change. Depicted in fig. 1 and 2 trajectories correspond to technological innovations norm value $\varepsilon_1=0{,}3$, $\varepsilon_2=0{,}1$. While increasing these parameters to values $\varepsilon_1=0{,}5$, $\varepsilon_2=0{,}3$ production (fig. 3 and 4) new trajectories were released.

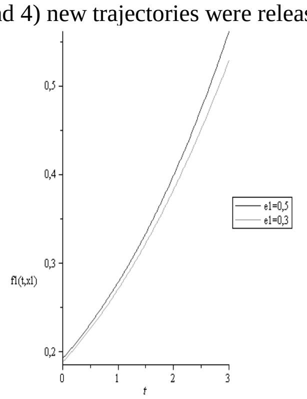

Fig. 3: Production output amount trajectories (function $f_1(t,x_1)$)

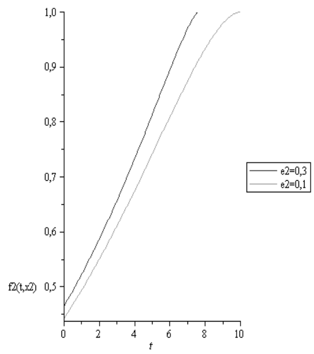

Fig. 4: Production output amount trajectories (function $f_2(t,x_2)$)

The depicted trajectories indicate an increase in product output $f_1(t, x_1)$ and in terms of increasing production technological level policy implementation and scientific and technological progress results implementation $f_2(t, x_2)$.

4. Conclusions

Consequently, economic system study, with the allocation of two resources categories ecological and economic, based on production capacities allocation to the technologies, made it possible to construct the EEPF in an explicit analytical form. Also, the model takes into account economic system technological structure evolution possibility. The proposed approach complements the existing econometric and optimization methods and provides an opportunity for further aggregation theory development as a tool for transition from micro-description to aggregate indicators.

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