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Imagining on The New Development Concept of Life-Long Learning Towards Carbon Action Plan

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Abstract: At this research we aim the increasing efficient and environmentally safe resource use and sustainability practicing development, based at life-long learning. For the above mentioned the aggregated modeling have been undertaken via the concept of life cycle thinking. Here are introduced: (1) Model for market of product with carbon risk towards application for development of carbon action plan; (2) Model for diffusion of innovative knowledge is introduced with conditions for its life-long learning implementation; (3) The adaptation mechanisms at competence acquisition and decision making. The perfect market theory, as the basic approach, is used for investigation the problems of corporate social responsibility and standardization in the field of sustainability. Having in mind the practical implications, the economic and technological integrated factors of the techno-economic system have been introduced, and their relationship with the tasks of sustainability, taking into account carbon risk, are considered, based at the quantitative measures. The novelty of the research is provided by the aggregated analytical results in order to form tools for quantitative modeling on the sustainability issues of communities, organizations, and individuals.

Keywords: carbon action plan, innovative knowledge, life cycle thinking, life-long learning, sustainable development.

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1. Introduction

As it was established by two classic publications (Grinin & Bondarenko, 2019), (Veetil, 2021), the emerging basic innovations in accordance to a line of Technological Stages, are going by the time-term period of about 40 – 60 years. Later, a number of papers have formulated key questions for scientific discussion about the patterns of sustainable development (SD). The innovative techno-economic modeling, e.g., (Maskin and Roberts, 2008), (Sadovnichy et al., 2012), (Glaziev, 2012) have been discussed. In particular, it has been noted a serious reform of the entire quality infrastructure, which is underway: changes in standardization legislation, roadmaps for improving certification and standardization, new quality tools are being actively created and popularized, as well as the new development conception at education. And this is a deeply natural process - standards are a tool for solving existing and future complex SD problems, based at fundamental laws, like the Environmental Kuznets Curve (Shahbaz & Sinha, 2019), (Mishra, 2020). The use of standards simplifies the transfer of knowledge and contributes to the further development of innovative solutions. Also, life cycle thinking approach is used to analyze the value chain specified for transforming the human resources matched with the problems of sustainability (Matthies et al., 2018). The existing economic practice is mainly aimed at the analysis of the behaviour of markets, and the tasks of market design and management, due to their extreme complexity, remain little explored (Roth, 2002). Global economic crisis phenomena necessitate the theoretical and practical development of the concept "an economist as a market engineer". In particular, the tasks of sustainability and innovation management, taking into account carbon risks, are relevant now. The global carbon challenge needs to put energy conservation in the first place, implement a comprehensive conservation strategy, continue to reduce energy and resource consumption and carbon emissions per unit of output, improve input-output efficiency, advocate a simple, moderate, green and low-carbon lifestyle, and form effective carbon emissions from the source and entrance control valve (Zheng et al., 2019) (Wang et al., 2021). Both the government and the market will work together to build a new development concept, strengthen technological and institutional innovation, and accelerate the green and low-carbon technological revolution (National Academies of Sciences, Engineering, and Medicine, 2024). Deepen reforms in energy and related fields, give play to the role of market mechanisms, and form effective incentive and restraint mechanisms (Cheng et al., 2019).

In turn, it has been established that the economic policies would only be efficient if they are accompanied by adequate policies in the field of education (Voronov, 2019). In this sense, lifelong learning has become the umbrella for all prospective training programs and initiatives for sustainability competence, the new one among which is, of course, the global carbon challenge (Sim & Kim, 2019). So, in practice there is need to study how lifelong learning could support sustainability. A bulk of publications on environmental, social and economic themes has been turned into consideration which measures can be best used for sustainability competences practicing (Ozili, 2022), (Korevaar et al, 2021), (Backes & Traverso, 2021). The solution of the above mentioned tasks involves an analytical consideration of the market equilibrium, under the criteria of Economic Efficiency, Environmental Safety and Social Well-being, the coordinated implementation of which is the essence of sustainability and innovation management (Zhifu, 2017). So, our imaginations on the integration of modern environmental and socially responsible technologies and competitive market mechanisms undertake constructive tools for improving innovative research for the new developments at lifelong learning towards carbon action plan.

2. Material and methods

To solve the problems mentioned above in terms of promoting sustainable development, we use the well-known concept of "Life Cycle Thinking"(Elegbede et al., 2023). This approach opens up wide opportunities for the development of constructive tools for the practical implementation of the principles of sustainable development (Voronov, 2018), (Wątróbski et al., 2019). Also, we apply the tools of the multi-criteria technique, which has successfully proven itself in solving complex problems in the study of the product life cycle. In the context of the undertaken research, we consider the model of establishing equilibrium in the system of markets of the product life cycle. At the same time, each producer and consumer acts in this way to maximize his profit. The equilibrium in the market is established by maximizing production and consumption preferences (QS, QD) and minimizing the corresponding damages (GS, GD):

$$Max\ QS^i\ \&\ Max\ QD^j\ \&\ Min\ GS^i\ \&\ Min\ GD^j$$

Here the private agents in the life cycle chain have cost (S) and utility (D) functions that ones at our approach are proposed in accordance to the principle of resource utility. The core of the appropriate models are the quality functions ($K_{S,D}$) of resource vector under universal Weber-Fechner Law at the exchange economy:

$$\begin{gathered} QS(u,W) = W - S(u), \\ S(u) = KS(R_S) - KS(R_S - u) + S(0), \\ QD(v,W) = D(v) - W, \\ D(v) = KD(R_D + v) - KD(R_D) \end{gathered}$$

Here W is value of transaction; $R_{S,D}$ – initial resource quantities; $K_{S,D}$ – quality of resources with condition: $\partial K_{S,D} > 0$, while $G_{S,D}$ will be the risk functions, produced by production and consumption activities. The material flow at every market of product life cycle is designed in balance of demand and supply driving forces (Voronov, A., 2020):

$$\begin{gathered} Max\ Q(v,u) \\ Q(v,u) = \sum_J DR^j\left(v^j\right) - \sum_I SR^i\left(u^i\right)], \\ while{:}\sum_J v^j = \sum_I u^i,\ and \\ DR^j = D^j - GD^j,\ SR^i = S^i + GS^i - S^i(0) \end{gathered}$$

And the key position at the noted optimization problem is the positivity of the function Q(v,u) that one is our first result under consideration below.

In order to study the product markets with carbon risk, a value-added model (AV) is being developed, which forms the basis for determining the carbon risk (CR) in the market of this product. Indeed, according to the task No. 9.4 “Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development: by 2030, modernize infrastructure and re-equip industrial enterprises, making them sustainable by increasing the efficiency of resource use and wider use of clean and environmentally friendly technologies and industrial processes, with the participation of all countries in accordance with their individual capabilities” the indicator No. 9.4.1 "CO_2 emissions on a unit of added value" is applied. According to the indicator No. 9.4.1., the model for carbon risk has the form:

$$CR = \sum_{I} \gamma^{i} * AV^{i}$$

Here the introduced parameter “γ^i” is argued by the innovative knowledge transformation, and is responsible for the technological efficiency of resource consumption by i-production.

To investigate the noted transformation there is need to provide the appropriate knowledge model. To clear the real value for the noted parameter, we have undertaken the following approach. In relation to the task of collective adaptation of supply and demand in the product market, taking into account the criteria of sustainability, we consider a model in the form of a theoretical construct "decision maker, DM". The DM uses the available information ("input") to form solutions ("output"). A constructive mathematical model of decision-making processes carried out by the DM is a scheme of multi-criteria selection from a set of acceptable alternatives.

The formalization of the choice problem is as follows: from a set of objects (in particular, "alternatives for decision-making", H), it is required to choose a subset with certain rational properties. If there is choice function “F” then the result of the decision is written as: $Y = F(X), Y \subset X \subset H$.

When the Pareto mechanism is used as a selection tool, such a choice function quite objectively formalizes the concept of "knowledge". Indeed, the following rationality conditions corresponding to the concept of "knowledge" are fulfilled (Aizerman, 1990), (Barseghyan et al., 2021), (Calder, 2024):

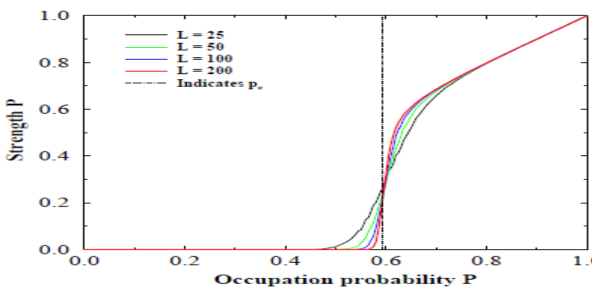
1) If an alternative is selected from a certain set, then it will be selected from any subset containing it;
2) If an alternative is selected in each of the given set of sets, then it will be selected from their union as well;
3) If all alternatives selected from some set are contained in its subset, then they, and only they, will be selected from this subset;
4) If an alternative is selected from a certain set, then there is no more preferred alternative in partial order.

Thus, the correct embodiment of such "natural" properties of rational knowledge are as inheritance of the results of previous decisions, consistency of general and particular results, independence of the new choice from already rejected alternatives. So, we have:

- Inheritance (I): $Y \subset X \rightarrow F(Y) \supset F(X) \cap Y$
- Consent (C): $X = Y \cup Z \rightarrow F(Y) \cap F(Z) \subset F(X)$
- Rejection (R): $F(X) \subset Y \subset X \rightarrow F(Y) = F(X)$

At last, we`ll use the threshold phenomenon at the 2-dimensional lattice (Christensen, 2002). For example, at each market from the product life cycle, the aggregates "demand" {J} and "supply" {I} form a 2-dimensional lattice, each node of which corresponds to the pair "j-demand, i-supply" (“i” is an element from the set I, “j” is an element from the set J). Such a pair, depending on the professional quality of market participants (here is the probability of meeting “the established requirements of SD”), may meet the requirements of sustainability (with probability “p”) or not be SD (with probability “1 — p”). So, let the probability of fulfilling the property “σ” for node (i, j) be the value “p”: $P\{\sigma(i, j)\} = p$. It is known, if $p > p_c$ (≈ 0,59) then there is a connected set of nodes percolating the opposite sides of the 2-lattice "percolating cluster, Σ". There is the threshold dependence of the probability site belongs to Σ along the lattice dimension, L. **Figure.1**.

Figure 1.
The threshold dependence of the probability site belongs to percolating cluster



The introduced version is called further as “market threshold”. But, there is the other example, which is called “competence threshold”. The last one is related to the 2-dimensional lattice of the selection functions. Here the desired property of the pair (F_i, F_j) is that $F_i \cap F_j$ is the selection function under the conditions I & C & R.

3.Results

Here we`ll consider the example of “market threshold”, where the desired SD property σ(i, j) contains the condition: $d^j = \partial DR^j|_{v=0} > \partial SR^i|_{u=0} = s^i$. Then the site (i, j), in view of e.g., $\partial^2 DR^j < 0$ and $\partial^2 SR^i > 0$, has the local stable equilibrium. In turn, if the noted condition holds for all pairs (i, j), then the market will have the equilibrium. Indeed, let: $d^j > s^i$ for all sites (i, j), then we have step by step:

$$v^j * d^j > s^i * v^j$$

$$\sum_{J} v^j * d^j > s^i * \sum_{J} v^j$$

$$u^i * \sum_J v^j * d^j > u^i * s^i * \sum_J v^j$$
$$\sum_I u^i * \sum_J v^j * d^j > \sum_I u^i * s^i * \sum_J v^j$$

And, in turn we have:

$$\sum_J v^j * d^j > \sum_I u^i * s^i,$$
$$\text{because} \sum_I u^i = \sum_J v^j$$

Due the last one, the maximization problem for Q(v,u) has the solution.

The represented above chain is true for the case: dim(d) = dim(s) = 1. In turn, for dim(d) = dim(s) = n > 1 by the induction process for "n", the undertaken optimization problem has the solution for the vector supply and demand too. In adds, the noted equilibrium will be local stable due the monotone decrease of the appropriate Lyapunov function.

Our main result provides the value of CR as a function of the equilibrium volume of the product (Z) in the form of the characteristic U-inverse relationship (analogous to Environmental Kuznets Curve). This result allows us to propose an iterative procedure for minimizing carbon risk while maintaining monotonous growth of income (GP) along the K-cycle.

According to the threshold concept of the competitive market, established above (market threshold), the existence of equilibrium at the elementary cells (node (i, j)), when their critical density is reached, is sufficient for the equilibrium at the corresponding part of the market. Therefore, omitting the indexes "i, j", we can limit ourselves to the basic model of a single node. So, the corresponding multi-criteria problem at such situation has the form: QS → Max, CR → Min, QD → Max (QS - producer's profit, QD - consumer's profit).

Then the supply is uniquely given by its production function: $U = U_0 K^\alpha A^\beta$ (A – "labor", K – "capital", α, β – inverse elasticity), which gives an expression for income (GP = π*U) according to the following relation:

$$GP = (a * K + A + M) * (1 + b) + P * (1 + c) + d * AV$$
$$AV = (a * K + A + M) * (1 + b) + P - M$$

Here: AV is the value added, "a" is the tariff for depreciation, "b" is the tariff for overhead costs, "c" is the profit tax tariff, "d" is the value added tax tariff, "M" is the material consumption by the product, "P" is the profit.

The classical utility function of demand in volume "V" (as part of the consumer's profit QD) has the form: $D = D_o*LN(1+V/V_0)$, and D_o is the available financial limit and V_0 is the available stock of the product. And, the equilibrium value of the product (Z) is determined from the condition:

$$\partial A(\text{Z}) * (1 + b) * (1 + \Delta) + \partial M(Z) * \left(1 + b * (1 + \Delta)\right) = \partial D(Z)$$

Here: the effective tariff of the value added tax Δ = d + γ*g/(1- γ*g/(1+c+d)), g is a parameter of the multi–criteria optimization problem, γ is a technological parameter determined by the efficiency of resource consumption.

The presented carbon risk model has the following boundary properties:

$$\partial_z CR(Z = 0) > 0, \partial_z CR(Z = Zmax) < 0$$

Due these conditions, there is the solution (Z_e) of the problem: $Max_{(Z)}CR(Z)$. Next, using the parameters Ω = {D_o, V_0, α, β, U_0, K, γ, g, a, b, c, d}, we can select $Ω_1$ from the condition $Z(Ω_1) > Z_e$. Then, by virtue of the boundary properties, we have: $CR(Z_e) > CR(Z(Ω_1))$ and $GP(Z(Ω_1)) > GP(Z_e)$. Then the procedure is repeated for the new parameters $Ω_2$ from the condition: $Z(Ω_2) > Z(Ω_1)$, etc. As a result, we get the sequence:

$$\ldots CR(Z(\Omega_k)) > CR(Z(\Omega_{k+1})) \ldots$$
$$\ldots GP(Z(\Omega_k)) < GP(Z(\Omega_{k+1})) \ldots$$

The represented sequences, due the features of the carbon risk and the income at the market are similar to the ones of every node, solves the problem of managing the market with carbon risk within the K-cycle.

Combining the represented results, we can imaging the following life-long learning program towards carbon action plan. Let the current and desired carbon risks will be CR_c, and CR_d respectively, and the time-term horizon $K = t_d - t_c$: $CR_{c,d} \rightarrow Z_{c,d} \rightarrow \gamma_{c,d}$, where we have the appropriate current and desired resources` efficiency due the technological parameter $\gamma_c > \gamma_d$. And, having $\partial_\gamma Z < 0$, the appropriate life-long learning plan for time-term horizon K could be the following γ = γ(k):

$$\gamma(k+1) = \gamma(k) - \Delta\gamma(k),\ 1 \leq k \leq K - 1,$$
$$\gamma(1) = \gamma_c,\ \sum\Delta\gamma(k) = \gamma_c - \gamma_d,$$

Some additional condition could be applied like this Δγ(k)/γ(k) = δ, it is constant that one provides the available equal intensity of innovation promotion by time.

These conditions represent a formalized position on the basic role of the concept of "individual preferences" in human activity in terms of decision-making, which is the core activity of the DM. If the selection functions {Fn} in the amount of "N" are used for the operating of the DM at the input, and the selection functions {Gm} in the amount of "M" at the output, then on the basis of such tools, the model characterizing the operating of the DM gets the form:

$$G_m(X) = \sum_n A_{mn} F_n(X)$$

Here: X ⊂ H is the set presented for selection, A_{mn} ⊂ H are constraints in the selection problem with the condition of completeness and independence of the events A_{ik} and A_{ij}, H is the basic set of alternatives to the selection problem, on the set of subsets of which the "multiplication, ∩" and "addition, U" operate, specifying the structure of the DM model.

The presented DM model is determined up to free events, and their number is $E(e) = C_R^{M+1} - N$, where R = N + M is the number of knowledge realization centers. The value "E(e)" represents the total number of free events that determine the choice functions in the number R, associated with the "M" operating conditions of the DM. The efficiency of the DM activity, as the resulting share of decision-making centers, is further characterized by the indicator $e = M/M_{max}$ ($0 \leq M \leq M_{max} = R-1$, "efficiency of the DM, e", $0 \leq e \leq 1$). Obviously, with the increase in the value of "E(e)", the possibilities of adaptation in the activities of the DM also grow. Taking into account the nature of the change in the value "E(e)" with an increase in the number of M-functions, in particular for the case R >> 1, we obtain a tool for optimizing decision-making processes:

$\uparrow e \rightarrow \uparrow E$, at $0 \le e \le [R/2]$; $\uparrow e \rightarrow \downarrow E$, at $R-1 \ge e > [R/2]$

Based on the introduced DM model, it is possible to formalize the relationship between the objective quantitative characteristics of the established requirements of SD, (p) and the professional competence of the DM (sustainability competence probability, q). Here we use the assessment of the level of competence as "The probability of performing a work activity in accordance with the certain sustainability requirements in a real working environment". So, the noted relation has the form p = WFL(q), which is a kind of the fundamental Weber-Fechner Law for the "stimulus-response" ratio. This dependence is due to the possibility of adapting the components of the input-output system of the DM, which is determined by the level of its complexity E(e). Then, considering the dependence E(e) as an un-normalized probability density of the DM efficiency indicator, for the desired dependence WFL(q), and the boundary conditions {WFL(0)=0, WFL(1)=1, WFL`(0)=ε, WFL`(1)=0}, we obtain the approximation of WFL(q) at 0(R >> 1) ≤ ε ≤ 1(R=5), refer (Voronov, A., 2020):

$$p = WFL(q) = (\varepsilon - 2)q^3 + (3 - 2\varepsilon)\, q^2 + \varepsilon\, q$$

The next step at our discussion is based at the version “competence threshold”. So, if $F_i \cap F_j$ is the selection function under the conditions I&C&R for all (i, j), then the same we have for the set $\{F_i\}$ and for all pairs $F_n \cap G_m$ at 2-dimensial lattice N x M. So, the last one, due the "natural" properties of the rational knowledge, is treated as the desired competence at the decision making process because G_m is I&C&R-selection function. Also, a number of dynamic regularities of large K-cycles are known. In particular, it is believed that the characteristic period of this phenomenon is about 50 years. The significant factor in the reduction of this period (e.g., acceleration of the pace of creation and implementation of innovative knowledge) is determined by the intensity of the processes of diffusion of knowledge carried out by the collective DM. Obviously, if the structure and parameters of the model of this phenomenon correspond to reality, then the estimates of characteristic quantities will correspond to the observed data. To the opposite, apparently, will be true only in a particular or narrow aspect. Based on the above proposed competence model, and the expression for the dependence p = WFL(q), it is possible to solve the problem of estimating the scale of K-cycle ($t^*(\delta, p_c)$ - the time term for which collective competence reaches the qualitative update) from the condition:

$$p_c = \left(\frac{1}{T}\right)\sum_{n=t-T+1}^{n=t} WFL(q(n))$$

Here: T is the characteristic period of professional activity of the collective DM (for example, T = 65 – 25 = 40 years), and q(n) is determined by the iterations:

$$q(n+1) = q(n) + \Delta q(n),\ q(0) = 0$$
$$\Delta q(n) = \delta^*(1 - q(n))$$
$$\text{or, } q(n) = 1 - X(n)$$
$$X(n+1) = X(n) - \Delta X(n),\ X(0) = 1$$
$$\Delta X(n)/X(n) = \delta$$

The undertaken calculations provide the following examples:

$$t^*(\delta = 0{,}03,\ p_c) = 49$$
$$t^*(\delta = 0{,}0236,\ p_c) = 56$$

Now, we can test our models, e.g., for the parameters from building and construction practice (production of some construction material): V_o = 5.0, D_o = 162.5*10^3, α = 0.356, β = 0.644, U_o = 177, a = 0, b = 0.3, c = 0.2, d = 0.15, 1.34 > γ > 0 (refer **Figure 2, Figure 3**), and for γ_c = 1.28, γ_d = 1.00 we have $K_1 \approx$ 10 years (with δ_1 = 0.0236) and $K_2 \approx$ 8 years (with δ_2 = 0.03). By this example one can find within K-cycle the standard rate K ~ 1/δ for the life-long learning time-term.

Figure 2
Carbon Risk as function of product volume (Z)
Environmental Kuznets Curve
of the market with carbon risk

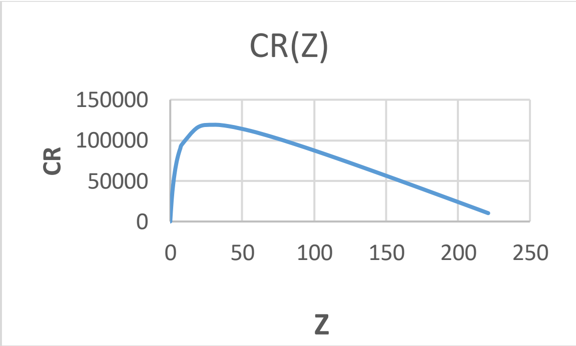
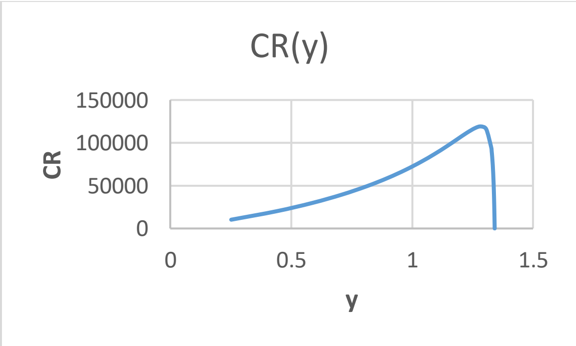


Figure 3
Carbon Risk as function of technological parameter (y)



The numerical order and regularity of the obtained result, along with the objectivity of the constructed DM models and the threshold phenomenon of sustainability, can serve as the important additional argument for the applied consistency of the considered innovative tools.

4. Conclusions

Our results start with the threshold phenomenon at the market, modeled by its cost and utility functions. So, the sustainability of the market (here it is the local stable equilibrium existence at the presence of the damage factors) is provided by the sustainability at the every pair of supply-demand. Based at the noted possibility, we`ve proposed the equation for the equilibrium of the appropriate multi-criteria problem for the product market with carbon risk. The represented model provides the value of carbon risk as a function of the equilibrium volume of the product in the form of the characteristic U-inverse relationship (analogous to Environmental Kuznets Curve). Here the carbon risk is measured with the proportion "CO_2 emissions on a unit of added value". The last one provides the iterations to improve production technology, based at innovative knowledge implementation through life-long learning. This procedure presents the imagination for the carbon action plan. The important parameter of such procedure is the rate of carbon risk decrease. We`ve tested an option for choosing this parameter based at the formation patterns (like some kind of Weber-Fechner Law) for large cycles of innovations.

In this regard, the introduced model parameters (the level of core competence; the scale of inertia of adaptation of management competencies; parameters of communication processes in a techno-economic cluster, etc.) determine important quantitative patterns of resource transformation chains. Thus, in the conditions of decision-making "by the majority", it is necessary to prevail the share of management, which ensures the level of average profile competence in the markets of the product life cycle above a certain critical value.

The estimates obtained, which, according to the presented results, give the bounds of the characteristic values, correspond well to the known theoretical and experimental facts about the dynamics of K-cycles of the economic conjuncture of "about half a century" duration. Due to the revealed properties of such dynamics, the acceleration of the formation of the technological structure could be facilitated. For example, it is provided by the unification (including standardization of quality) of the processes of training specialists. Continuous updating of qualifications throughout the entire period of work activity is improved due the distributed educational networks, as well as increased communicative intensity in the corresponding techno-economic cluster. It is also significant that at the same time, the elasticity of the period of establishing SD in the conditions of an expected increase in the average duration of labour activity turns out to be less than one.

In general, the introduced analytical models of innovative techno-economic development correspond to the known qualitative patterns of these processes and allow us to obtain new reliable quantitative results in the tasks of personnel adaptation for successful innovative technologies. The represented models of sustainable resource transformation provide a sound practical toolkit for the investigation of new qualitative and quantitative patterns in solving complex socio-economic problems, corresponding to the dynamics of K-cycles and long-term requirements for standardization at sustainable development paradigm. At the same time, modeling in the context of the product life cycle turns into a conceptual basis for the rational analysis, which tools have appeared and are being improved that have significant prospects for the development of analytical methods in the sustainability engineering.

For example, among solutions for some prospective tasks, based at our approach, the task of tariff management could be discussed. So, in the tariff regulation of economic activities, along with tariffs for assets amortization, overhead costs and profit tax, value added tax is also available for management. The analysis of the multi-criteria model used above as the basis for carbon risk modeling makes it possible to introduce an equivalent tariff for the value added tax, taking into account the component of the corresponding damage term. Then the growth of this tariff increases the weight of the problem of reducing carbon risk, which serves as an additional tool for tariff management of a product market with carbon risk.

The other task of managing the regional economy also could be tested. In a number of works on econometrics, models of aggregated production and consumption for the region as a whole have been developed. As can be seen, such model corresponds by the form to our consideration of a fixed node of the market network. So, the noted fact allows the application of the introduced iterative risk and income management procedure in the case of individual regions.

Of course, the introduced applications of the threshold phenomenon are not restricted by the tested tasks. The other prospective area for the noted design is connected to Stock-Exchange and Rating Agencies practicing.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

The data that support the findings of this study are openly available at https://rosstat.gov.ru/bgd/regl/b14_46/Main.htm.

Author Contribution Statement

Alexander Voronov: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Visualization, Supervision, Project administration.

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