Original Paper
https://doi.org/10.15826/jtr.2024.10.2.171

Modeling the Policy of Tax Incentives for Sustainable Development of the Region: The Case of the Far Eastern Federal District of Russia

Olga A. Sinenko ✉
Far Eastern Federal University, Vladivostok, Russian Federation
✉ *sinenko.oa@dvfu.ru*

ABSTRACT
The article is devoted to the problem of tax incentives for sustainable development in the Russian Far East – a vast region dealing with significant demographic and environmental challenges. To solve this problem, the study applied methods of mathematical modeling. We built a hybrid mathematical model of the Far East development based on the principles of agent-based and system-dynamic approaches, implemented in AnyLogic 8.0 simulation modelling program. The model's accuracy was confirmed by comparing its predictions with actual data from 2010 to 2021. The result of the study is the construction and interpretation of several scenarios of regional development involving different types of tax incentive policies: investment-oriented tax incentives to stimulate specific growth poles, increased budgetary spending with a social focus funded by taxes on future generations, higher environmental taxes, and a combination of different incentives. The main conclusions from the experiments showed that none of the tax incentive scenarios is a panacea. The most effective tool has proven to be targeted investment-oriented tax incentives for residents of special economic zones. Nevertheless, these incentives do not automatically solve the region's sustainable development challenges stemming from the existing environmental constraints. In addition, the tax policy options under consideration are limited by demographic problems in the Far East, which adversely affect the rates of technological change and economic growth. From a practical standpoint, it can be concluded that a strategic tax policy in question should be based on a more comprehensive approach, employing mutually reinforcing tax incentives for innovation and investment in special economic zones and environmental incentives, capable of gradually improve the environmental situation. Further research in the field of tax policy of the Russian Far East should be directed to the search for measures of fiscal regulation of not only economic, but also demographic and environmental problems of the region in a complex.

KEYWORDS
tax policy, tax incentives, system dynamics, agent-based modeling, Russian Far East

JEL H2, H5, H7

УДК 332.02

Моделирование политики налогового стимулирования устойчивого развития региона на примере Дальневосточного федерального округа России

О.А. Синенко ✉
Дальневосточный федеральный университет, г. Владивосток, Россия
✉ *sinenko.oa@dvfu.ru*

АННОТАЦИЯ
Статья посвящена проблеме налогового стимулирования устойчивого развития Дальнего Востока России – обширного региона, сталкивающегося со значительными демографическими и экологическими проблемами. Для решения этой задачи в исследовании применены методы математического моделирования.

© Sinenko O.A., 2024

Построена гибридная математическая модель развития Дальнего Востока, основанная на принципах агентного и системно-динамического подходов, реализованная в программе имитационного моделирования AnyLogic 7.0. Модель была проверена на адекватность на фактических данных о развитии Дальнего Востока в 2010–2021 гг. Результат исследования – построение ряда сценариев развития региона под влиянием различных типов политики налогового стимулирования: налогового поощрения полюсов роста в регионе, повышения бюджетных расходов социальной направленности за счёт налогов на будущие поколения, повышения экологических налогов и комплексный. Основные выводы по результатам проведенных экспериментов, показали, что ни один из них сценариев налогового стимулирования не является панацеей. Самый действенный из рассмотренных налоговых инструментов – концентрированные налоговые стимулы для инноваций субъектам специальных экономических зон. Однако эти стимулы не обеспечивают автоматически решение проблем устойчивого развития региона, поскольку упираются в экологический потолок. Кроме того, рассматриваемые варианты налоговой политики ограничены демографическими проблемами Дальнего Востока, которые могут нивелировать научно-техническое развитие и темпы экономического роста. Поэтому практический вывод выполненного исследования состоит в том, что стратегическая фискальная политика должна предусматривать совместное использование – с взаимной поддержкой и взаимный усилением – налоговых стимулов для инноваций и инвестиций в специальных экономических зонах и стимулов экологических, способное со временем поднять экологический потолок. Дальнейшие исследования в сфере налоговой политики Дальнего Востока России целесообразно направить на поиски мер налогово-бюджетного регулирования не только экономических, но и демографических и экологических проблем региона.

КЛЮЧЕВЫЕ СЛОВА

налоговая политика, налоговые льготы, системная динамика, агентное моделирование, Дальний Восток России

1. Introduction

Tax regulation plays a crucial role in promoting sustainable development, especially as many countries worldwide shift their focus from monetary instruments to tax measures. This shift is partly attributed to the predominant concentration of monetary authorities on inflation-related concerns[1]. Tax instruments, being capable of selectively influencing the behavior of specific economic entities, prove effective in addressing sustainable development issues. Notably, they can incentivize certain classes of entities to adopt environmentally friendly practices.

This study explores the impact of tax regulation on sustainable development, using the Far Eastern Federal District as a case study. Spanning approximately 7 million square kilometers, comparable in size to Australia, this vast region is a key area in Russia's pivot to the East. Its proximity to technological powerhouses such as China, Japan, and Korea add significance to both economic considerations, fostering regional cooperation, and environmental concerns, given the potential implications beyond its borders.

The current development of the Far Eastern Federal District (FEFD) is experiencing adverse trends, primarily characterized by depopulation. This phenomenon is influenced by a complex interplay of economic, social, environmental, and other factors. Drawing in-sights from the experiences of China and other countries, one viable solution to address these challenges is the strategic use of tax instruments [1]. However, so far, their use has not helped to put the FEFD economy on a sustainable development trajectory.

This raises *research questions*:

RQ1: Can taxes be used to stimulate innovation, increase employment and production in a way that improves the environmental situation in the region

[1] Regime shift: the return of "fiscal activism". Available at: https://www.schroders.com/en-ch/ch/professional/insights/regime-shift-the-return-of-fiscal-activism-/ (accessed: 25.03.2024).

and reverses negative demographic dynamics?

RQ2: What are the best types of tax incentives to use for this purpose?

The purpose of the study is to determine the parameters of tax incentive policy for the region's economy, capable of bringing it to the trajectory of sustainable development.

The hypothesis of the study HO: the transition to the trajectory of sustainable development FEFD with the maintenance of the balance of economic, social and environmental factors, requires the application of concentrated tax incentives for the subjects of special economic zones (SEZ), capable of cultivating a new innovative environment and widely replicate new technologies, the application of which can reverse the current negative trends.

The structure of this study. The Introduction of the study provides a description of the purpose at hand and the hypothesis of the study follows from the formulation of the scientific problem. The Literature Review provides a brief characterization of the state of research on tax incentives for sustainable regional development, as well as the problems that require further analysis. The Methods, Model and Data section presents a characteristic of the scientific and methodological approach used to solve the research problems and the developed mathematical model designed to perform computational experiments. Experiments contains a detailed description of a series of computational experiments and the results of mathematical modeling of the processes of tax incentives for sustainable development of the Far Eastern Federal District. Discussion analyzes and interprets the results obtained and establishes the relationship between these results and the objectives of the study. Conclusions conclude the paper with a brief summary of key takeaways from the paper and their implications for future research.

2. Literature review

The relationship between taxes, tax incentives and sustainable development of a region is complex and multifaceted.

Achieving sustainable development goals involves a certain public cost, which must be financed through taxes on current and / or future generations of people. Therefore, one of the types of tax policies that facilitate the transition to a sustainable development trajectory is a high-tax policy. However, as we know from tax theory, raising taxes or keeping them high can adversely affect business activity, hinder economic growth and narrow the size of the tax base (see e.g. Romer & Romer [2]), thus undermining the potential for financing sustainable development.

Therefore, a more sophisticated type of tax policy may consist of tax incentives to stimulate economic growth and broaden the tax base, but in a way that also takes into account the requirements of sustainable development. But its implementation is associated with the risks that the incentives will be weak to support economic growth and / or misdirected from a sustainable development perspective.

This dilemma is reflected in the specialized literature on the subject.

Halim & Rahman [3] analyzed the impact of taxes on sustainable development in BRIC (Brazil, Russia, India, and China) and CIVETS (Colombia, Indonesia, Vietnam, Egypt, Turkey, and South Africa) countries using panel data for 2000–2021, found that the corporate tax rate is positively and significantly related to the Sustainable Development Goals (SDGs). The study considered both individual effects and the combined effects of corporate tax rate, personal income tax, sales tax and effective tax rate with SDGs. In both cases, the study found a significant and positive relationship of taxation with SDGs.

Rahman [4] obtained similar results. They are using data from 38 OECD countries for the period 2000-2021, which found that the effective average tax, personal income tax, corporate income tax and goods and services tax have a unidirectional causal relationship with the SDGs.

Kouam & Asongu [5] show that taxation is perceived as a brake on economic growth in many developing countries. High business taxes undermine social innovation and hence the achievement of the SDGs, as social innovation is known to be the driving force behind most SDGs and business is the means to achieve them.

Similar considerations are made by Long & Miller [6], who argue that there are risks in trying to squeeze too much tax to achieve the SDGs. High tax rates can discourage private investment, and tax and spending policies are often regressive rather than progressive. Therefore, blindly following the desire to increase taxation is likely to have negative consequences.

Godinho et al. [7] show that tax incentives for innovation linked to sustainable development goals are important, as tax incentives encourage technological progress and help develop sustainable solutions to global challenges.

At the same time, tax incentives are often applied not to the entire territory of a country or region, but only to certain growth poles in the form of special economic zones and other types of territories with special economic status, which are often used in the world practice as a mechanism of sustainable development.

Li et. al. [8] confirmed that industrial enterprises (CIED) in the PRC from 1998 to 2007 performed better on average inside SEZs than outside them.

Wang et al. [9] found that free trade zone has a significant impact on the efficiency of green enterprise innovation through the effects of cost reduction, tax incentives and reverse technology diffusion.

Yan et al. [10] show that establishment of free trade zones is conducive to local green economic development, in particular, technological progress and industrial structure upgrading are two important channels to achieve the positive effect of green economy development.

However, tax incentives for growth poles do not always lead to positive results. Nel & Rogerson [11] note that despite the tax incentives introduced, SEZs in Africa are inefficient mainly due to poor strategic planning, weak governance, low investment, poor quality of job provision, low wages and poor development of appropriate social infrastructure.

Xi et al. [12] found that preferential tax policies in SEZs may attract not only innovators but also inefficient firms, with negative effects on productivity and efficiency gains.

Thus, as this brief overview shows, there are no universal recipes for tax policies that contribute to the achievement of sustainable development goals and objectives, and obviously there cannot be in principle. Sinenko [13] show that much depends on the content of tax measures and the context in which they are applied.

As far as the FEFD is concerned, two circumstances are of fundamental importance. The first is that this macro-region has been facing complex demographic and environmental problems for many years. And the second is that there are several territories with special economic status in the FEFD, the potential of which can be used to change the current negative trends in demography and ecology. This predetermined the content of the analysis presented below, aimed at identifying the parameters of tax policy that can direct this type of region on the path of sustainable development.

3. Methods, Model and Data

3.1. Methods

Individual economic entities respond differently to tax incentives depending on specific contextual factors, both in terms of location and time. To address this issue, it is desirable to anticipate their behavior, which can be achieved through the use of agent-based modeling tools. This aspect represents one facet of the problem. On the other hand, the cumulative outcomes of diverse economic entities' activities carry macroeconomic consequences, impacting areas such as ecology and demography. These broader effects are conventionally with the help of the tools of system dynamics.

Hence, the justification and anticipation of the outcomes of regional sustainable development policy require a hybrid approach – combining Agent-Based Modeling (AB) and System Dynamics (SD). Hybrid AB-SD modeling is becoming increasingly popular worldwide because, despite the apparent implementation challenges, when analyzing complex adaptive systems, it can provide

«...a simpler, more natural, or more effective solution" [14, p. 118].

Numerous AB-SD models have already been created to analyze various subject are-as, including:

– the diffusion of technological innovations (Swinerd & McNaught [15]);

– management of state investment project portfolios (Jo et al. [16]);

– redesign of industrial territories (Demartini et al. [17]);

– industrial water management (Langarudi et al. [18]);

– spread of COVID-19 (Nguyen et al. [19]);

– global climate change (Siebers et al. [20]).

Uehara et al. [21] used the AB-SD approach is also applied to analyze the development of socio-ecological systems.

Zulkepli & Eldabi [22] argue that hybrid AB-SD modeling provides a clearer understanding of the real-world situation because it allows model developers to evaluate the problem under study in different dimensions.

The coevolutionary socio-ecological population model proposed by Polovyan & Vishnevskaya [23] is particularly relevant to the objectives outlined in this article. Their study was conducted in the context of an emerging economy, explicitly accounting for environmental considerations (Bogachov et al. [24]).

According to the classification proposed by Swinerd & McNaught [14], this model falls within the category of integrated models, characterized by feedback loops between AB (Agent-Based) and SD (System Dynamics) modules, with outputs combined to depict the desired outcome over time. The study uses an integrated model; however, unlike previous studies, it is designed to address a tax policy-focused task, which is reflected in the composition and structure of the model. Additionally, it considers several additional factors, including a greater number of economic agent classes, the endogenous nature of R&D, population migration, and others (Sinenko [25]).

In the most general form, the approach we have developed is characterized by Figure 1.

As the diagram illustrates, the region in this approach consists of two interconnected subsystems: the economic-technological subsystem (represented by enterprises) and the socio-ecological subsystem (represented by the population). Together, these subsystems constitute the overarching socio-ecological system of the territory, characterized by dynamic expansions or contractions. The modeling of each subsystem is based on the two distinct approaches: agent-based modeling for the economic-technological subsystem and system dynamics for the socio-ecological subsystem (Sinenko [26]).

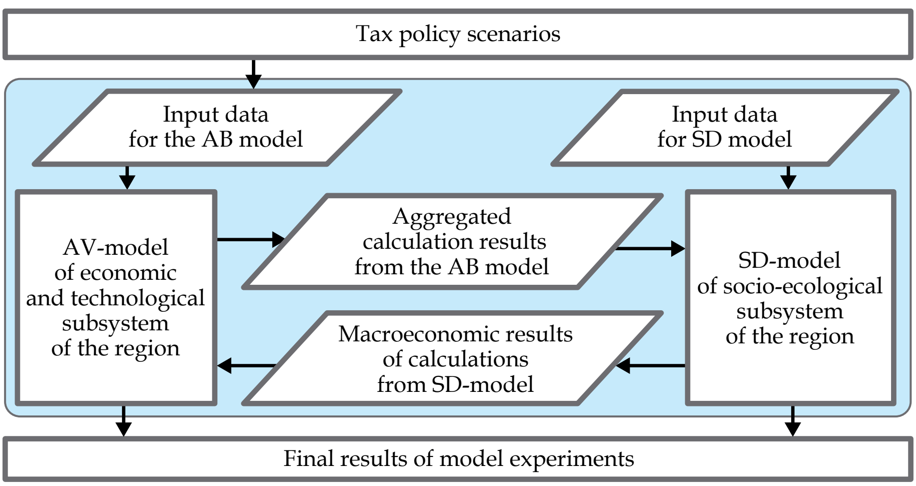


Figure 1. Principle scheme of the proposed approach to the study of the problems of tax regulation of sustainable development of the region

When we look at the development of the economic-technological subsystem, our key consideration is the actions of autonomous economic agents – specifically, enterprises in the region. These enterprises, subjects to government tax policy, operate depending on their own interests and institutional constraints, engaging in successive production cycles that involve both goods production and pollution emission. Notably, enterprises can be roughly divided into imitators and innovators. Imitators utilize existing technologies without investing in R&D, while innovators allocate a portion of their value added to developing new technologies. The success of these innovations depends on government fiscal support for them.

We suggest modeling the development of the socio-ecological subsystem using the principles of system dynamics, considering both positive and negative feedback loops. This subsystem encompasses the population residing and working in the area, including indigenous residents and the net migration flow. The population is influenced by demographic characteristics and indicators reflecting changes in the quality of life – such as income and environmental pollution – linked to the activities of the economic-technological subsystem. Public goods provided by the government (state funding for social policies, education, healthcare, science, and culture) also shape population dynamics.

In the interaction between the region's subsystems, the economic-technological subsystem generates value added, serving as a source of income for both the population and the government. Simultaneously, this subsystem releases pollutants that impact the socio-ecological subsystem. The dynamics of income and pollutants have varying effects on population reproduction and migration processes, influencing expenses for maintenance and the workforce used in the production process of the economic-technological subsystem.

The goal of modeling is to assess the potential for achieving sustainable development in the region – specifically, the growth of its human population – through the implementation of a tax policy aimed at stimulating technological development. Additionally, our aim is to examine the potential consequences of such a policy on the budget. Our hypothesis suggests that if the concentration of financial resources exceeds a certain threshold at specific hubs of scientific and technological growth, it can lead to a cascade of technological innovations in the region. This, in turn, can enhance the institutional environment for business operations, fostering sustainable development more effectively than the implementation of dispersed, systemic measures aimed at stimulating R&D for all economic entities.

3.2. Model

3.2.1. Economic-technological subsystem

1. Economic agents. The economic-technological subsystem is represented by economic agents. This sets of innovator enterprises (*Un*) and imitator enterprises (*Um*) operating in the region. Both innovators and imitators can be residents of a territory with a special legal status (special economic zone, SEZ), where the government applies special tax incentives to encourage R&D. Thus, in the region, there are four classes of economic agents:

1) innovator enterprises outside the SEZ – $\{u^c_{n1}, u^c_{n2}, u^c_{n3}, \ldots, u^c_{nr}\} = U^c_n$;

2) innovator residents within the SEZ – $\{u^r_{n1}, u^r_{n2}, u^r_{n3}, \ldots, u^r_{ns}\} = U^r_n$;

3) imitator enterprises outside the SEZ – $\{u^c_{m1}, u^c_{m2}, u^c_{m3}, \ldots, u^c_{mt}\} = U^c_m$;

4) imitator residents within the SEZ – $\{u^r_{m1}, u^r_{m2}, u^r_{m3}, \ldots, u^r_{mu}\} = U^r_m$.

All economic agents in the region, regardless of the specifics of their behavior and location, are involved in the processes of production and product sales, the details of which are described further in the production block.

2. Production block. Enterprises in the region produce goods, generating value added, while simultaneously emitting pollutants and disposing of them into the surrounding environment.

The annual production output of the Q^i_t enterprise in the year is calculated by using the following production function [23]:

$$Q_t^i = \frac{Q_t^i}{F_t^i}\frac{F_t^i}{L_t^i}L_t^i = \varphi_t^i \cdot f_t^i \cdot L_t^i, \qquad (1)$$

where F_t^i is the cost of the fixed assets of enterprise *i* in year *t*; φ_t^i is the capital productivity of enterprise *i* in year *t*; f_t^i is the capital intensity of enterprise *i* in year $t(f_t^i = f(t))$; L_t^i is the number of employees at enterprise *i* in year *t*.

In the production process, in addition to fixed assets, working capital is also required. The latter is not explicitly represented in equation (1) as the money supply for the region's enterprises is considered unlimited (perfectly elastic) at the market price, that is, we assume that in the production process, there is always access to the necessary working capital for the fixed assets used, and the associated costs are accounted for in the production cost.

The disposal of pollutants by the region's enterprises ("cleanliness production"), analogous to formula (1), is described by functions:

$$^{+}Qa_t^i = \varphi a_t^i \cdot f_t^i \cdot L_t^i; \qquad (2)$$

$$^{+}Qw_t^i = \varphi w_t^i \cdot f_t^i \cdot L_t^i; \qquad (3)$$

$$^{+}Qg_t^i = \varphi g_t^i \cdot f_t^i \cdot L_t^i, \qquad (4)$$

where $^{+}Qa_t^i$, $^{+}Qw_t^i$ and $^{+}Qg_t^i$ stand for the volumes of utilization of emissions of pollutants into the atmosphere, discharges into surface and groundwater, disposal of hazardous waste, respectively; φa_t^i, φw_t^i, φg_t^i stand for the capital productivity of fixed assets for the utilization of emissions of pollutants into the atmosphere, discharges into surface and groundwater, disposal of hazardous waste, respectively.

It is assumed that companies face no issues with the sale of the produced goods, and all of the production is fully sold in the current year at the prevailing exogenous market prices. In other words, firstly, we do not consider potential sales issues as they are beyond the scope of analysis, and secondly, we assume that enterprises in the region do not possess market power, which can be considered a realistic assumption for the conditions of the FEFD. In this case, the profitability of production is solely regulated by the production cost – the lower the production cost, the higher the profitability, and conversely, the higher the production cost, the lower the profitability.

The financial outcomes of enterprises' activities, i.e., profit (P_t^i), are determined as the difference between the value of the produced goods and production costs (production cost) (C_t^i).

$$P_t^i = Q_t^i - C_t^i, \qquad (5)$$

and the net financial result after paying the corporate income tax at the rate (τ_t^p) (i.e., net profit P_{0t}^i), is as follows:

$$P_{0t}^i = (Q_t^i - C_t^i)(1 - \tau_t^p). \qquad (6)$$

The production cost includes three main elements: capital consumption, labor consumption, and environmental costs (payments for environmental pollution).

This method of breaking down costs is chosen to help analyze and justify the tax incentive policy aimed at fostering sustainable regional development, in other words, the focus is placed on fiscal policy and those key taxes that have the most significant impact on business activities. These include the following: corporate income tax (τ_t^p); corporate property tax (τ_t^f); social security contributions (τ_t^l); environmental payments for emissions, discharges, and disposal of pollutants τ_t^a, τ_t^w, τ_t^g.

Another significant source of government revenue, the value-added tax (VAT), is not considered in the production block of the model. The value-added tax (VAT) is a consumption tax that reduces the incomes of final consumers of goods and has little impact on the results of enterprise activities (it passes through their accounts in a "transit" manner). Additionally, this study does not analyze such well-known issues as VAT evasion or delayed budget reimbursement, which could potentially affect enterprise costs. Additionally, it does not separately model taxes related to the functioning of the oil and gas sector and international trade.

These taxes serve as economic regulators in the model – meaning economic variables whose values (within certain ranges) can be manipulated to influence economic processes. In addition, the calculation of government revenue includes the personal income tax (τ_t^h), which does not directly impact the activities of enterprises.

Values τ_t^p, τ_t^f, τ_t^l, τ_t^h are the effective (real) tax rates. They are defined as nominal (set by law – $_0^p$, τ_0^f, τ_0^l, τ_0^h) minus the benefits provided under the general tax regime ($\tau_t'^p$, $\tau_t'^f$, $\tau_t'^l$, $\tau_t'^h$) or the SEZ tax regime ($\tau_t''^p$, $\tau_t''^f$, $\tau_t''^l$, $\tau_t''^h$).

The calculation of the production cost explicitly includes a variable such as the labor compensation per unit of time w_t^i, which affects population migration and some other modeled processes:

$$w_t^i = A_w \left(\sum_{i=1}^{n+m} Q_t^i\right)^{\lambda}, \qquad (7)$$

where A_w is the scale factor; and is the exponent ($0 < \lambda < 1$).

The economic meaning of formula (7) is that workers' incomes usually grow in connection with economic growth but, as a rule, at a slower pace (in conditions of expanded reproduction, the growth rates of labor productivity outpace the growth rates of wages).

The total labor costs are determined by the formula:

$$Cl_t^i = L_t^i w_t^i (1 + \tau_t^l). \qquad (8)$$

The amount of payment for environmental pollution is as follows:

$$Ce_t^i = {}^{-}Qa_t^i \cdot \tau_t^a + {}^{-}Qw_t^i \cdot \tau_t^w + {}^{-}Qg_t^i \cdot \tau_t^g. \qquad (9)$$

In that case, the cost of production can be presented as:

$$C_t^i = A(Q_t^i)^{\varphi} \cdot (F_t^i \tau_t^f)^{\alpha} \cdot (Cl_t^i)^{\beta} + Ce_t^i. \qquad (10)$$

The number of imitators and innovators in the economic subpopulation changes over time, reflecting the evolutionary nature of the region's economic development and the processes of natural selection among economic agents. If the strategy of a given agent leads to an improvement in its performance, the population reproduces similar agents. If not, reproduction does not occur.

The condition for the reproduction of economic agents is defined by the formula:

$$r_t^i = \frac{P_t^i}{C_t^i} \geq r_n = r_0 \cdot k_r, \qquad (11)$$

where r_n is the normative level of profitability; r_0 is the risk-free interest rate; k_r is the risk premium coefficient for entrepreneurial activity (determined depending on the institutional conditions established in the region, $k_r > 1$).

Economic agents are excluded from the population if their profitability falls below the threshold value (r_0) for three consecutive periods.

Companies can allocate a portion of their net profit to production investments. The model assumes that the percentage of profit allocated for investments is the same for all economic agents and is determined by the conditions of economic activity in the region, including institutional factors. The varying inclination of innovators and imitators toward investment is determined by the type of investment. For imitators, this involves low-risk investments in the already available technologies. In contrast, innovators opt for high-risk investments in new technologies.

In this context, imitator enterprises merely replicate the technologies available within the population, including environmentally friendly options. On the other hand, innovator enterprises actively participate in developing new technologies, using both their internal resources and government financing facilitated by tax incentives.

Investment implementation leads to changes in the value of fixed assets:

$$F_t^i = \begin{cases} F_{t-1}^i - n_A \cdot F_{t-1}^i + I_t^i = \\ = F_0^i - \int_0^T H_t^i dt + \int_0^T I_t^i dt, \; P_t^I > 0; \\ F_{t-1}^i - n_A \cdot F_{t-1}^i = F_0^i - \int_0^T H_t^i dt, \; P_t^I \leq 0, \end{cases} \qquad (12)$$

where n_A is the depreciation rate; H_t^i is the amount of the decrease in the value of fixed assets; and T is the total number of periods.

Due to the changes in F_t^i and considering that $f_t^i = f(t)$, the amount of labor used in production L_t^i also changes. In this case, the demand for labor by the enterprise ($\tilde{\Lambda}_t^i$) is as follows:

$$\tilde{\Lambda}_t^i = \frac{F_t^i}{f_t^i}. \qquad (13)$$

This demand can be satisfied either fully or partially. The enterprise's satisfied demand for labor L_t^i depends on the labor market supply $\widehat{L}_t^i$ (see the socio-economic subsystem).

$$L_t^i = \begin{cases} \tilde{\Lambda}_t^i, \ \widehat{L}_t^i \geq \sum_{i=1}^{n+m} \tilde{\Lambda}_t^i; \\ \tilde{\Lambda}_t^i \cdot \widehat{L}_t^i / \sum_{i=1}^{n+m} \tilde{\Lambda}_t^i, \ \widehat{L}_t^i < \sum_{i=1}^{n+m} \tilde{\Lambda}_t^i, \end{cases} \quad (14)$$

The modernization of production based on new or already known technologies, leading to an increase in the capital-output ratio, is implemented by following the logic proposed by Nelson et al. [27]. New values of capital productivity for each economic agent are generated through a two-stage stochastic process.

At the first stage, we define independent random variables *dm* and *dn*, which can take values of 0 or 1. This means that enterprises are assigned (or not assigned) the task of modernization. At the second stage, the probabilities of investment success are determined:

$$Pr(dm = 1) = \frac{K_{rm_t^i} - K_{rm_t^{\min}}}{K_{rm_t^{\max}} - K_{rm_t^{\min}}};$$

$$Pr(dn = 1) = \frac{K_{rn_t^i} - K_{rn_t^{\min}}}{K_{rn_t^{\max}} - K_{rn_t^{\min}}}, \quad (15)$$

where $K_{rm_t^{\max}}$, $K_{rm_t^{\min}}$ – represent the maximum and minimum costs, respectively, for imitation of an already known technology by regional enterprises in period *t*, while $K_{rn_t^{\max}}$, $K_{rn_t^{\min}}$ – represent the maximum and minimum costs, respectively, for the development of a new technology in period *t*.

The sizes of investments in imitation and innovation depend on the net profit earned by imitating enterprises (*m*) and innovators (*n*):

$$K_{rm_t^i} = f^m(P_{0t}^i); \quad (16)$$

$$K_{rn_t^i} = f^n(P_{0t}^i). \quad (17)$$

If an enterprise engages in imitation, it gets an opportunity to obtain and adopt the best practices available in the region. Innovator enterprises, however, select the technology based on the distribution of technological capabilities in region An_t:

$$An_t = f^n(L_t^N, G_t^N, t), \quad (18)$$

where L_t^N is the number of people employed in the field of R&D in the given region.

3. *Environmental protection block*. As was mentioned above, in addition to their primary production activities, regional enterprises are engaged in "producing cleanliness", which results in the reduction of pollutants in the environment. The pollution is determined by the formula [23]:

$$\begin{cases} {}^{-}Qa_t^i = {}^{-}Qa_0^i + \int_0^T {}^{-}Atm_t^i \cdot dt - \int_0^T {}^{+}Qa_t^i \cdot dt, \\ {}^{-}Qw_t^i = {}^{-}Qw_0^i + \int_0^T {}^{-}Wat_t^i \cdot dt - \int_0^T {}^{+}Qw_t^i \cdot dt, \\ {}^{-}Qg_t^i = {}^{-}Qg_0^i + \int_0^T {}^{-}Geo_t^i \cdot dt - \int_0^T {}^{+}Qg_t^i \cdot dt, \end{cases} \quad (19)$$

where ${}^{-}Qa_t^i$, ${}^{-}Qw_t^i$, ${}^{-}Qg_t^i$ denote the pollution balance in terms of air emissions, water discharges, and waste disposal, respectively; ${}^{-}Atm_t^i$, ${}^{-}Wat$, ${}^{-}Geo_t^i$ represent the volumes of pollution from air emissions, water discharges, and waste disposal, respectively.

The volumes of pollutants in the air, water discharges, and waste disposal in period *t* are calculated as:

$$\begin{cases} {}^{-}Atm_t^i = f^{Atm-}(Q_t^i), \\ {}^{-}Wat_t^i = f^{Wat-}(Q_t^i), \\ {}^{-}Geo_t^i = f^{Geo-}(Q_t^i), \end{cases} \quad (20)$$

where f^{Atm-}, f^{Wat-}, f^{Geo-} are pollution functions. The model assumes that the enterprises in the region dispose only of their own waste.

4. *Budget and tax block*. A portion of the added value produced by the region's enterprises is allocated to the government: to the regional budget (consolidated budget of the FEFD) and extrabudgetary funds.

According to Russia's budget regulations, the regional budget receives: 85% of the corporate profit tax ($T_t^p = \tau_t^p \sum_{i=1}^{n+m} P_t^i$); 100% of the personal income tax ($T_t^h = \tau_t^h \sum_{i=1}^{n+m} L_t^i w_t^i$); 1005 of the property tax ($T_t^f = \tau_t^f \sum_{i=1}^{n+m} F_t^i$); as well as 100% of the corresponding environmental payments ($T_t^a = \tau_t^a \sum_{i=1}^{n+m} Qa_t^i$; $T_t^w = \tau_t^w \sum_{i=1}^{n+m} Qw_t^i$; $T_t^g = \tau_t^g \sum_{i=1}^{n+m} Qg_t^i$).

In the extrabudgetary (pension) fund, amounts from social security contributions ($T_i^l = \tau_t^l \sum_{i=1}^{n+m} L_t^i w_t^i$) are credited and allocated for specific purposes.

Revenues of the regional budget ($B_t = f^T(T_t^p, T_t^h, T_t^f, T_t^a, T_t^w, T_t^g)$) are used to provide public goods, including state financing of social policies, education, and healthcare:

$$G_t^P = E_t(k_t^S + k_t^E + k_t^M), \quad (21)$$

where k_t^S, k_t^E, k_t^M stand for the share of expenditures on social policy, education, and healthcare, respectively; E_t is the expenditures of the regional budget in year t.

In this case, if in the given year the current revenues of the regional budget exceed its current expenditures ($B_t < E_t$), a budget surplus occurs, and if less, a deficit ($D_t = B_t - E_t$), which must be covered. The interest on such financing (at the rate r_0) is included in the budget expenditures of the next period:

$$E_{t+1} = f^E((G_{t+1}^P + D_t r_0),\ G_{t+1}^z), \quad (22)$$

where G_{t+1}^z denotes the other expenditures of the regional budget.

3.2.2. Socio-ecological subsystem

The socio-ecological subsystem is represented by the population residing in the region, divided into four age groups (0–14, 15–24, 25–64, and over 64 years).

The dynamics of the population for groups 2–4 (15–24, 25–64, and over 64 years) are calculated according to the formula:

$$PL_t^v = PL_{t-1}^v - Rd_t^v + Rs_t^{v-1} - Rs_t^v, \quad (23)$$

where PL_t^v is the population in group v; Rd_t^v is the number of deaths in group v; Rs_t^{v-1}, Rs_t^v denote the number of individuals moving from one age group to another.

The dynamics of the population for the 1st group (0–14 years) are calculated somewhat differently:

$$PL_t^1 = PL_{t-1}^1 + rb_t(PL_t^2 + PL_t^3) - Rd_t^1, \quad (24)$$

where rb_t is the birth rate; Rd_t^1 is the number of deaths in group 1.

The total population of the region is determined by the following:

$$PL_t^R = \sum_{v=1}^{4} PL_t^v + S_t, \quad (25)$$

where S_t is the balance of population migration.

The birth rate coefficient depends on the income levels of the population, the public goods provided by the government, and the state of the environment:

$$rb_t = f^{rb}\begin{pmatrix} w_t^{ar}, G_t^S, G_t^M, G_t^I, \\ {}^{-}AQa_t, {}^{-}AQw_t, {}^{-}AQg_t \end{pmatrix}, \quad (26)$$

where w_t^{ar} is the average wage level in the region; G_t^S, G_t^M, G_t^I are government expenditures on social policy, healthcare, and infrastructure, respectively; ${}^{-}AQa_t$, ${}^{-}AQw_t$, ${}^{-}AQg_t$ stand for aggregated (i.e., accumulated over the entire calculation period, taking into account the carryover balance) pollution of the atmospheric air, aquatic systems, and land with waste;

Similarly, the balance of population migration in the region is as follows:

$$S_t = f^S\begin{pmatrix} w_t^{ar}, G_t^E, G_t^I, \\ {}^{-}AQa_t, {}^{-}AQw_t, {}^{-}AQg_t \end{pmatrix}. \quad (27)$$

The mortality rate for the respective population group depends on the level of aggregated air pollution:

$$rd_t^v = f^{rd}({}^{-}AQa_t, {}^{-}AQw_t, {}^{-}AQg_t). \quad (28)$$

Taking the above into account, the labor market supply in the region ($\widehat{L}_t^i$) is determined as

$$\widehat{L}_t^i = f^l(PL_t^2 + PL_t^3), \quad (29)$$

where PL_t^v is the number of deaths in groups 2 and 3.

This labor supply is considered when calculating the satisfied labor demand (see the production block).

3.3. Data

The focus of the study is the socio-economic and ecological system of the Far Eastern Federal District. Accordingly, for the parameterization of the model (setting the values of significant factors), its calibration (adjustment based on actual data from the training sample), and verification (comparison of calculated results with the actual data from the control sample), we used statistical information on the chosen region.

It consists of a large dataset covering the years 2010–2021 and includes the following range of indicators: the population broken down by age groups; birth, death, and migration rates; the number of enterprises in the entire region and SEZ residents; volumes of goods, works, and services sold by enterprises; the cost and depreciation of fixed assets, including those of environmental significance; the number and salaries of workers; investments in fixed capital, including capital of environmental significance; budget revenues and expenditures; atmospheric emissions, wastewater discharges, generation of industrial waste, etc.

All cost indicators are presented in comparable prices using the GDP deflator.

4. Results

4.1. Model implementation: parameterization, calibration and verification

Based on the dataset for the Far Eastern Federal District for 2010–2021, parameterization was performed – numerical values were set for a series of key indicators that determine the structural features of the model (Table 1).

Next, the entire dataset was divided into two parts: a training sample (2010–2017), used for model tuning, and a control sample (2018–2022), used to assess its quality (Table 2).

As indicated by the presented data, the simulation of the FEFD's economy overall accurately reflects the key structural and dynamic characteristics of the original. It is, however, important to emphasize that the results of the modelling experiments presented here and further are not intended for forecasting, i.e., predicting the future based on establishing possibly more accurate (within confidence intervals) values of economic indicators for upcoming years. The aim of these calculations is to construct and analyze potential alternative scenarios. This process helps us better understand emerging opportunities and risks in the future, providing a foundation for justifying decisions in tax policy.

The model is implemented in the AnyLogic 7.0 programming environment[2] (Figure 2), which supports both agent-based and system dynamics modeling.

Table 1. Values of the main parameters of the economic-mathematical model of the region's socio-ecological system

Parameter	Value
Share of innovator enterprises in the total sample, %*	15
Share of SEZ resident enterprises in the total sample, %*	1.5
Depreciation rate of fixed assets, %	8
Risk-free interest rate, %	4
Birth rate, %**	1.3
Mortality rate, %**	1.3
Nominal (legally established) rates of taxes:	
personal income tax, %	13
corporate income tax, %	20
corporate property tax, %	2
social security contributions, %	30
Effective (real) tax rates for the enterprises in the region***:	
personal income tax, %	8.6
corporate income tax, %	18.8
corporate property tax, %	2.0
social security contributions, %	19.7
Effective (real) tax rates for SEZ resident enterprises***:	
personal income tax, %	8.6
corporate income tax, %	0.5
corporate property tax, %	0.5
social security contributions, %	7.6
Effective rates of environmental payments***:	
payments for emissions into the atmosphere, rubles per ton	33.1
payments for water discharges, rubles per thousand m^3	74.2
payments for waste disposal, rubles per ton	1.13
The share of the regional budget expenditures by usage categories:	
social policy, %	18
education, %	22
healthcare, %	9

Notes: * The number of innovators and SEZ resident enterprises changes over time due to the evolutionary processes of reproduction and the exit of economic agents from the population. ** The initial birth and death rates change over time due to the variations in the conditions of reproduction of the region's population. *** Defined as the ratio of the actual amounts of taxes paid to the amounts of taxes at nominal rates.

[2] AnyLogic: Simulation modeling for business. 2023. https://www.anylogic.ru/

Table 2. Verification results of the model (on average for 2019–2021)

Indicator	Fact	Model	Error
Population of the FEFD, mln people	8.130	8.194	+0,78%
Population growth rates, %	99.60	99.90	+0,36%
Production output, bln rub *	3 126	3 158	+1,02%
Growth rate of production output, %	104.0	103.0	–1,04%
Average monthly earnings of employees, ths rub per person*	35.12	34.88	–0,85%
Growth rate of the average monthly wage, %	103.7	103.7	+0,00%
Emissions into the atmosphere, mln tons	1.165	1.111	–4,64%
Growth rate of atmospheric emissions, %	107.6	103.9	–8,65%
Main tax revenues of the budget, bln rub	309,6	292,7	–5,46%
Growth rate of the budget's main tax revenues, %	102.1	104.1	+1,96%

Note. * In constant prices of 2010.

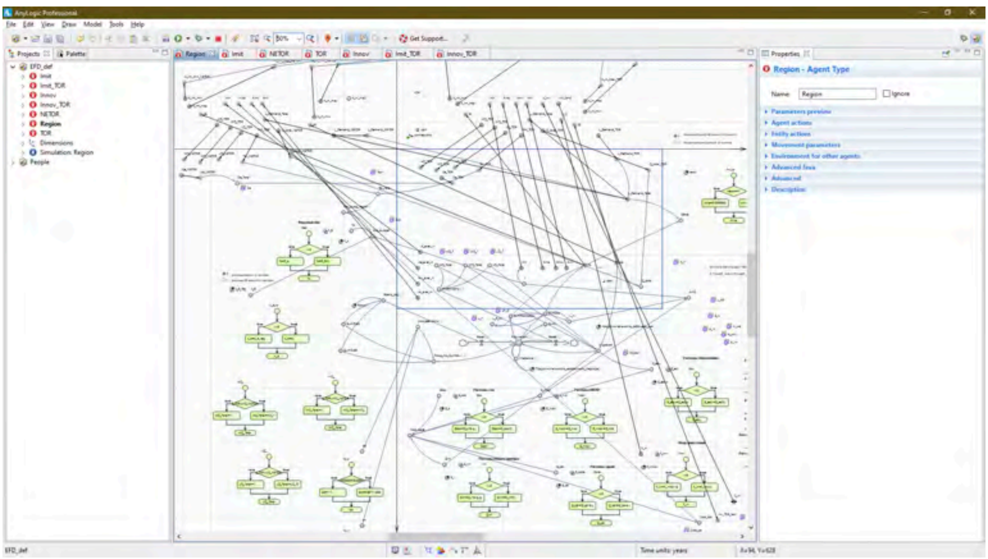


Figure 2. Fragment of the AB-SD model of the region's socio-economic system in the simulation modeling environment, AnyLogic 7.0

4.2. Experiments

4.2.1. Scenario 1. Inertial development of the region

This particular scenario delineates the essential trajectory of economic and ecological development in the FEFD, serving as the baseline for comparison with various alternatives. It projects the continuation of current trends over time while keeping the fundamental influencing factors unchanged and without making adjustments to the state tax policy.

As shown in Figure 3, the inertial scenario in the long term (until 2050[3]) is associated with further escalation of issues in the Far East, primarily demographic ones, raising doubts about the possibility of the region's sustainable development.

Overall, the situation looks typical for the last decades. The population of the Far East, including the working-age population, is gradually decreasing while

[3] Here and further, the results of calculations are presented for the period until 2050.

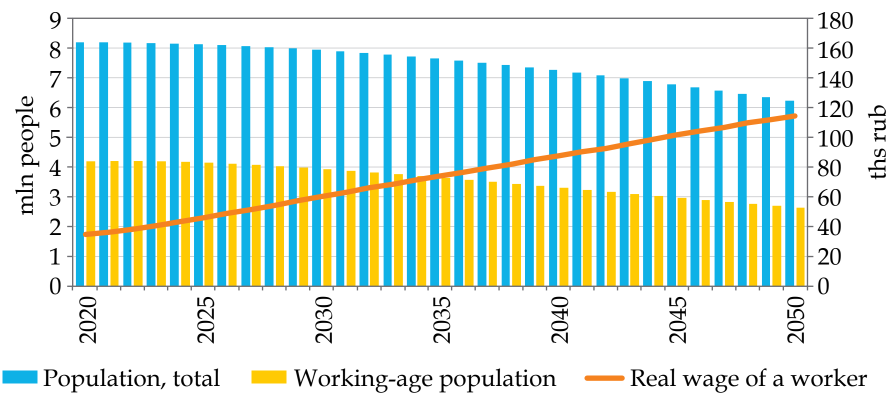
the economy continues to operate, and the production output continues to grow. With the increase in production, the real incomes of the population and tax revenues to the budget moderately rise, while the volumes of pollutant emissions also increase in parallel.

Despite compensatory budgetary measures (an increase in social and other public expenditures due to the growth of tax revenues), this has a negative impact on the population size, ultimately leading to a slowdown in growth rates (as seen in the change in the slope of the production line). Essentially, this is a path of gradual degradation of the territory with all the resulting consequences. This course is unacceptable, and a change in the government's economic policy is imperative. Various possible courses of action have been analyzed in the subsequent scenarios.

4.2.2. Scenario 2. Stimulating growth poles

The root cause of numerous development challenges confronting the Far East, as well as Russia as a whole, is the delay in R&D progress. This is a widely recognized issue, and one effective approach to tackle it, actively employed in many countries globally, involves the implementation of special tax incentives. Hence the idea is to enhance tax incentives for SEZ residents, small but dynamic "growth poles" in the Far East. They can generate new technologies, which, when spread across the region, will significantly improve overall development indicators.

Zhang et. al. [28], Gasmi et. al. [29] and Yuan et. al. [30] show that targeted tax incentives allow for more efficient use of existing infrastructure, human capital and other resources.



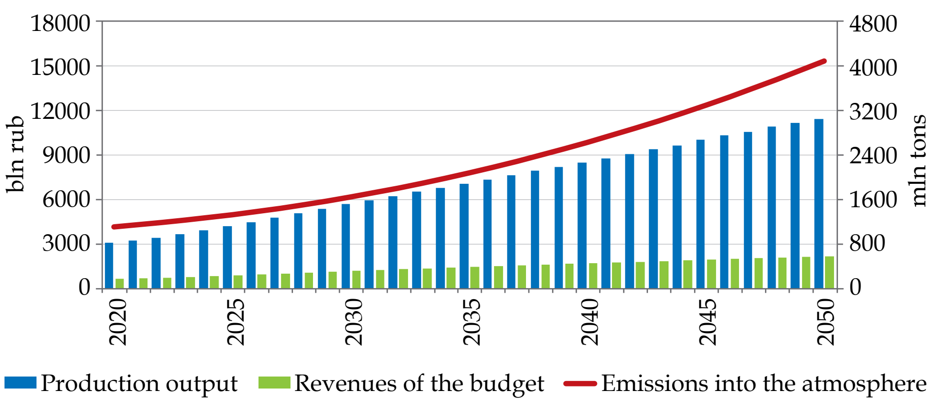


Figure 3. Inertial scenario. Indicators characterizing the dynamics of the region's economic-technological and socio-ecological subsystems

Currently, in the SEZs operating in the region, various tax benefits and preferences are applied to attract enterprises: reduced corporate income tax rates, reduced social insurance contributions, reduced land tax rates, etc. These benefits enhance the profitability of businesses, measured by return on equity (ROE), which is undoubtedly important for them.

This is, however, not the only important and necessary thing. Given the prolonged unfavorable trends in the development of the region and the comparatively weak motivation for innovation in the private sector, it is advisable to use tax incentives that depend on businesses making reciprocal commitments, especially regarding investments in innovation and capital.

This approach involves structuring incentives based on contractual agreements. Specifically, this could take the form of an Investment Tax Credit (ITC), allowing the company to offset its obligations for any tax payment. Such a mechanism is used, for example, in Italy, where a substantial tax credit of 12% is provided for qualified R&D expenditures. This credit can be used to offset any type of tax obligations for the enterprise[4].

Essentially, this refers to a government grant that constitutes a share of eligible investments, particularly in R&D or new capital assets. The purpose of this grant is to facilitate investment co-financing, specifically within the framework of public-private partnerships.

[4] Available at: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Tax/dttl-tax-survey-of-global-investment-and-innovation-incentives-italy-2020.pdf (accessed: 25.03.2024)

Table 3 contains the results of computational experiments using an ITC rate of 100%. In practice, a lower ITC rate is typically used, but for this study, this detail is not of fundamental importance.

As suggested by the provided data, while the impact is modest for the region, it proves substantial for enterprises in SEZs. Tax expenditures can lead to noticeable economic growth outcomes, with an approximate 0.5 percentage point increase in production volumes during the first ten years compared to the baseline scenario. This shift is primarily attributed to a qualitative change: government co-financing significantly amplifies per capita investments, enhancing the likelihood of surpassing the innovation threshold. The innovation threshold represents a minimum level of costs necessary for the success of new technologies (Brouwer et. al. [31]).

Thus, microeconomic tax expenditures yield results that, while relatively small on a microeconomic scale, are macroeconomically significant. The fact that they are relatively small is understandable since the population of SEZ resident enterprises in the region is only 1.5%. A substantial increase in this figure, based on the observed trend, could potentially lead to a more rapid growth in production volumes; however, there is no certainty regarding this outcome.

Firstly, this will already be a fundamentally different structure of the model, characterized by its own patterns of development, and different from the actual type of economy in the Far East. Secondly,

Table 3. Scenario 2. Stimulating growth poles (introducing ICT for SEZ enterprises at a rate of 100%)

Increase compared to the baseline scenario, percentage points	On average		
	2021–2030	2031–2040	2041–2050
Population	–0.00	-0.02	–0.08
Production output	+0.47	+0.58	+0.02
Average salary	+0.53	+0.36	+0.07
Atmosphere emissions	+0.10	+0.28	+0.23
Budget deficit*	+1.12	+1.34	+0.97

Note. * In relation to output.

radically increasing the number of SEZs or their residents is a complex problem that, in addition to obvious financing issues, is associated with institutional risks, including political ones. And, thirdly, scaling the special economic regimes beyond certain limits undermines the very idea of growth poles as geographically close entities with complementary competencies, exchanging tacit knowledge, etc. (Morgan [32]), rather than just entities consuming specific benefits but separated by vast distances (due to the extremely large territory of the Far East).

Given that the task of determining the optimal scales for SEZs is outside the scope of this analysis and requires a separate investigation, we will explore alternative approaches to address the defined objectives under the assumption of the existing structure of enterprises, encompassing both residents and non-residents of SEZs.

4.2.3. Scenario 3. Improvement of the overall socio-economic climate

If we return to the scenario discussed above, it is important to note that it contributes to some population growth in the region compared to the baseline scenario, but only to a very limited extent, so the overall unfavorable depopulation trend is not overcome.

But it is possible to try to approach the problem from a different perspective, namely, by creating a better socio-economic climate across the entire region. This would contribute to the better reproduction of human capital, including increasing birth rates, reducing mortality, and attracting people from outside (through migration). In addition, it will also create better conditions for generating and disseminating innovations through a significant increase, for example, by 20%, in public expenditures on social policy, education, and healthcare.

It is proposed that funding for such additional expenditures should be sourced from public loans, which means that the tax burden would be shifted onto future generations. In other words, this scenario may be considered as yet another alternative for the government's tax policy but with taxes deferred to the future. This policy is not inconsistent with economic theory, as the benefits of addressing socio-economic issues extend to future generations of people.

As the calculations have shown, increasing investments of a social nature has a clearly positive impact on the population of the Far East, and the strength of this impact (percentage population growth) becomes greater over time. This is associated, in part, with the expected intensification of migration processes (the increase in migrants to the region compared to the baseline is approximately 10,000 people per year).

However, this scenario is characterized by lower volumes of resources directed towards economic development goals (compared to the scenario of stimulating growth poles), resulting in smaller increases in output and worker salaries. The growth rates of output in the scenario of improving the overall socio-economic climate (an average of +0.01 percentage points for 2021–2030) leave much to be desired. Moreover, it is important to consider the factor of increa-

Table 4. Scenario 3. Improvement of the overall socio-economic climate (increase in budget expenditures on social policy, education, and healthcare by 20%)

Increase compared to the baseline scenario, percentage points	On average		
	2021–2030	2031–2040	2041–2050
Population	+0.52	+0.21	+0.34
Production output	–0.51	+0.56	–0.34
Average salary	–0.41	+0.37	–0.22
Atmosphere emissions	–0.09	–0.06	–0.03
Budget deficit*	+1.58	+3.03	+2.85

Note. * In relation to output

sing budget expenditures to service the debt (due to the budget deficit growth), which has its objective limits.

In this regard, it should be noted that one of the main impediments to sustainable development in scenarios 2 and 3 is the negative influence of the environmental factor on the population size. In the current conditions in the region, an increase in production volumes leads to a significant growth in pollution, impacting the reproductive processes known as the environmental "ceiling". Certainly, such a dependency can and should be altered by influencing the behavior of economic agents through the "polluter pays" principle, i.e. through environmental taxes.

4.2.4. Scenario 4. Environmental, associated with an increase in environmental payments

The general problem for Russia and its regions is that environmental payments, due to historically established circumstances, are relatively low. Consequently, they may not consistently exert a significant impact on the activities of economic agents[5].

International experience suggests that environmental payments can potentially serve as an effective tool for "green" policies. This is achieved by incentivizing Research and Development (R&D) and the innovative reduction of pollutant emissions. Moreover, it promotes the adoption of not only more efficient but also more sustainable methods of production and consumption. The rationale lies in the fact that as tax rates increase, the cost associated with pollution surpasses the cost of developing and implementing clean technologies or products. In practice, this has led to a decrease in emissions, as illustrated by the cases of several developed countries with stringent environmental standards.

As shown in Table 5, the scenario of a significant increase in environmental payment rates in the Far East – by 2 times – also results in a gradual reduction of pollutant emissions and improvement in the environmental situation compared to the baseline scenario. This, in turn, has a positive impact on population dynamics.

The issue, however, is that such a scenario shift, as seen in scenario 3, is associated with certain adverse consequences for economic growth. This outcome is predictable, considering that the rise in environmental fees has a negative impact on the profitability of enterprises and their capacity for expanded reproduction. This is exacerbated by insufficient innovation and the inadequate level of R&D in the region. Consequently, economic agents often struggle to identify effective methods for reducing pollution emissions, completing a cycle that brings us back to the persistent challenge of the region lagging behind in terms of innovation.

4.2.5. Scenario 5. Comprehensive

Various tools of tax regulation for sustainable territorial development (tax incentives for growth poles, improving the socio-economic climate through taxes for future generations, or increasing environmental payment rates) have their pros and

[5] Bulletin of the Accounts Chamber of the Russian Federation. Non-tax payments. (In Russ.) Available at: https://ach.gov.ru/upload/iblock/cfb/h75p4x5t2ron78jtt0ymi307066wg0sx.pdf (accessed: 25.03.2024).

Table 5. Scenario 4. Environmental, associated with a double increase in environmental payments

Increase compared to the baseline scenario, percentage points	On average		
	2021–2030	2031–2040	2041–2050
Population	+0.11	+0.18	+0.47
Production output	–0.07	+0.23	–0.15
Average salary	+0.06	+0.01	–0.05
Atmosphere emissions	–0.49	–1.34	–0.62
Budget deficit*	–0.25	–0.00	–0.02

Note. * In relation to output

cons. As our analysis shows, these tools can effectively complement each other. For example, for the successful development of production based on innovation incentives, it is necessary to make sure that the general socio-economic climate in the area is favourable.

Additionally, it is crucial that the growth in production volumes minimally harms the environment, necessitating environmental taxes. To ensure a meaningful increase in public spending on areas such as education, healthcare, and science, it is essential that such increases occur within the context of stable economic growth and a healthy ecological environment.

Therefore, further on, we are going to explore a comprehensive scenario based on the concept of a practical compromise, which involves simultaneously applying all the above-discussed tools but with parameters that are closer to real-world conditions (Table 6).

As shown in Figure 4, through such a compromise approach, we can achieve significantly better outcomes compared

Table 6. Scenario 5. Comprehensive (ICT rate 50%, increase in budget expenditures by 10%, environmental payment rates – 1.5 times)

Increase compared to the baseline scenario, percentage points	On average		
	2021–2030	2031–2040	2041–2050
Population	+0.58	+0.33	+0.64
Production output	+0.14	+0.40	+0.02
Average salary	+0.26	+0.12	+0.12
Atmosphere emissions	–0.39	–1.08	–0.47
Budget deficit*	+0.72	+1.34	+1.36

Note. * In relation to output

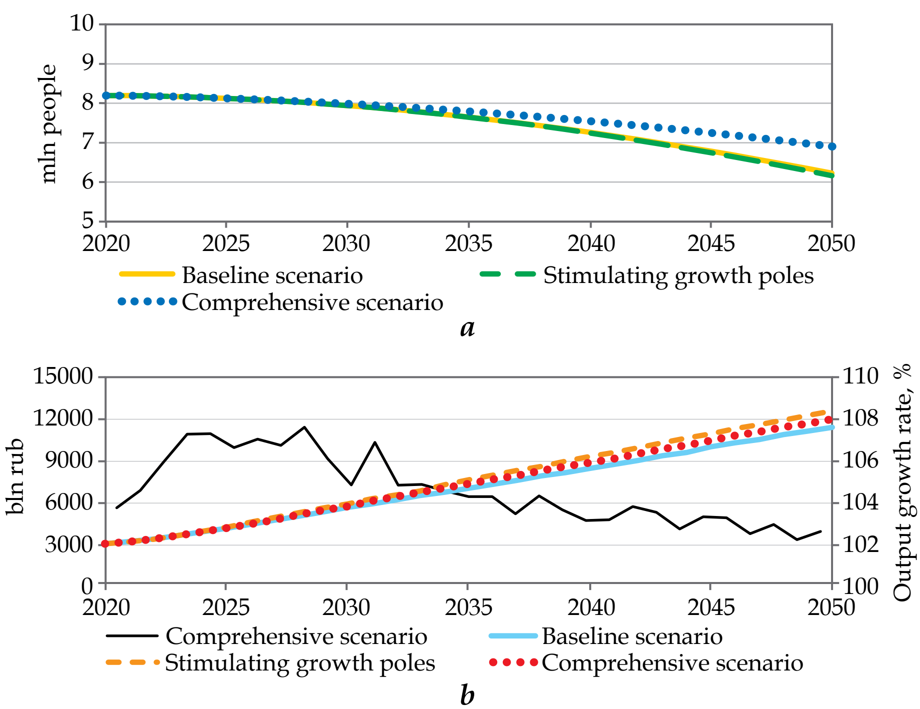


Figure 4. Comprehensive scenario. Indicators characterizing the dynamics of the socio-ecological and economic-technological subsystems of the region: *a* – production output; *b* – population

to baseline scenario, both in terms of economic growth and the size of the human population.

Clearly, it is possible to search for and identify other, potentially better, combinations of tax incentives. Yet, in general, the outcomes of computational experiments suggest a less than optimistic assessment of the prospects for the region's sustainable development under the influence of tax incentives.

5. Discussion

While it is possible to construct numerous development scenarios involving different tax rates, tax credits, interest rates, and other factors, such a detailed analysis is not required in this case. The results obtained from the experimentation already provide sufficient insights, allowing us to draw specific conclusions.

Firstly, it is not possible to achieve a decisive reversal of the current depopulation trends solely through tax policy measures, considering the existing initial structure and dynamics of the socio-economic system in the Far East. To achieve this, it is necessary to change the initial key characteristics of this system that determine the development patterns in the long term: improve business behavior patterns, the institutional environment for innovation, the scales and parameters of growth poles, conditions for reproduction and attraction of human capital, and the attitude of economic agents toward ecology, which influences pollution dynamics. All of this requires time and political will to implement gradualist reforms (Polterovich [33]).

Secondly, as the results of computational experiments have shown, the most potent fiscal instrument at the government's disposal is the active support of hubs for scientific, technological, and economic growth within the framework of public-private partnership policies, followed by scaling up innovations across the entire region. The option is quite evident but far from ideal in terms of sustainability. It resembles the path previously taken by China, characterized by rapid economic growth, which was largely associated with SEZs but at the expense of the environment and population reproduction (Jianguo & Raven [34]).

In steering tax policy directions for the FEFD, it's crucial to strategically prioritize "green" tax instruments alongside innovation. Without these measures, ensuring stable production growth becomes a challenge, hindering efforts to increase public expenditures and improve the overall socio-economic climate. Addressing all these elements collectively is essential for achieving a path of sustainable regional development. Therefore, embracing a "green" policy isn't merely a trend but a necessary (though not sufficient) condition to effectively tackle the region's challenges.

Thirdly, it is not possible to solve the accumulated regional problems solely through the efforts of the current generation of taxpayers, which is fundamentally incorrect and unfair. It is also necessary to involve future generations in financing public expenditures, which means developing the infrastructure and institutions required to activate policies of public loans at the regional level.

As our calculations have shown, such loans can be an effective tool, enabling the government to increase investments in education, healthcare, infrastructure, and other areas. Finding the right balance in the Far East is crucial: we need to attract borrowed funds to meet current development needs, but it's equally important to ensure that the debt doesn't burden future generations excessively. In this regard, there is much to learn from China, considering both the positive and negative experiences of regional public loans (Ho-Mou & Feng [35], Liu et al. [36]).

The dynamics of economic performance in the model confirms that the initial impetus given to economic growth in the region fades under the influence of population decline and ageing. This finding confirms the findings of many studies on the negative impact of population ageing (once it reaches a certain level) on economic growth, with the strength of this impact increasing as population ageing deepens (Lee & Shin [37]).

In contrast to Halim & Rahman [3], our computational experiments do not confirm that raising taxes and increasing domestic resource mobilization linked to sustainable development goals is a good idea for a region with demographic challenges. Based on our computations, the best policy alternative is to selectively stimulate innovation and investment in the growth poles, financed by taxes on future generations of the region and the country as a whole.

However, as already noted, selective incentives for innovation and investment are not a panacea. In this sense, the findings of Ding et al [38] that the promotion of technological innovation promotes inclusive harmonious and sustainable development need to be clarified. The content and context of technological innovation is important. For the Far Eastern Federal District, the strategic fiscal policy should provide for the integrated use of tax instruments of innovation and environmental orientation, which can eventually raise the environmental "ceiling" and improve demographic dynamics in the region.

Thus, the working hypothesis of the study (see introduction) was confirmed, but only partially. Concentrated tax incentives for SEZ subjects, as it was supposed, are indeed able to cultivate a better innovation environment and promote the replication of new technologies necessary for the sustainable development of the region, but, as it turned out, they themselves are not enough to change the negative trends that have developed in it.

In connection with the proposed emphasis on strengthening environmental regulation, one of the most promising avenues for further research is the study of the characteristics of the long-term behavior of economic agents in the region under the influence of alternative "green" policy measures (Schomers & Matzdorf [39]). Firstly, it is necessary to conduct specialized simulation modeling of the features of their reactions to changes in tax incentives (following Pigou [40]), considering the established institutional realities in the FEFD. Secondly, an analysis of the possible consequences of market-based (following Coase [41]) methods of regulating the environment is required.

6. Conclusions

Taxes play a vital role in achieving sustainable regional development, especially when the regulatory potential of monetary policy is problematic.

The research method used in this work involves the synthesis of Agent-Based (AB) and System Dynamics (SD) approaches to mathematical modeling of economic processes. It is based on the analysis of the behavior of a heterogeneous mass of economic agents that are integrated into direct and feedback relationships with systemic processes, including ecological ones.

The use of this method has demonstrated its ability to yield meaningful and novel results in the research field. This is achieved by adopting a comprehensive approach and considering the interaction of factors at both the micro and macro levels, with a particular emphasis on behavioral factors crucial for understanding the effects of taxes. This is particularly crucial for understanding the impact of taxes, especially behavioral factors. Therefore, the AB-SD synthesis method looks quite promising in the field of public finance.

In the context of the issues in the Far East, the application of the AB-SD synthesis method has shown that there is no straightforward tax solution to the complex challenges of sustainable regional development. Fiscal policy alone, including various combinations of tax instruments, does not guarantee the transition to a trajectory of stable economic growth for the region and its population. For this purpose, in addition to the positive impact of taxes, it is necessary to consistently improve the fundamental structural and dynamic characteristics of the region's socio-economic system, which includes providing more investments in science, infrastructure, human capital, and cultivating new behavior patterns among economic agents that better align with the opportunities and challenges of the cyber-physical industrial revolution.

Among the tax instruments considered, the most potent ones are focused tax incentives for growth poles in the region. These incentives are based on the principle of government and technological innovators' partnership, involving co-financing of scientific and technical projects. As our computational experiments have shown, such incentives can contribute significantly to the improvement of regional development by accelerating and scaling innovations. However, they do not automatically ensure its sustainability. The environmental "ceiling" is one of the main obstacles to long-term growth. Therefore, strategic fiscal policy should involve a combination – with mutual support and mutual reinforcement – of innovative tax incentives and environmental incentives, capable of gradually raising this "ceiling" over time.

The transition to a trajectory of sustainable development for the Far East cannot be resolved solely through taxes on the current generations. To achieve this, it is necessary to involve the incomes of future generations, who will also benefit from the advantages of sustainable development. In this regard, the improvement of the sub-federal loan institution is important, considering the experience of developing countries that actively apply this instrument in their economic practices.

However, when interpreting the obtained results, one should take into account the main limitation of our approach, which consists in the postulated nature of the behavior of economic agents, the parameters of which require empirical substantiation in further studies taking into account the recent trends in the development of the Far East.

References

1. Meng G., Zeng D. Structural transformation through free trade zones: the case of Shanghai. *Transnational Corporations*. 2019;26(2):95–116. https://doi.org/10.18356/70a11ff7-en

2. Romer C.D., Romer D.H. The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks. *American Economic Review*. 2010;100(3):763–801. https://doi.org/10.1257/aer.100.3.763

3. Halim M.A., Rahman M.M. The effect of taxation on sustainable development goals: evidence from emerging countries. *Heliyon*. 2022;8(9):e10512 https://doi.org/10.1016/j.heliyon.2022.e10512

4. Rahman M.M. Impact of taxes on the 2030 agenda for sustainable development: Evidence from Organization for Economic Co-operation and Development (OECD) countries. *Regional Sustainability*. 2023;4(3):235–248. https://doi.org/10.1016/j.regsus.2023.07.001

5. Kouam J.C., Asongu S.A. Effects of taxation on social innovation and implications for achieving sustainable development goals in developing countries: A literature review. *International Journal of Innovation Studies*. 2022;6(4):259–275. https://doi.org/10.1016/j.ijis.2022.08.002

6. Long C., Miller M. Taxation and the Sustainable Development Goals: Do Good Things Come to Those Who Tax More? Overseas Development Institute; 2017. 14 p. Available at: http://www.jstor.org/stable/resrep50128 (accessed: 25.03.2024).

7. Godinho V., Monteiro C., do Carmo Azevedo G.M. Effects of taxation on innovation and implications for the sustainable development goals. In: Tavares M.C., Azevedo G., Vale J., Marques R., Bastos M. (eds). *Artificial Intelligence Approaches to Sustainable Accounting*. IGI Global; 2024, pp. 249–265. https://doi.org/10.4018/979-8-3693-0847-9.ch014

8. Li X., Wu X., Tan Y. Impact of special economic zones on firm performance. *Research in International Business and Finance*. 2021;58:101463. https://doi.org/10.1016/j.ribaf.2021.101463

9. Wang G., Hou Y., Du S., Shen C. Do pilot free trade zones promote green innovation efficiency in enterprises? – Evidence from listed companies in China. *Heliyon*. 2023;9(10):e21079. https://doi.org/10.1016/j.heliyon.2023.e21079

10. Yan X., He T., Qian P., Liu Z. Does the construction of Pilot Free Trade Zones promote the development of green economy? – A quasi-natural experiment evidence from China. *Economic Analysis and Policy*. 2024;81:208–224. https://doi.org/10.1016/j.eap.2023.11.032

11. Nel E.L., Rogerson C.M. Special Economic Zones in South Africa: Reflections from International Debates. *Urban Forum*. 2013;24:205–217. https://doi.org/10.1007/s12132-012-9184-7

12. Xi Q., Sun R., Lin M. The impact of special economic zones on producer services productivity: Evidence from China. *China Economic Review*. 2021;65:101558. https://doi.org/10.1016/j.chieco.2020.101558

13. Sinenko O.A. Methods of assessing of tax incentives effectiveness in special economic zones: an analytical overview. *Journal of Tax Reform*. 2016;2(3):168-179. https://doi.org/10.15826/jtr.2016.2.3.022

14. Swinerd C., McNaught K.R. Design classes for hybrid simulations involving agent-based and system dynamics models. *Simulation Modelling Practice and Theory*. 2012;25:118–133. https://doi.org/10.1016/j.simpat.2011.09.002

15. Swinerd C., McNaught K.R. Simulating the diffusion of technological innovation with an integrated hybrid agent-based system dynamics model. *Journal of Simulation*. 2014;8(3):231–240. https://doi.org/10.1057/jos.2014.2

16. Jo H., Lee H., Suh Y., Kim J., Park Y. A dynamic feasibility analysis of public investment projects: An integrated approach using system dynamics and agent-based modeling. *International Journal of Project Management*. 2015;33(8):1863–1876. https://doi.org/10.1016/j.ijproman.2015.07.002

17. Demartini M., Bertani F., Tonelli F. AB-SD Hybrid Modelling Approach: A Framework for Evaluating Industrial Sustainability Scenarios. In: Borangiu T., Trentesaux D., Thomas A., Cavalieri S. (eds). *Service Orientation in Holonic and Multi-Agent Manufacturing. Proceedings of SOHOMA 2018*. Springer, Cham. 2019, pp. 222–232. https://doi.org/10.1007/978-3-030-03003-2_17

18. Langarudi S.P., Sabie R.P., Bahaddin B., Fernlad A.G. A Literature Review of Hybrid System Dynamics and Agent-Based Modeling in a Produced Water Management Context. *Modelling*. 2021;2(2):224–239. https://doi.org/10.3390/modelling2020012

19. Nguyen L.K.N., Megiddo I, Howick S. Hybrid simulation modelling of networks of heterogeneous care homes and the inter-facility spread of Covid-19 by sharing staff. *PLoS Computational Biology*. 2022;18(1):e1009780. https://doi.org/10.1371/journal.pcbi.1009780

20. Siebers P.O., Lim Z.E., Figueredo G.P., Hey J. An Innovative Approach to Multi-Method Integrated Assessment Modelling of Global Climate Change. *Journal of Artificial Societies and Social Simulation*. 2020;23(1):10. https://doi.org/10.18564/jasss.4209

21. Uehara T., Cordier M., Hamaide B. Fully Dynamic Input-Output/System Dynamics Modeling for Ecological-Economic System Analysis. *Sustainability*. 2018;10(6):1765. https://doi.org/10.3390/su10061765

22. Zulkepli J., Eldabi T. Towards a Framework for Conceptual Model Hybridization in Healthcare. In: *Winter Simulation Conference (WSC). Huntington Beach, CA, USA, 6–9 December 2015*. IEEE; 2015, pp. 1597–1608. https://doi.org/10.1109/WSC.2015.7408280

23. Polovyan A., Vishnevskaya E. Regulating co-evolution of the economic and environmental populations in the context of sustainable development. *Economics and Mathematical Methods*. 2017;53(2):101–117. (In Russ.) Available at: https://emm.jes.su/s042473880000525-6-1-ru-7/ (accessed: 25.03.2024).

24. Bogachov S.V., Vishnevsky V.P., Gurnak A.V., Nekliudova V.D. Modern Tax Trends and Economic Growth in a Turbulent World: Insights from Developed and Developing Economies. *Journal of Tax Reform*. 2024;10(1):63–83. https://doi.org/10.15826/jtr.2024.10.1.157

25. Sinenko O.A. Modeling tax incentives for sustainable development of territories. *Bulletin of Baikal State University*. 2023;33(3):466–474. (In Russ.). https://doi.org/10.17150/2500-2759.2023.33(3).466-474

26. Sinenko O.A. Tax Incentives for Economic Growth in the Russian Far East: Broad vs. Targeted Stimuli. *Emerging Science Journal*. 2024;8(3):1153–1166. https://doi.org/10.28991/ESJ-2024-08-03-021

27. Nelson R.R., Dosi G., Helfat C.E., Pyka A., Saviotti P.P., Lee K., Dopfer K., Malerba F., Winter S.G. *Modern Evolutionary Economics*. Cambridge, United Kingdom: Cambridge University Press; 2018. 272 p. https://doi.org/10.1017/9781108661928

28. Zhang J., Qi Y., Song Y., Li Y., Lin R., Su X., Zhu D. The relationship between industrial transfer parks and county economic growth: Evidence from Guangdong Province, China. *Habitat International*. 2023;139:102894. https://doi.org/10.1016/j.habitatint.2023.102894

29. Gasmi F., Recuero Virto L., Couvet D. An empirical analysis of economic growth in countries exposed to coastal risks: Implications for their ecosystems. *Economic Systems*. 2023;47(4):101130. https://doi.org/10.1016/j.ecosys.2023.101130

30. Yuan L., Li R., Wu X., He W., Kong Y., Ramsey T.S., Degefu D.M. De-coupling of economic growth and resources-environmental pressure in the Yangtze River Economic Belt, China. *Ecological Indicators*. 2023;153:110399. https://doi.org/10.1016/j.ecolind.2023.110399

31. Brouwer E., Poot T., Van Montfort K. The Innovation Threshold. *De Economist*. 2008;156:45–71. https://doi.org/10.1007/s10645-007-9081-y

32. Morgan K. The Learning Region: Institutions, Innovation and Regional Renewal. *Regional Studies*. 2007;41(1):147–159. https://doi.org/10.1080/00343400701232322

33. Polterovich V.M. Towards a general theory of socio-economic development. Part 1. Geography, institutions, or culture? *Voprosy Ekonomiki*. 2018; (11):5–26. (In Russ.) https://doi.org/10.32609/0042-8736-2018-11-5-26

34. Jianguo L., Raven P.H. China's Environmental Challenges and Implications for the World. *Critical Reviews in Environmental Science and Technology*. 2010;40(9-10):823–851. https://doi.org/10.1080/10643389.2010.502645

35. Ho-Mou W., Feng S. A Study of China's Local Government Debt with Regional and Provincial Characteristics. *China Economic Journal*. 2014;7(3):277–298. https://doi.org/10.1080/17538963.2014.961688

36. Liu A.Y., Oi J.C., Zhang Y. China's Local Government Debt: The Grand Bargain. *The China Journal*. 2022;87:40–71. https://doi.org/10.1086/717256

37. Lee H.H., Shin K. Nonlinear effects of population aging on economic growth. *Japan and the World Economy*. 2019;51:100963. https://doi.org/10.1016/j.japwor.2019.100963

38. Ding S., Li R., Liu Z., Li Y., Geng S. Sustainable potential of the strategic emerging industries: Insights from technological innovation, economy, and ecology. *Journal of Cleaner Production*. 2024;434:140038. https://doi.org/10.1016/j.jclepro.2023.140038

39. Schomers S., Matzdorf B. Payments for ecosystem services: A review and comparison of developing and industrialized countries. *Ecosystem Services*. 2013;6:16–30. https://doi.org/10.1016/j.ecoser.2013.01.002

40. Pigou A.C., Aslanbeigui N. *The Economics of Welfare*. Routledge eBooks; 2017. 876 p. https://doi.org/10.4324/9781351304368

41. Coase R.H. *Essays on Economics and Economists*. University of Chicago Press; 1994. https://doi.org/10.7208/chicago/9780226051345.001.0001

Acknowledgments

The study was funded by the Ministry of Science and High Education of the Russian Federation, project number FZNS-2023-0016 "Sustainable regional development: efficient economic mechanisms for organizing markets and entrepreneurial competencies of the population under uncertainty (balancing security and risk)".

Information about the author

Olga A. Sinenko – Cand. Sci. (Econ.), Associate Professor, Senior researcher, School of Economics and Management, Far Eastern Federal University, Vladivostok, Russian Federation (FEFU Campus, 10 Ajax Bay, Russky Island, Vladivostok, 690922, Russian Federation), https://orcid.org/0000-0001-7497-9475; e-mail: sinenko.oa@dvfu.ru

For citation

Sinenko O.A. Modeling the Policy of Tax Incentives for Sustainable Development of the Region: The Case of the Far Eastern Federal District of Russia. *Journal of Tax Reform*. 2024;10(2):312–333. https://doi.org/10.15826/jtr.2024.10.2.171

Article info

Received *May 9, 2024*; Revised *June 5, 2024*; Accepted *July 8, 2024*

Благодарности

Работа выполнена при поддержке Министерства науки и высшего образования Российской Федерации, проект № FZNS-2023–0016 «Устойчивое развитие региона: эффективные экономические механизмы организации рынков и предпринимательские компетенции населения в условиях неопределённости (баланс безопасности и риска)».

Информация об авторе

Синенко Ольга Андреевна – кандидат экономических наук, доцент, старший научный сотрудник Школы экономики и менеджмента Дальневосточного федерального университета, г. Владивосток, Россия (690922, г. Владивосток, остров Русский, п. Аякс 10, кампус ДВФУ); https://orcid.org/0000-0001-7497-9475, e-mail: sinenko.oa@dvfu.ru

Для цитирования

Sinenko O.A. Modeling the Policy of Tax Incentives for Sustainable Development of the Region: The Case of the Far Eastern Federal District of Russia. *Journal of Tax Reform*. 2024;10(2):312–333. https://doi.org/10.15826/jtr.2024.10.2.171

Информация о статье

Дата поступления *9 мая 2024 г.*; дата поступления после рецензирования *5 июня 2024 г.*; дата принятия к печати *8 июля 2024 г.*