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Performance of Enterprises and Countries to Achieve Sustainable Development

In the era of digitalization, when changes in various spheres of life occur as quickly as possible, scientists from different countries have comprehended the need to establish a course for consistent, correlated development of the economy, ecology, legal culture and social sphere. The concept of sustainable development provides doing business without harming the environment and future generations, caring for the company's counterparties and society. The issue is devoted to considering the degree of influence of various factors on the performance of specific enterprises and countries and determining the impact of digital technologies on existing economic systems.

In the fourth issue of the journal "Sustainable Development and Engineering Economics" for 2023, the authors examined various aspects of the sustainable development of enterprises and territories and ways to achieve it.

The first section named Economics of engineering and innovation decisions as a part of sustainable development is presented by the article "Data storage and statistical data processing tools for solving the tasks of managing regional innovation systems" by Gintciak A., Skhvediani A., Fedyaevskaya D., Burlutskaya Z., Rodionova M., the authors are designing a digital platform data storage and processing system for analyzing the level of innovative development of the region. The study also examined the development of the server part of the digital platform, which is responsible for storing and processing data, and highlighted the levels of database modeling.

The Enterprises and sustainable development of regions section presents the work "Forecasting financial condition of an industrial organization in dynamics nowadays" by Nazarov A., Zhogova E. The purpose of the article is to observe the external environment of the functioning of an industrial enterprise and the possibility of its strategic development in the future, considering innovations brought by digital technologies and Industrial revolutions. The authors concluded that any enterprise needs development reserves in the form of the ability to attract investments from the external environment, as well as the introduction of new technologies into the production process of industrial enterprises to ensure their competitiveness in the long term.

Issues of sustainable development of regional infrastructure are reflected in the article "Influence of the External Environment on the RES Development Intensity" by Rodionov D., Konnikov E., Konnikova O., Smirnova I., Kryzhko D., Brazovskaia, V. The authors identify factors that influence the availability of renewable sources energy in the energy systems of countries, describe the nature of such influence. The article uses cluster analysis, which results in a classification of countries depending on the level of use of renewable energy sources.

Another work of the third section is "Methodology for Assessing the Level of Harmonization of Industrial and Trade Policy" by Sidorenko Y. During the study, the author proposed a methodology for assessing the level of harmonization of the components of industrial and trade policy of St. Petersburg at the institutional level, which is based on a score-rating method. The article defines the criteria and principles for the harmonization of industrial and trade policies and proposes a list of indicators for assessing the socio-economic effect of the harmonization of industrial and trade policies in the region using the example of light industry.

The section named Management of knowledge and innovation for sustainable development includes the article "Motivation Model of Top Management in Government Agencies of Regions" by Koshelev E. The article examines the problem of global increase in the rate of natural population growth using a multi-purpose genetic algorithm. The purpose of the article is to create a motivation model for top management of regional government structures, using the Pareto front function.

Irina Rudskaya, *Editor-in-Chief of SDEE Journal, Doctor of Economics, Professor*

TABLE OF CONTENTS

СОДЕРЖАНИЕ

SECTION 1

ECONOMICS OF ENGINEERING AND INNOVATION DECISIONS AS A PART OF SUSTANABLE DEVELOPMENT

РАЗДЕЛ 1

ЭКОНОМИКА ИНЖЕНЕРНЫХ И ИННОВАЦИОННЫХ РЕШЕНИЙ КАК ЧАСТЬ УСТОЙЧИВОГО РАЗВИТИЯ

Research article

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Data Storage and Statistical Data Processing Tools for Solving the Tasks of Managing Regional Innovation Systems

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Abstract

Digital platforms, as an example of digital tools for data handling, provide an entire cycle of working with data, from data acquisition, processing, and storage to visualisation and software simulation. The digital platform comprises a data storage and processing system that ensures compliance with data usage protocols by other modules of the digital application. Moreover, such data storage and processing systems should be adapted to multi-user work with large amounts of data, which are assumed to be part of the operation of the digital platform. The purpose of this article is to describe the design and software implementation of a data storage and processing system for a digital platform capable of analysing regional innovative development levels. The data storage and processing system was developed based on the data structure and features, as well as on the requirements for data operation. The development process is presented in the form of the implementation of sequential steps, starting with the analysis of the requirements for the data storage and processing system for the proposed digital platform, the development of an ER diagram, and an infological and logical data model. The description ends with a discussion of the software tools and the physical implementation of the system. This article discusses an approach to data storage system design based on the analysis of data features and structure, as well as the proposed algorithm for data handling. The approach offers the advantages of solution flexibility and scalability, as well as user convenience, which consists of a query structure adapted to the appropriate specifics.

Keywords: database; digital platform; data curation; data processing; design database; digital technologies

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Инструменты Хранения и Статической Обработки Данных для Решения Задач Управления Региональными Инновационными Системами

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Аннотация

Цифровые платформы, как частный пример цифровых инструментов для работы с данными, обеспечивают полный цикл работы с данными: от сбора, обработки и хранения до визуализации и программной симуляции на их основе. В основе цифровой платформы лежит система хранения и обработки данных, обеспечивающая соблюдение протоколов использования данных другими модулями цифрового приложения. Более того, подобные системы хранения и обработки информации должны быть адаптированы под многопользовательскую работу с большими объемами данных, предполагаемую в рамках эксплуатации цифровой платформы. Целью работы является проектирование и программная реализация системы хранения и обработки данных для цифровой платформы анализа инновационного развития регионов. В результате разработана система хранения и обработки данных с учетом особенностей и структуры данных, а также предполагаемого алгоритма работы с данными. Процесс разработки представлен в виде реализации последовательных шагов, начиная с анализа требований к системе хранения и обработки данных для разрабатываемой цифровой платформы, разработки ER-диаграммы, инфологической и логической модели данных, заканчивая обсуждением программных инструментов и физической реализации самой системы. В ходе исследование обсуждается подход к проектированию систем хранения данных, основанный на анализе особенностей и структуры данных, а также предполагаемого алгоритма работы с данными. Среди преимуществ выделяются: гибкость и масштабируемость решения, а также удобство для пользователя, выраженное в адаптированной под соответствующую специфику структуру запросов.

Ключевые слова: база данных; цифровая платформа; хранение данных; обработка данных; проектирование базы данных; цифровые технологии.

Цитирование: Гинцяк, А., Схведиани, А., Федяевская, Д., Бурлуцкая, Ж., Родионова, М., 2023. Инструменты Хранения и Статической Обработки Данных для Решения Задач Управления Региональными Инновационными Системами. Sustainable Development and Engineering Economics 4, 1. https://doi.org/10.48554/SDEE.2023.4.1

1. Introduction

The rapid development of digital technologies has led to the emergence of new trends in analytical research, including those in the socioeconomic field (Popov et al., 2021; Baran et al., 2021). Official statistical centres have switched to acquiring and analysing big data on various regional systems, which can later be used in socioeconomic research (Belov et al., 2021; Hasell et al., 2020; Mathieu et al., 2021). Further, the data of official statistical offices are marked not only by large volumes but also by completeness and accuracy (Ricciato et al., 2019; Constantinides et al., 2018). Data from these sources does not require further data cleaning and verification. However, large volumes of data may require more complex technical means and tools for processing and analysis.

Within socioeconomic research, specialists are developing digital platforms covering the entire cycle of data analysis, from data acquisition to result visualisation (Liu et al., 2022). The data from the state statistical offices are applied in the calculation of economic indicators and are used in mathematical models to analyse the social and economic spheres of the region and/or country. The tasks that are solved with digital platforms include dynamic analysis of forming collaborations in the supply chain, regional cluster policy analysis, business environment dynamics analysis, dynamics of social security processes, or the support of scientific research (Jovanovic et al., 2022; Yanagisava et al., 2016; Winther et al., 2019; Mirziyoeva et al., 2020; Morozov et al., 2020; Turk, 2016; Tarasov et al., 2022). Thus, digital platforms allow for a timely analysis of regional development by means of complex work with data provided by state statistical offices (Rudskaya et al., 2022). As part of ensuring digital platform operation, there is a need to develop methods for acquiring and storing data from official statistics sources (Belov et al., 2021), including automated data processing methods (Kudryavtseva et al., 2021). Since the database is the main server-side element of the digital platform, providing access to data for calculation modules and data visualisation modules, its design and software implementation is the first task in digital platform creation.

The purpose of the research is to develop functional requirements and software support of a digital platform's server side for the analysis of a regional innovation system that provides data storage, processing, and visualisation. Within the research, a digital platform data processing diagram, ER diagram, infological data model, and logical data model were developed. The developed database was implemented in the code. These solutions are the first steps in creating a digital platform for analysing regional innovation systems.

This paper is part of a project aimed at developing a digital modelling tool for a digital platform-based regional innovation system.

2. Literature review

Statistical offices are important data sources for socio-economic research. They collect and process (including aggregation) data (Gintciak et al., 2023). The Federal State Statistics Service website provides information on the activities of state bodies and local self-government bodies, placed in the form of data arrays in a format that ensures their automatic processing for reuse without prior modification by the users (machine-readable format) on the terms of its free use. Other sources of such statistical data include 5G, 4G, and LTE, social networks, and mobile operators.

Digital data sources close the gaps that statistics offices do not cover due to data aggregation (Gintciak et al., 2023). However, digital data require additional preprocessing (Yu et al., 2022). Given the heterogeneity of data sources in socioeconomic systems, the task of building a data warehouse becomes a class of complex tasks. Database formation is a complex task (Yanagisava et al., 2016; Liu et al., 2022; Cenamor et al., 2019), as the subsequent operability of software modules depends on the efficiency and correctness level of the created system. The database must meet the following characteristics: minimal redundancy, consistency, independence, and the possibility of adding/deleting and updating the data.

To meet these requirements, when designing databases, step-by-step-level modelling and database

normalisation must be performed. As part of database development problem-solving, the content of the database, the way of arranging data, and data management tools should be outlined (Liu et al., 2022; Cenamor et al., 2019). The process of database development is marked by a transition from a natural human-understandable text to a formalised description and design of a data model. When developing a relational database model, several modelling levels are distinguished: domain model (conceptual scheme), infological data model, logical data model, physical data model, and database and applications.

Based on findings from relative worldwide projects, the most suitable instruments for database implementation are MySQL (Tarasov et al., 2022; Abd et al., 2021) and PostgreSQL (Belov et al., 2021).

3. Materials and methods

The development of innovation activity in regions is marked by the complex interaction of business entities with certain inputs and outputs. Regional innovation activity analysis requires consideration of key process components. For this task, specialists use the following methods: data envelope analysis (DEA) (Evtyanova, 2017), regional index of innovative and digital development calculation (Evtyanova, 2017), factor analysis of the influence of the index components on its formation (Evtyanova, 2017), and cluster distribution analysis (including calculation of the cluster localisation coefficient in the region) (Abd Rahman et al., 2021).

The initial data for the innovation activity analysis were the data from the state statistical offices. The data are provided as annual reports of official statistical offices. In this regard, the data have already been processed (cleaned, aggregated, etc.) and are in a template that can be machine-processed. These data can be entered into the system semi-automatically. The option of fully automating data uploading may be available if the source data are in one template. However, data from the official statistics offices of the Russian Federation are currently available in several template versions and cannot be automatically processed. Thus, the algorithm for semi-automatic data uploading can be described in two consecutive steps:

1. CSV source data from the portal of state statistical offices are processed by experts and brought to a certain template.

2. The tabular data are uploaded to the database by an authorised user with the appropriate “administrator”-level access rights through the integrated interface.

In addition to the data uploading module, it is necessary to consider the interaction with calculation and data visualisation modules. Calculation modules perform data processing and calculations in accordance with the selected methods for analysing the innovative development of regions. Thus, there is a need to record the results of the simulation experiments for subsequent analysis and comparison. Interactive work with indicators through the platform interface is also expected. Therefore, the user should be able to vary the parameter values, which will automatically recalculate a certain number of indicators. Figure 1 shows the entire cycle of working with the data.

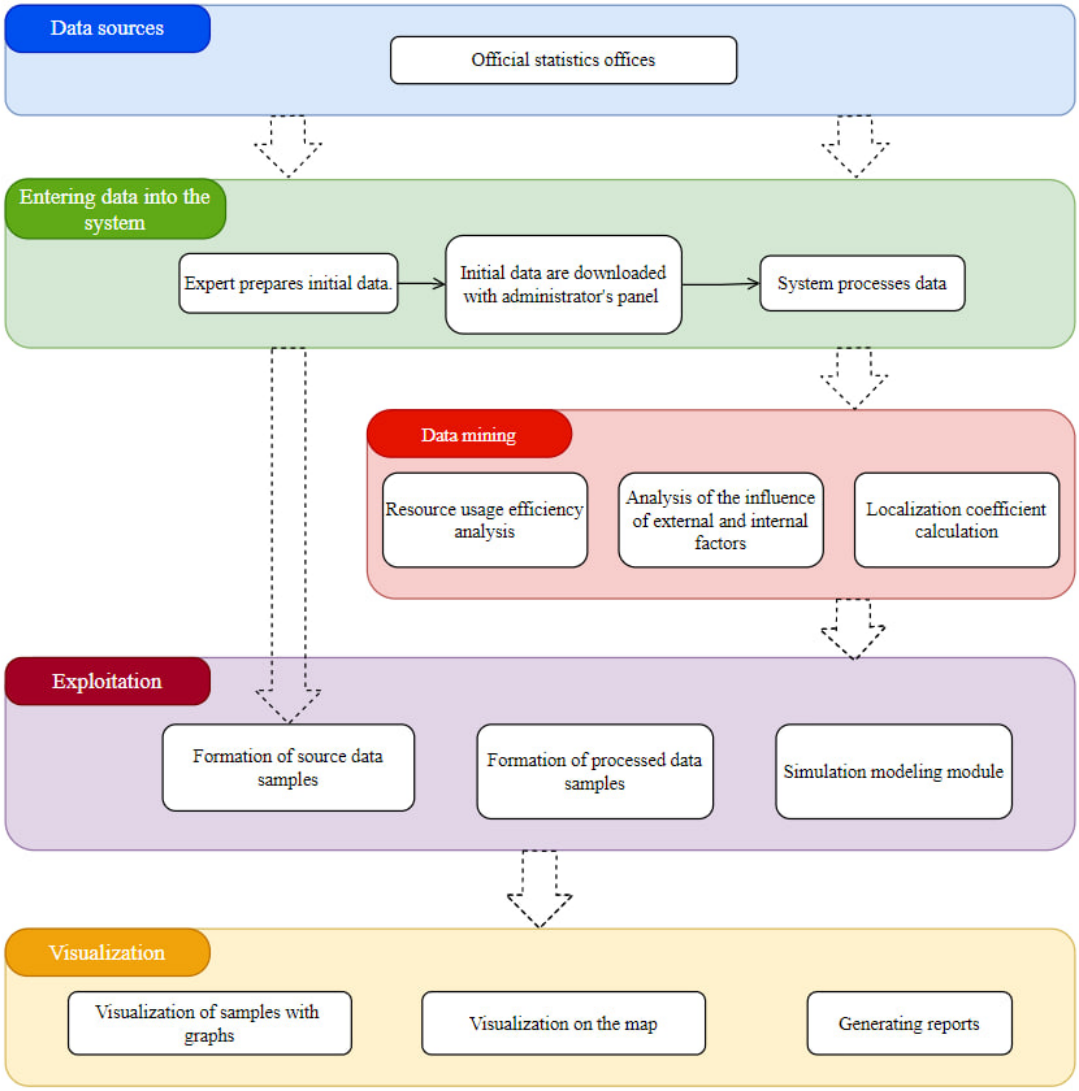

Figure 1. Cycle of working with data

4. Results

Conceptual framework development

The proposed digital platform can provide automated data uploading, processing of the data with consideration for the recording of query results, and storing the results of a given number of experiments in a simulator. The subject domain does not require storing all data about entities (as in the case of information retrieval systems). Thus, a set of data required for software processing and obtaining arrays of necessary indicators as a result should be determined.

In this work, innovation activity in the country's regions was analysed in terms of particular regions and years. The innovation activity of the region was marked by the presence of input and output parameters. The researchers distinguished the following parameters: the intrinsic value of R&D projects, the number of entities conducting R&D projects, the cost of technical innovations, the number of patents granted, and the volume of innovative goods and services. Moreover, regions were marked by the presence of the region's number and name attributes. The researchers used the input–output matrix analysis method to classify industries into clusters (Evtyanova, 2017; Abd Rahman et al., 2021). In total, the classification method revealed 98 industries, which, as a result of the analysis, were divided into 22 clusters. Industries are marked by the labour activities of a certain number of people. This indicator allows for the calculation of the localisation coefficient, which represents the region's industry concentration extent.

Innovation activity is supported by key actors in the environment. Researchers are developing

methods for analysing such activities from the perspectives of the environment-provided key actors' and conditions' perspectives (Evtyanova, 2017; Abd Rahman et al., 2021). In this study, business, research entities, universities, and the state were singled out as actors of innovation activity. The region's conditions consist of economic and social factors, as well as its digitalisation level. Further, actors and the environment have attributes that make up indicators that allow the assessment of the region's development degree.

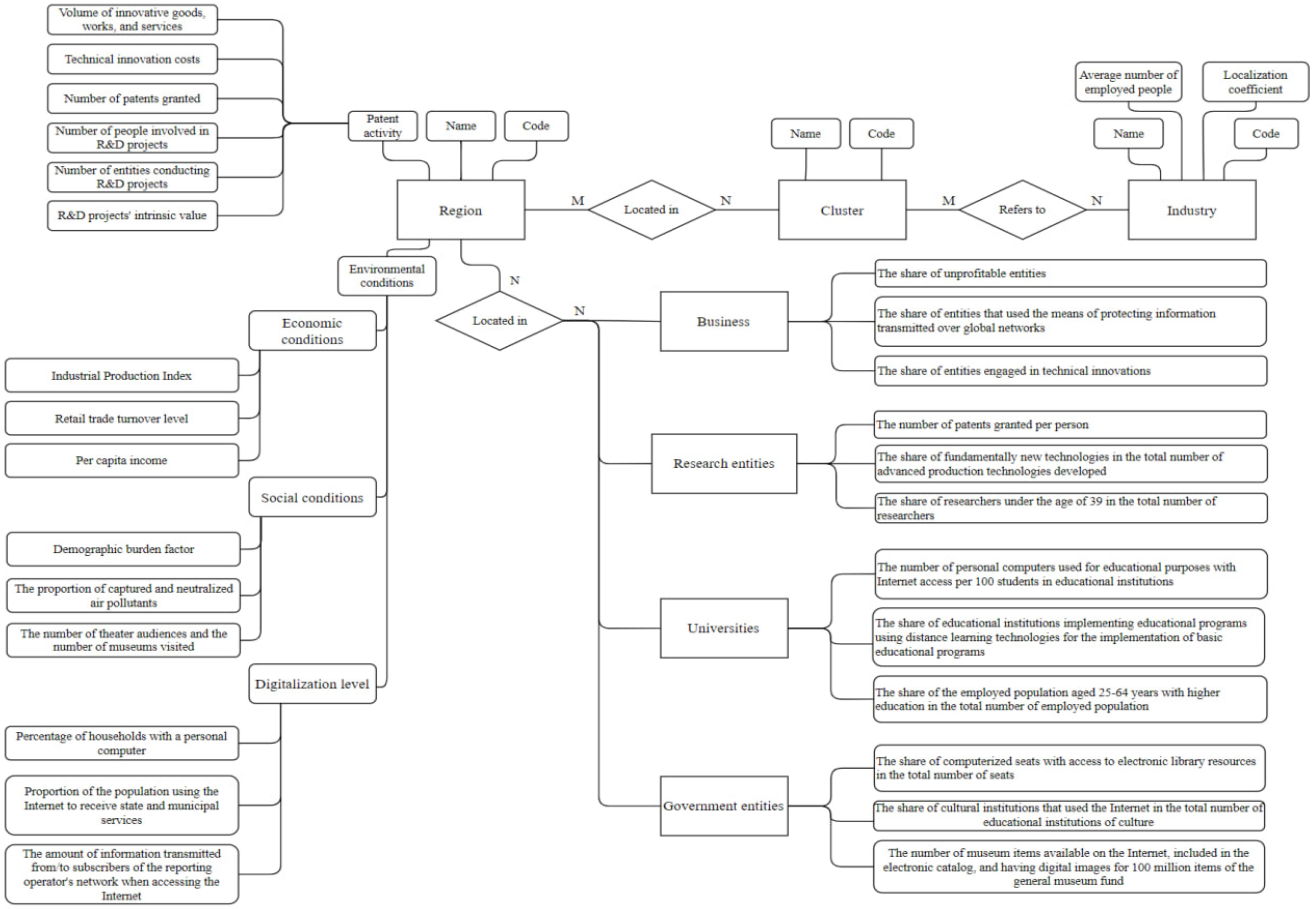

Figure 2. ER diagram

Infological model development

Based on the subject domain description, an ER diagram was compiled to reflect entities, their relationships, and attributes (see Fig. 2). The subject domain description and the ER diagram were used to create an infological model, which represents the entities of the future database, the data being stored, and the relationship between the data. To structure information and ease the access and data uploading, information about the region (name and code), its attributes were divided into separate entities: region, patent activity, and environmental conditions. It is noteworthy that the attributes of the environmental conditions were aggregated into groups for the convenience of the model. However, the database can store complete information about environmental conditions according to the classification shown in the ER diagram. The database can also store information about the regions in terms of years. Therefore, the relationship between the region entity and the patent activity and environmental conditions entities will be one-to-many (see Fig. 3).

In the model, clusters consist of several industries, while the industry is included only in a specific cluster. Thus, the relationship between entities is one-to-many (Fig. 4). Actors consist of businesses, research entities, universities, and the state. Each actor has its own properties, but they have not been mapped out for better visual representation. They will be stored in one actor entity. Each property is unique for a region; however, because the database contains information from 2009, the relationship between entities will be one-to-many (Fig. 5).

Based on the description of the entities and their attributes, an infological scheme was compiled (Fig. 6). The region entity is linked to the cluster entity by a many-to-many relationship since each region has a set of clusters, and each cluster is represented in a set of regions. This type of relationship requires further elimination.

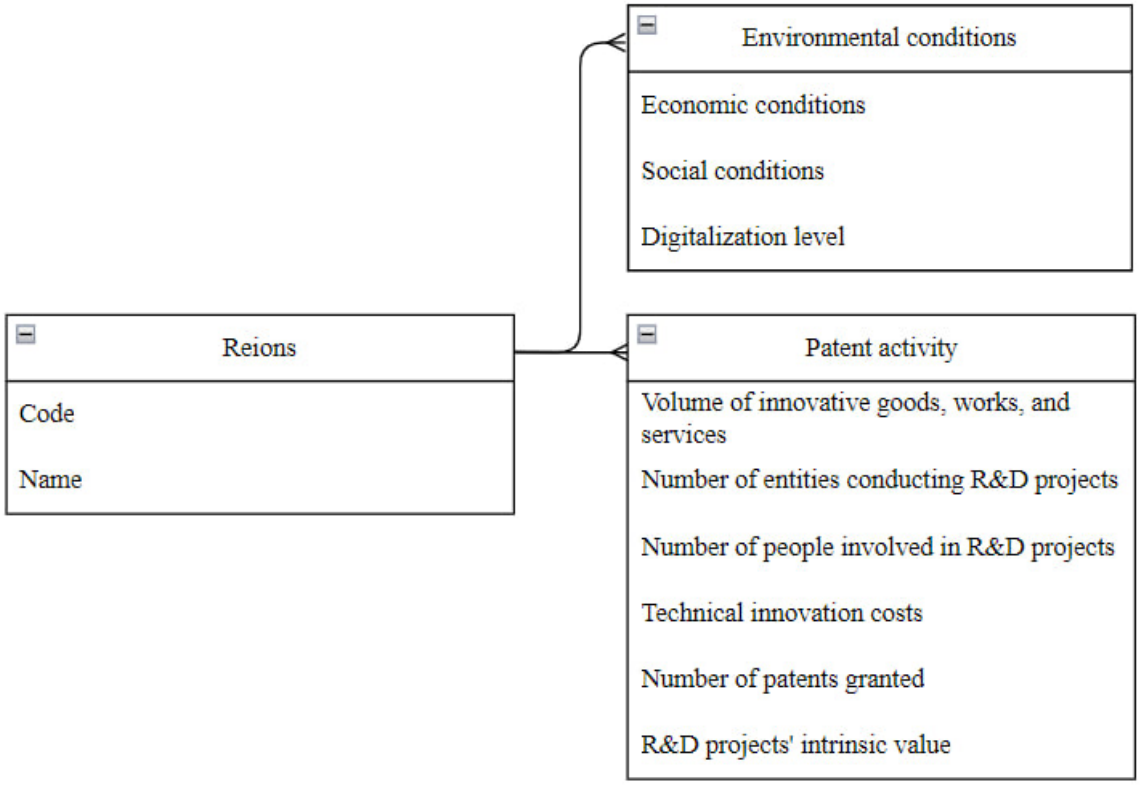

Figure 3. Infological scheme of regions, environmental conditions, patent activity

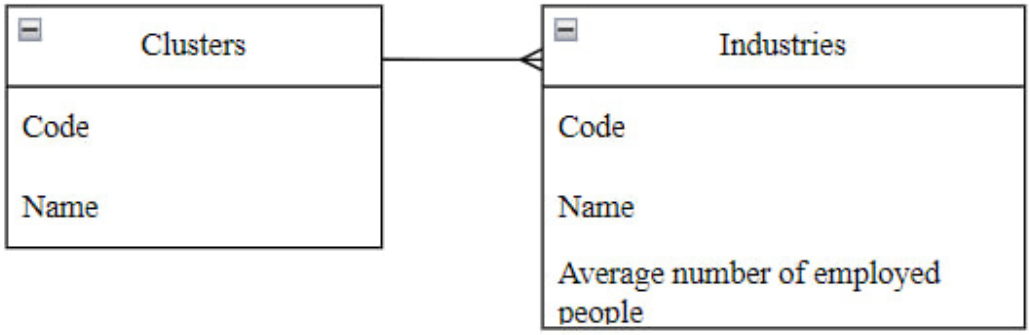

Figure 4. Infological scheme of clusters and industries

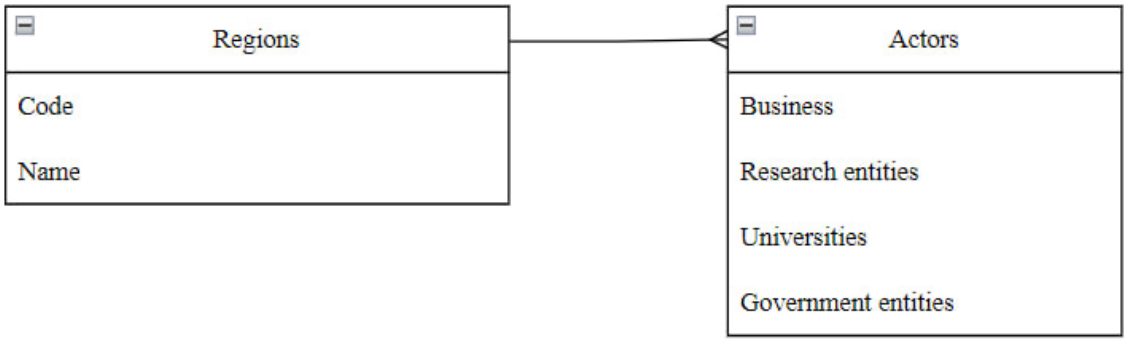

Figure 5. Infological scheme of regions and actors

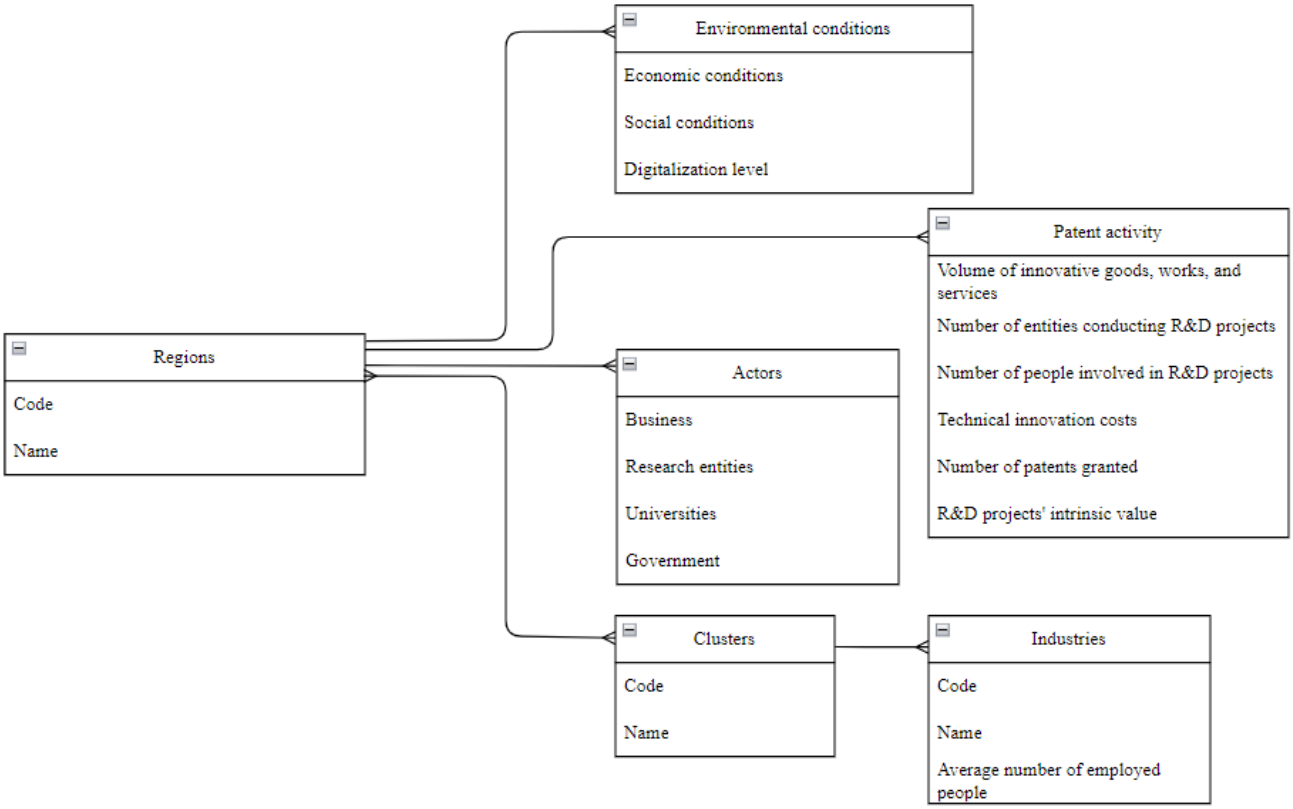

Figure 6. Infological scheme

Logical data model

Since innovation activity is analysed over time for different regions, all indicators by region are stored by year. Thus, a table with a list of regions and years (ID relation) was selected as the pivotal relation. The key field of this relationship is id_regions, which connects two non-key fields. Information about regions is stored in the region directory. The key field in the directory is id_region, which is the area code. This relationship also contains the name (the region name) and slug (the region name to address in the code) attributes.

The industries directory contains the attributes id_industry (industry code according to the OKVED classification), which is the key field, and industry_name (the name of the industry according to the OKVED classification). The cluster relationship contains their OKVED classification codes (id_cluster, key field), name (cluster_name), and system name (slug). The clusters and industry directories are linked by the relation industry_cluster with the id_industry key field and the dependent id_cluster. Although these relations are one-to-many (see Fig. 6), the researchers decided to avoid deletion and modification anomalies. Since the classification of the industries to clusters ratio is original and was developed by specialists (Evtyanova, 2017; Abd Rahman et al., 2021), it can be changed (e.g. in accordance with the generally accepted OKVED state classification) or modified. Data on the industry–cluster relationship and entity attributes are separated to ensure that data on industries and clusters are not lost when deleting or changing this classification (see Fig. 7). Data on the localisation of industries in the region are calculated annually based on information about the number of people employed in the region's industry. Given that these data must be calculated annually, the lq (the region's industry localisation) and d_ind (the number of people employed in the region's industry) attributes are separated into lq/industries relation with the key id field, which is a foreign key to the ID table.

Data on the region's patent activity are stored in relation to the patent activity. The DEA results are recorded in the DEA relationship, which consists of the following fields: id (key field), rank, theta, is_vtz, is_ospd, is_patent, is_cfti, and is_res_hum. The input data for the DEA product are written on the patent_activity relation:

• vtz – R&D projects' intrinsic value;

• opsrd – the number of entities conducting R&D projects;

• res_hum – the number of people involved in R&D projects;

• patent – the number of patents granted;

• cfti – the cost of technical innovations;

• qing – the volume of innovative goods and services.

One of the platform's functional clusters is the module of the simulation experiments. This allows the user to change the indicators of the region's innovative development to compare the resulting indicators of its innovative development index and the rating in the country, as well as to save experimental data. To implement the option of saving the results in the user's personal account, a sim relation with fields duplicating the regions_indexes relation has been added to the database structure. Since experiments can be performed with the same region for the same reporting year, the code_sim field has been added as the key field. Figure 7 shows a digital platform database diagram for assessing the innovative development of the country's regions.

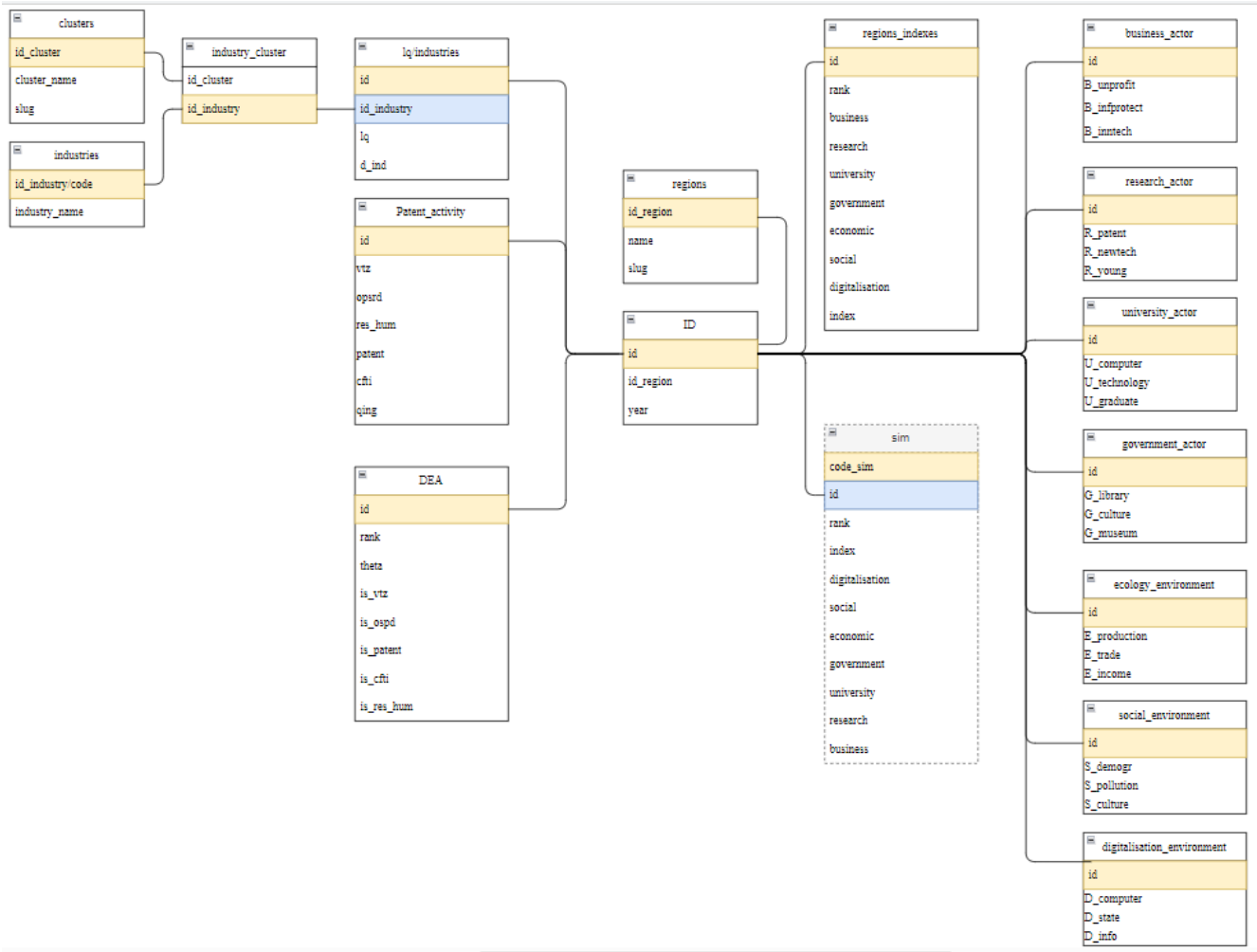

Figure 7. Logical data model

5. Discussion

Based on the application architecture and the requirements for the client and server sides of the proposed digital platform, database management tools were selected. Since React.js was chosen as the main language for the digital platform design, Next.js was selected for client (user) interaction with the platform, which provides SSR (server-side rendering) capabilities, increasing perceived performance.

Nest.js was also selected for the server side, since it meets all the requirements and sets a conveniently scalable architecture. PostgreSQL for relational models was chosen as the DBMS.

The choice of PostgreSQL is informed not only by the popularity of this solution but also by its obvious advantages. Using PostgreSQL ensures data integrity and reliability. As the tool can create a personal user account and store personal data, reliability becomes an important requirement. Further, using PostgreSQL provides extensibility, which is also a necessary requirement for a platform.

The developed database was built from scratch for a specific digital solution. Therefore, it is not versatile and applicable to a wide range of tasks. However, this approach takes into account the various combinations of input parameters necessary for automating methodologies for calculating innovative indicators. The complexity of the techniques and their unique features impose certain requirements on the database, such as flexibility and extensibility (Evtyanova, 2017; Abd Rahman et al., 2021).

An approach to database development based on the design of a data storage system for a specific digital solution, along with data structure and features, has also been used as described in other works. The advantages of the proposed approach are solution flexibility and scalability, as well as user convenience, which involves a query structure adapted to the appropriate specifics (Liu et al., 2022; Cenamor et al., 2019).

6. Conclusion

This study presented the sequential development of the digital platform's server side, which is responsible for data storage and processing. The proposed database's consistent development relies on the data structure and features, as well as on the requirements for data operation as part of using a digital platform on the server and client sides of the application. Thus, the following database modelling levels were outlined: domain model (conceptual schema), infological data model, logical data model, physical data model, and database. This study is an approach to data storage system design based on the analysis of data features and structure, as well as the proposed algorithm for data handling. The approach exhibits the advantages of solution flexibility and scalability, considering the specifics of data and working with them. However, this solution is not versatile and can only be adapted for other applications as an approach or top-level structure.

This paper is part of a project aimed at developing a digital modelling tool for a digital platform-based regional innovation system. In the next stage of the research, the logic and software implementation of the calculation and simulation experiments module will be developed and integrated with the database.

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SECTION 2

ENTERPRISES AND THE SUSTAINABLE DEVELOPMENT OF REGIONS

РАЗДЕЛ 2

ПРЕДПРИЯТИЯ И УСТОЙЧИВОЕ РАЗВИТИЕ РЕГИОНОВ

Research article

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Forecasting the Financial Performance Dynamics of a Present-Day Industrial Enterprise in Today's Market

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Abstract

Forecasting financial performance dynamics is one of the most fundamental processes for analysing the development trends of any company. For large-scale forecasting, however, it is necessary to consider numerous relevant factors, including the external environment in which a company operates. This particular factor has proven the most vital aspect to consider, because even minor environmental shifts shape the entire development trajectories of all industries and enterprises involved. What is more, the ability of an industrial enterprise to adjust to external environmental changes of any sort represents a prerequisite of successful competition and increased investment prospects within the framework of newly emerging challenges and resources, both digital and technological. In this research, the authors aim to investigate the external environment of a particular industrial enterprise and to assess the prospects of its strategic development, accounting for the innovations introduced by digital technologies and industrial revolutions. As a result, this research suggests a range of measures for enterprises to stabilise the internal environment, thus contributing to the dynamic stability of business models. Overall, combining scientific analysis with these stabilising measures justifies the statement that the development strategies and management approaches of industrial enterprises must be consistent and co-integrated.

Keywords: financial performance, financial indicators, digital transformation, industry, enterprise

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Научная статья

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Прогноз Динамики Финансовых Показателей Промышленного Предприятия в Текущих Условиях

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Аннотация

Прогноз динамики финансовых показателей является достаточно важным инструментом анализа тенденций развития компании. Однако для его проведения необходимо учитывать обширный перечень релевантных факторов, одним из которых модно назвать внешнюю среду, в которой функционирует предприятие. Именно тенденции ее изменения придают ключевые рамки в развитии промышленности и промышленных предприятий. И наличие гибкости промышленного предприятия в вопросах адаптации к нестабильной внешней среде дает ему возможность достигать конкурентоспособного уровня и инвестиционной привлекательности с учетом новых вызовов и ресурсов (цифровых и технологических). Целью данного исследованию стало исследование внешне среды функционирования конкретного промышленного предприятия и возможности его стратегического развития в будущем, с учетом нововведений, привнесенных цифровыми технологиями и Индустриальными революциями.

Ключевые слова: финансовые показатели, цифровая трансформация, промышленность, предприятие

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1. Introduction

This research considers the activity of an industrial enterprise and the dynamics of its financial performance within an unstable external environment, as well as the innovations brought by industrial revolutions (Industry 4.0–Industry 6.0). As such, the herein research topic is of significant relevance at present. For instance, today, the scientific community is exerting much effort to determine the most appropriate development strategy to meet the challenges introduced by extreme instability, thus enabling enterprises to perform better and to adapt to new market realities (Ismailova et al., 2021).

In effect, a leading challenge among industrial enterprises has proven to be developing the ability to adjust to a widened range of digital opportunities and functions, a fact that guided the development of the goals and tasks of this research. As such, the herein authors strive to define and justify the importance of alignment between the development strategy and the above-mentioned priority tasks and threats.

Forecasting the financial performance dynamics of industrial enterprises begins with a definition of the external environment in which the company operates, namely its current development vectors. Accordingly, the provisions of Industry 4.0 have shaped the grounds for a precedent concerning the complete digitalisation of (all or singular) business processes (Sandberg et al., 2019). Relative to this, Figure 1 presents the vision of Industry 4.0, together with the range of associated benefits.

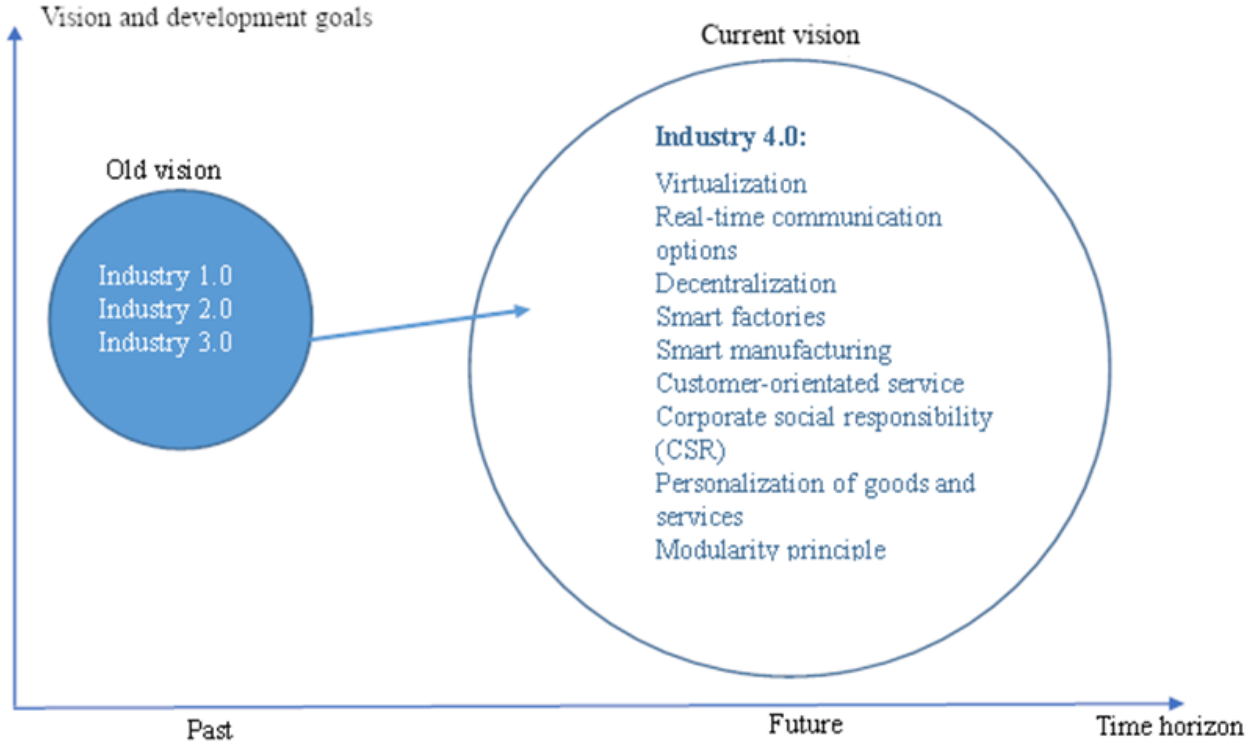

Figure 1. Old and current visions of industrial development

Figure 1 demonstrates the already available digital functions of the Industry 4.0 framework implemented in multiple fields, including industry (Annanperä et al., 2021), providing the basis for the evolution from semi-automated labour to neural networks and cyber-physical automation. The 2019 pandemic became a jumping-off point for significant changes, leading to growth in the prospects of a new Industry 6.0 vision to be implemented in the near future. Beneficially, the core technical and technological elements of "smart production", relevant for Industry 3.0, have already been exploited in Industry 4.0, thus shaping the basis for Industry 6.0 (Figure 2) (Annanperä et al., 2021).

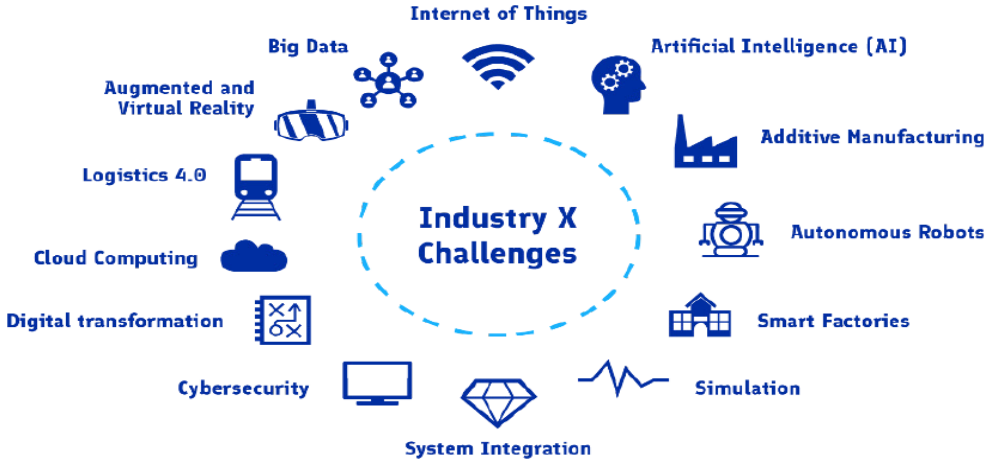

Figure 2. Core technologies available for the transition from Industry 4.0 to Industry 6.0

Figure 2 explicitly demonstrates that all the Industry 4.0 functions available now function as sufficient prerequisites for the whole-scale digital transformation of the industry—meaning that achieving this shift is simply a matter of time (Samonova, 2020).

Even now, the functionality of digital services is rapidly changing (Li et al., 2009), involving the transformation of traditional business models and market relations (Orekhova, 2018). Further, the relentlessness of this process dictates the necessity for industries to invite technologies (digital and industrial) to maintain their financial stability, competitiveness, profitability and investment prospects (Kovtunenko et al., 2016).

However, the unstable and unpredictable external environment of today cannot be neglected by industrial enterprises (Mironova, 2008; Nikolaev, 2005), which is exactly why an enterprise's ability to adjust will enable not only survival during a crisis, but also the implementation of modern technological solutions and digital services for optimisation (Shestakova, 2021). Consequently, costs will be reduced (Lukasevich, 2010), and financial performance will improve once the company overcomes the impediments to production and business models.

For an industrial company to adapt successful (Orfanidi et al., 2023) to the external environment, it is necessary to attract additional funding sources (Ryabova, 2015), and the concept of investment prospects should be considered in more detail, because investment management is—undoubtedly—an integral component of any development strategy (Aleksandrova, 2013).

Generally, the investment prospects of an economic entity (Zakirova, 2016), including an industrial enterprise, can be considered from different angles. Particularly, Tolkachenko et al. (2008) distinguish four approaches to the definition:

1. Investment prospects as a condition of enterprise development,

2. Investment prospects as a condition for investment,

3. Investment prospects as a set of indicators and

4. Investment prospects as an indicator of investment efficiency.

Each approach includes three main components: economic relations, investment resources (Ryabova, 2015) and competitiveness (Golov et al., 2018), each of which plays a key role for a number of reasons.

First, an economic relationship between donor and investment recipient is a basic requirement of

the investment process of capital redistribution at the macro- and microeconomic levels. As such, an industrial enterprise need not increase its investment prospects simply for the sake of it. Indeed, the need comes from the presence of counterparty relations. Simultaneously, the need to attract investments arises when an industrial enterprise lacks sufficient investment capital and the opportunity to generate capital at the expense of its own financial resources—which is where investing becomes relevant. However, when allocating their own funds, investors require certain term guarantees (urgency, repayment, fee), because as a rule, the amount of temporarily free funds that can be invested is limited. Logically, only a competitive and, therefore, strategically sustainable industrial corporate structure can be considered a dependable recipient (Skobeleva, 2007).

Investment resources, both external and generated at the expense of the industrial enterprise, can be allocated to meet various needs, as in theory, investments are always a contribution to the future development of the corporate structure, i.e. expanded reproduction. Concurrently, the investment prospects of an industrial enterprise can only be considered seriously if strategic management and planning prove effective, as the presence of both indicates the company has sufficient fixed assets, current assets (material resources), human resources and intellectual and technological potential, furthering the development strategy (Laursen et al., 2016). Another important enhancer of company strategy and overall performance is financial, tax and management accounting, because these data provide the grounds for comprehensive decision-making.

As such, the financial indicator dynamics in this research are assessed and case-based on the OOO 'StalNefteMash', though the example enterprise choice is not random, resting on the fact that the company operates in the oil sector, which is vastly exposed to the external environment and has high prospects for attracting funds for digital transformation.

2. Materials and methods

In their assessment, the authors selected the following financial indicators for analysis: growth rates of revenue and net profit and the dynamics of investment attractiveness indicators (EBITDA, EBIT, profitability indicators, etc.) (Magomedov et al., 2020). When considered complex, these indicators enable assessment of the enterprise's current performance and forecasting the future financial indicators based on the price dynamics of one barrel of oil (as OOO 'StalNefteMas' operates in the oil sector). The table below presents data on the growth rate of the enterprise and its revenue for 2018–2021.

Table 1. The revenue of 'StalNefteMash', 2018–2021

Company	Revenue, thd. rub.			
	2018	2019	2020	2021
OOO "StalNefteMash"	48,924	50,166	53,217	76,763
	Growth rate, %			
		2.5%	6.1%	44.2%

Source: (compiled by the author)

Figures 3 and 4 showcase the same growth trends for examples of other indicators.

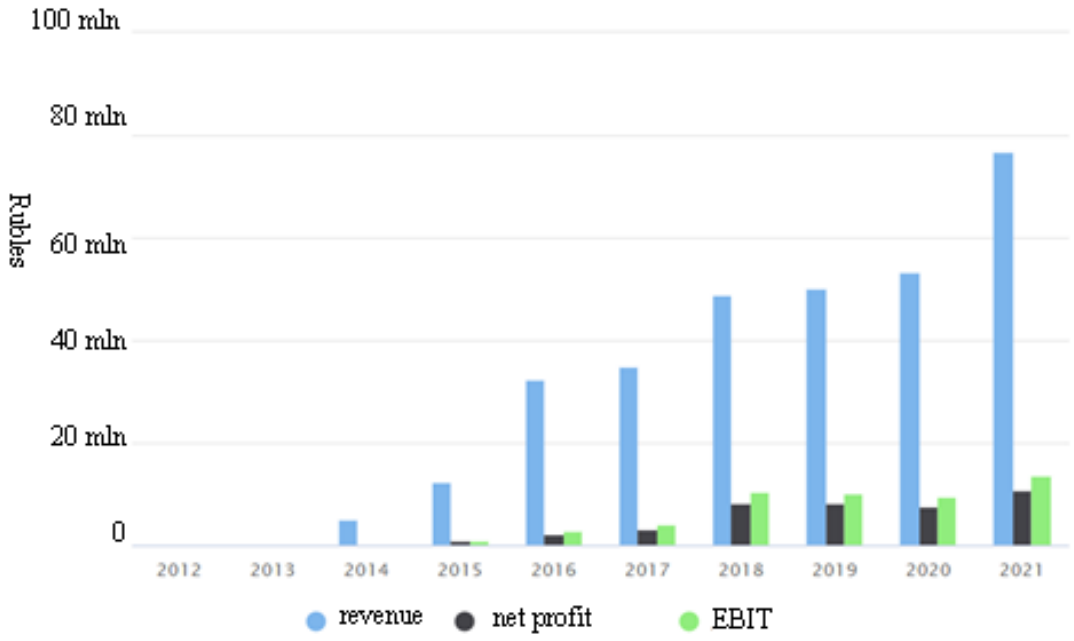

Figure 3. Financial performance of OOO 'StalNefteMash'

Source: (compiled by the author)

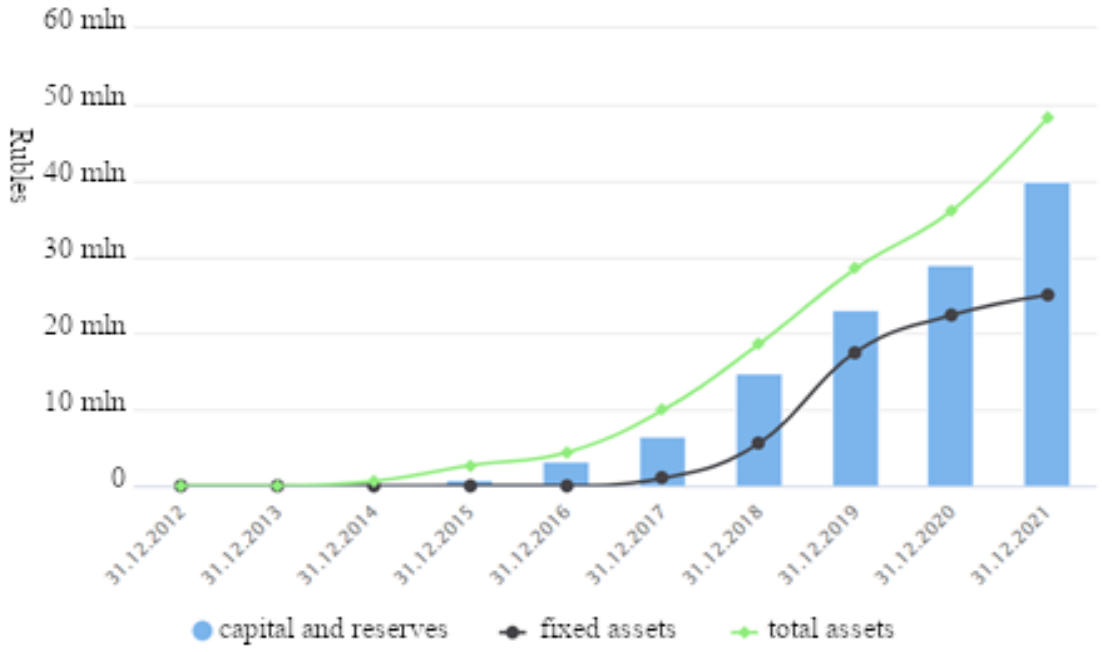

Figure 4. Balance sheet data of OOO 'StalNefteMash'

Source: (compiled by the author)

Table 2. Company net profit and EBITDA

Company	Net profit, thd.rub.			
	2018	2019	2020	2021
OOO 'StalNefteMash'	8,398	8,202	7,598	10,872
	EBITDA, thd.rub.			
	2018	2019	2020	2021
	10,502	10,282	9,531	13,634
	Net profit growth rate,%			
	2018	2019	2020	2021
		98%	93%	143%
	EBITDA growth rate, %			
	2018	2019	2020	2021
		98%	93%	143%

Source: (compiled by the author)

The data presented in Table 2 and Figures 3 and 4 showcase the accelerated business performance and growing financial stability from 2018–2021.

Table 3. Year-end financial and economic indicators of OOO 'StalNefteMash'

Financial indicator	2021	2020	2019	2018	2017	2016	2015	2014
EBIT	13,634	9,531	10,282	10,502	4,087	2,861	1,011	154
Return on sales (profit from sales per each revenue rouble)	18%	18.4%	20.9%	21.5%	11.9%	9.1%	8.1%	3.7%
Return on equity (ROE)	27%	26%	43%	78%	67%	109%	148%	151%
Return on assets (ROA)	26%	23.5%	34.8%	58.7%	45.5%	64.4%	48.5%	37.8%

Source: (compiled by the author)

Based on actual data of the company's performance, it is possible to track the indicators' existing dynamics, thereby enabling the projection of future trends. In addition, the projected value of financial indicators was assessed until the year 2027, and calculations of the projected values were based on the cost per barrel of oil (USD) from 2023–2027, which according to public sources was as follows: 2019, $64.21; 2020, $41.84; 2021, $70.91; and 2022, $85.99. Further, Monetary Policy Report No. 4 by the Central Bank of the Russian Federation (2022) states that the cost per barrel of oil was fixed at US$84.47 in 2023, US$70 in 2024, US$60 in 2025 and US$55 in 2026; meanwhile, for 2027, the authors determined a fixed US$56.

Table 4. Projected financial indicator values, 2019-2027

Figures as of 31 December

Period	2019	2020	2021	2022	2023	2024	2025	2026	2027
Revenue									
Volume (thd. barrels)	781	1,272	1,083	911	911	911	911	911	911
Estimated annual growth rate (%)		62.8%	14.9%	15.9%	-	-	-	-	-
Average cost per barrel of oil (USD)	64.21	41.84	70.91	85.99	100.00	100.00	100.00	100.00	100.00

Sustain. Dev. Eng. Econ. 2023, 4, 2. https://doi.org/10.48554/SDEE.2023.4.2

Estimated annual growth rate (%)		34.8%	69.5%	21.3%	16.3%	-	-	-	-
Total revenue	**50,166**	**53,218**	**76,764**	**78,299**	**91,056**	**91,055**	**91,055**	**91,055**	**91,055**
Cost of finished products	33,278	36,855	45,927	46,846	54,478	54,478	54,478	54,478	54,478
Gross profit	**16,888**	**16,362**	**30,836**	**31,453**	**36,578**	**36,577**	**36,577**	**36,577**	**36,577**
Gross profit (% of total revenue)	33.7%	30.7%	40.2%	40.2%	40.2%	40.2%	40.2%	40.2%	40.2%

Source: (compiled by the author)

Table 4 offers a view of the changes in revenue, gross profit and other indicators if the projected volume is maintained; however, changes in the projected cost per barrel are considered. According to the data, in the event of an oil price decrease, the company's financial indicators will cease to grow significantly, suggesting a logical shift in focus towards innovative development or market share expansion, as the company still has sufficient development potential. For instance, gross profit takes 40% of gross revenue, meaning that with a comprehensive investment policy, the company can achieve a new level.

Table 5 summarises the data from the previously mentioned calculation, demonstrating an average growth rate of 16% in revenue and 10.5% in EBITDA/EBIT for the period to 2022, despite a recorded decline in financial indicators of 8.2%, following declining oil prices.

Table 5. Summarised projected values of financial indicators, 2019–2027

Thd. Rub.

Figures as of 31 December	Actual data				Forecast data					Average growth rate (%)	
	2019	2020	2021	2022	2023	2024	2025	2026	2027	'19–'22	'22–'27
Revenue	**50,166**	**53,217**	**76,763**	**78,298**	**50,992**	**50,991**	**50,991**	**50,991**	**50,991**	**16.0%**	**(8.2)%**
Costs	(33,278)	(36,855)	(45,927)	(46,846)	(30,508)	(30,508)	(30,508)	(30,508)	(30,508)	**12.1%**	**(8.2)%**
Gross profit	**16,888**	**16,362**	**30,836**	**31,453**	**20,484**	**20,483**	**20,483**	**20,483**	**20,483**	**23.0%**	**(8.2)%**
Selling expenses	(436)	(516)	(919)	(937)	(610)	(610)	(610)	(610)	(610)	**29.1%**	**(8.2)%**
Profit after deduction of selling expenses	**16,452**	**15,846**	**29,917**	**30,515**	**19,874**	**19,873**	**19,873**	**19,873**	**19,873**	**22.9%**	**(8.2)%**
Administrative expenses	(5,970)	(6,046)	(16,115)	(16,437)	(14,356)	(16,079)	(18,008)	(20,169)	(22,589)	**40.2%**	**6.6%**
Other expenses	0	0	0	0	0	0	0	0	0	**0.0%**	**0.0%**
10, 482	**9,800**	**13,802**	**14,078**	**5,518**	**3,794**	**1,865**	**(296)**	**(2,717)**	**10.3%**	**(172.0)%**	
Amortisation	(200)	(269)	(168)	(203)	(245)	(245)	(245)	(245)	(245)	0.5%	3.8%
10,282	**9,531**	**13,634**	**13,875**	**5,273**	**3,549**	**1,620**	**(541)**	**(2,961)**	**10.5%**	**(173.4)%**	
Net profit	**8,202**	**7,598**	**10,872**	**11,089**							

Dynamic of indicators

	6.1%	44.2%	2.0%	34.9%	0.0%	0.0%	0.0%	0.0%
20.9%	18.4%	18.0%	18.0%	10.8%	7.4%	3.7%	(0.6)%	(5.3)%
20.5%	17.9%	17.8%	17.7%	10.3%	7.0%	3.2%	(1.1)%	(5.8)%
16.3%	14.3%	14.2%	14.2%					

Source: (compiled by the author)

The data presented in Table 5 shows a significant decrease among EBITDA/EBIT indicators when compared with 2022, if the company does not adjust its current activities and does not seek new development paths.

3. Results

This section of the research is organised in accordance with the statements suggested earlier. Figure 5 below graphically presents the results summarised from Table 5.

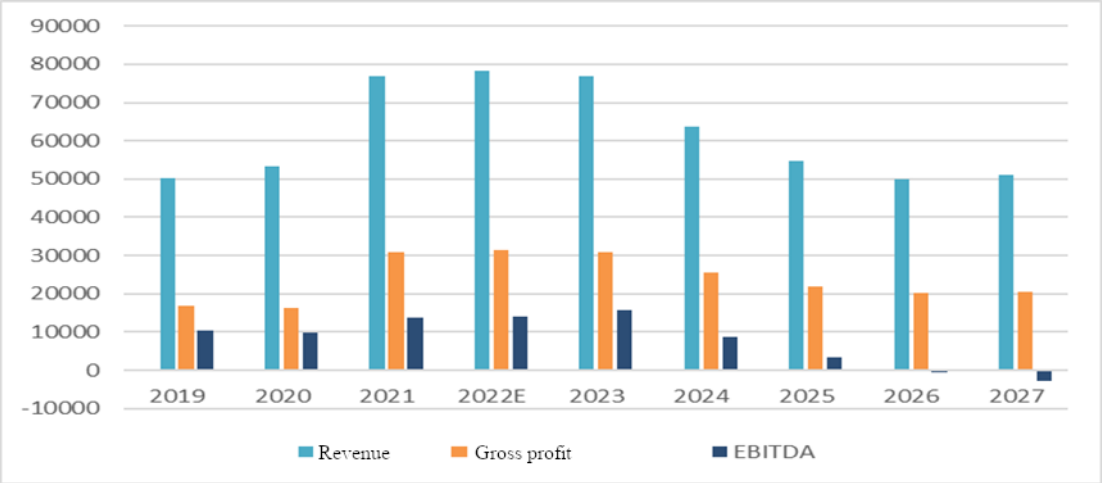

Figure 5. Projected revenue, gross profit and EBITDA indicators, in accordance with the oil price forecast by the Central Bank of the Russian Federation, 2023–2027

Source: (compiled by the author)

Let us analyse the dynamics of the company's financial indicators if the oil price remains at US$100/barrel (Table 6).

Table 6. Summarised forecast values of financial indicators at US$100/barrel, 2019–2027

Thd. Rub.

Figures as of 31 December	Actual data				Forecast data					Average growth rate (%)	
Revenue	2019	2020	2021	2022	2023	2024	2025	2026	2027	'19–'22	'22–'27
	50,166	**53,217**	**76,763**	**78,298**	**91,056**	**91,055**	**91,055**	**91,055**	**91,055**	**16.0%**	**3.1%**
Cost	(33,278)	(36,855)	(45,927)	(46,846)	(54,478)	(54,478)	(54,478)	(54,478)	(54,478)	**12.1%**	**3.1%**
Gross profit	**16,888**	**16,362**	**30,836**	**31,453**	**36,578**	**36,577**	**36,577**	**36,577**	**36,577**	**23.0%**	**3.1%**
Selling expenses	(436)	(516)	(919)	(937)	(1,090)	(1,090)	(1,090)	(1,090)	(1,090)	**29.1%**	**3.1%**
Profit after deduction of selling expenses	**16,452**	**15,846**	**29,917**	**30,515**	**35,488**	**35,487**	**35,487**	**35,487**	**35,487**	**22.9%**	**3.1%**
Administrative expenses	(5,970)	(6,046)	(16,115)	(16,437)	(14,356)	(16,079)	(18,008)	(20,169)	(22,589)	**40.2%**	**6.6%**
EBITDA	**10,482**	**9,800**	**13,802**	**14,078**	**21,132**	**19,408**	**17 479**	**15,318**	**12,898**	**10.3%**	**(1.7)%**
Amortisation	(200)	(269)	(168)	(203)	(245)	(245)	(245)	(245)	(245)	**0.5%**	**3.8%**
EBIT (Operating Profit)	**10,282**	**9,531**	**13,634**	**13,875**	**20,887**	**19,164**	**17,234**	**15,073**	**12,653**	**10.5%**	**(1.8)%**
Net profit	**8,202**	**7,598**	**10,872**	**11,089**							

Indicators Dynamics

Revenue growth rate (%)		6.1%	44.2%	2.0%	16.3%	0.0%	0.0%	0.0%	0.0%
EBITDA Margin	20.9%	18.4%	18.0%	18.0%	23.2%	21.3%	19.2%	16.8%	14.2%
EBIT Margin	20.5%	17.9%	17.8%	17.7%	22.9%	21.0%	18.9%	16.6%	13.9%
Net profit growth rate	16.3%	14.3%	14.2%	14.2%					

Source: (compiled by the author)

In the analysis of the dynamics of financial indicators, according to the table above, the decline in activity is observed to a much lower extent. What is more, for the period from 2022 to 2027, the indicators of revenue and gross profit show an increase of 3.1%; EBITDA/EBIT in this case declines by 1.7–1.8% only.

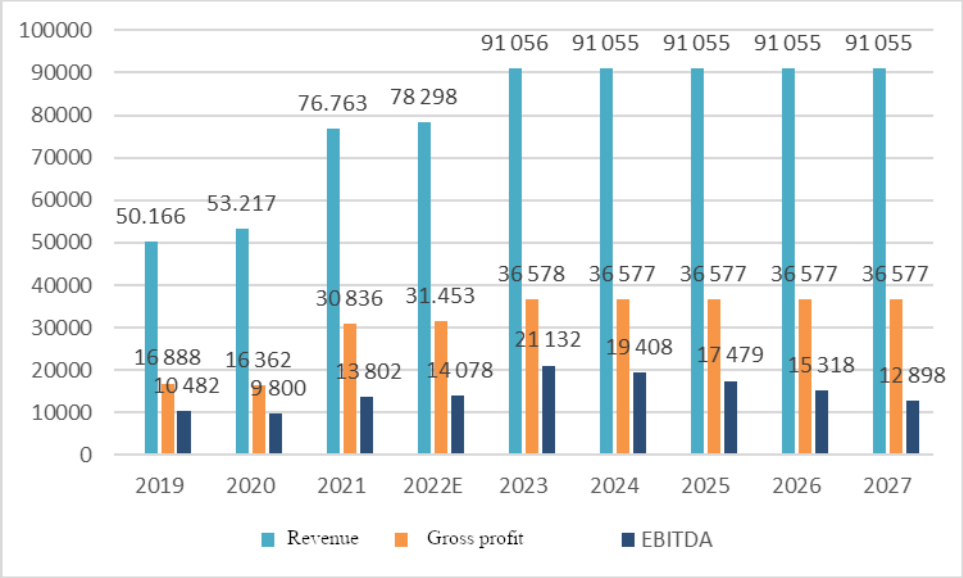

Figure 6. Projected revenue, gross profit and EBITDA indicators, in accordance with the forecast for 2023–2027, at an oil price of $100/barrel

Source: (compiled by the author)

Figure 6 also clearly demonstrates the stability of financial indicators when oil prices are fixed at a specified level. In this research, such an approach is considered promising, but currently, experts primarily tend to expect growth in oil prices due to the ongoing recovery of the Chinese economy. Thus, to assess development prospects in detail, it is necessary to compare the value volume of OOO 'StalNefteMash' in terms of current and potentially possible markets. For instance, according to analytical data, the potential capacity of petrochemistry and oil refining is 1.5 times higher than its current capacity, with an annual average market growth of 20%. Further, calculations based on industry data show the gap between the current market position and the potential market position of OOO 'StalNefteMash', amounting to 55–60%, or 1.14 million roubles in current prices (Fig. 7).

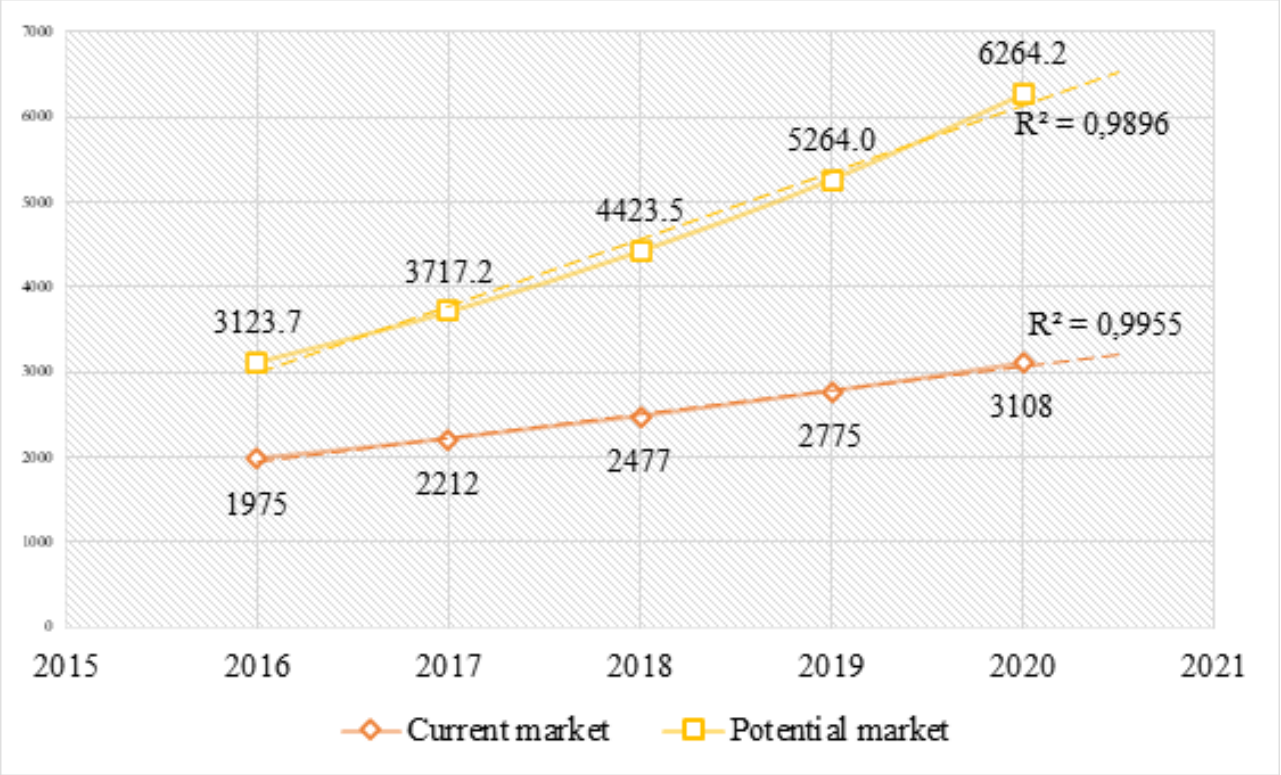

Figure 7. Assessment of opportunities for strategic development of OOO 'StalNefteMash'

Source: (compiled by the author)

The analysis reveals the obvious dependence of the company's financial performance on changes in oil price; what becomes even more apparent is the need for the company to introduce innovations to reduce production costs and increase investment prospects. Overall, the company has a certain potential to expand its market niche.

4. Discussion

OOO 'StalNefteMash' could certainly opt for an aggressive form of development and regain its lost market position; however, it is important to remember that this type of development is a short-term strategy only (Kundytskyj et al., 2019). In the future, it will be necessary to transition to a diversified development strategy to maintain and improve market positions, as well as the economic security of the business model (Bogoviz et al., 2020).

As such, an aggressive strategy would be authentic to the market opportunities and would allow OOO 'StalNefteMash' to broaden its market capacity and boost investment prospects (Shitkina, 2006). Nonetheless, aggressive growth requires a high-quality internal environment and efficiency in its development strategy, both of which are largely supported by the dynamic stability of the adopted business model and positive financial indicator dynamics. This means attracting additional funds and digital technologies can result in a significant positive change (Nabieva et al., 2023), even with the current financial performance and projected values.

The current development strategy of OOO 'StalNefteMash' features the following drawbacks. The first group is associated with management's general inefficiency and, accordingly, corporate strategy failures. Meanwhile, the second is associated with financial and investment strategy inefficiency. As such, the identified problems contradict the range of managerial decisions aimed at improving the internal environment of OOO 'StalNefteMash' to achieve the company's strategic goals. All effective solutions boil down to corporate development management (Vorontsova et al., 2023) and require the company to reduce excessive staff, sell and (or) lease excessive property (fixed assets) and find ways to

increase the exploitation of intangible assets.

Implementation of these measures by OOO 'StalNefteMash' would enable the company to reduce operating activity expenses and, partially, investments, as well as to obtain additional income from the exploitation of intangible assets, thus leading to reductions in the growth rates of expenses for primary (operating) and investment activities. This means that by achieving a balance between income and expense growth rates, the company can increase profitability and self-finance. This also leads to a reduced debt burden via redirecting additional revenues to secure current and long-term liabilities, reduced operating activity expenses and the redistribution of additionally released financial resources to limit current and long-term liabilities.

It is obvious that from the nearest five-year perspective, OOO 'StalNefteMash' demonstrates a high quality of economic growth and, consequently, will develop an elevated level of economic security and sufficient investment prospects. It is also important to note that such dynamic and sustainable development will be possible only if the business model and approach to strategic planning and management are updated—if the necessary funds are allocated and if the price per barrel remains at US$100.

As well, the implemented measures will allow OOO 'StalNefteMash' to stabilise its internal environment and contribute to the dynamic stability of its business model. In this case, the analysis and measures proposed above once again substantiate the statement that the development strategy and management approaches should be coordinated and co-integrated. It is important for strategic management to target specifically measures that would stabilise the company's socio-economic and financial status, as this is the only way to identify growth and development reserves in accordance with the adopted strategic updates.

Another group of co-dependent indicators is represented by development sustainability, economic growth, investment prospects and investment profitability (Susilo et al., 2023). Nevertheless, many researchers emphasise the functional aspects related to management in industrial enterprises. For example, Mironova prioritised the operational aspect as the leading impediment to economic growth, and according to her vision, the excessively long production–operation cycle must be minimised to incentivise advanced economic growth.

However, such an outcome is practically impossible, as much of the production–operation cycle in industry is occupied by unfinished production. Accordingly, to increase productivity and hasten the production process, certain changes must be introduced regularly. An industrial enterprise should constantly increase investments in non-current assets, increase the capital intensity of its activities and maximise economic benefits (primarily revenue from operating activities).

Similarly, Lukasevich singles out another impediment to accelerating turnover in the operating cycle: the need to maintain an optimal (sufficient) stock of resource volumes (raw materials and supplies) to ensure uninterrupted production and sales. The researcher argues this is an optimal solution for the company to minimise its financial cycle. However, this strategy is far from universal, as for large industrial enterprises with external flows of financial, material and other resources, a condensed financial cycle might promote shortages in one or another production area.

5. Conclusion

In 2022, 46 projects based on a public–private partnership were announced in the Republic of Bashkortostan, totalling 47.5 million roubles. Hopefully, when implemented, such a partnership model will spread widely throughout the industry, giving industrial enterprises, in general, the opportunity to invite funds from the external environment to boost their development potential. Therefore, the focus of theoretical and methodological research on investment prospects must shift more towards private investments and practice-oriented models of attraction.

Global development trends should also be tracked carefully by enterprises, including industrial

ones, and modern technologies should be employed in production among industrial enterprises to ensure long-term competitiveness. Moreover, the general development strategy of industrial enterprises should combine the features of Industry 6.0 and potential opportunities for the future with their assessment based on tracking classical financial indicators. Based on the accumulated variety of data, any company can choose one or another type of development strategy, but in this research, an aggressive development strategy was proven the most efficient for the specific conditions of OOO 'StalNefteMash'.

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SECTION 3

SUSTAINABLE DEVELOPMENT OF REGIONAL INFRASTRUCTURE

РАЗДЕЛ 3

УСТОЙЧИВОЕ РАЗВИТИЕ РЕГИОНАЛЬНОЙ ИНФРАСТРУКТУРЫ

Research article

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The External Environment's Influence on RES Development Intensity

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Abstract

The increasing energy consumption associated with scientific and technological progress has led to environmental concerns. The transition to renewable energy sources is a potential solution to mitigate the negative effects of energy consumption. This study's objective is to determine the factors influencing the presence of renewable energy in countries' energy systems and to describe the pattern of their influence. The validated regression model has a high coefficient of determination of 0.9034, indicating the model's reliability in identifying factors influencing the presence of renewable energy in energy systems. The countries were divided into three groups based on their renewable energy usage level using cluster analysis, indicating the importance of the current usage for further development. The study found that the Human Development Index (HDI) is correlated negatively with the share of renewable energy in energy systems. An increase in the innovation index leads to the development of renewable energy. This study allows for an in-depth analysis of the individual countries in the sample and provides meaningful insights into the current state of renewable energy globally. Overall, this research helps to understand the factors influencing renewable energy usage, and the findings can be used to inform policy decisions regarding renewable energy development.

Keywords: renewable energy, regression, cluster analysis, human development index, innovation

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Влияние Внешней Среды на Интенсивность Развития ВИЭ

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Аннотация

Увеличение потребления энергии, связанное с научно-техническим прогрессом, привело к экологическим проблемам. Переход на возобновляемые источники энергии является потенциальным решением для смягчения негативных последствий энергопотребления. Целью данного исследования является определение факторов, влияющих на присутствие возобновляемых источников энергии в энергосистемах стран, и описание характера их влияния. Валидированная регрессионная модель имеет высокий коэффициент детерминации 0,9034, что указывает на надежность модели при выявлении факторов, влияющих на наличие возобновляемых источников энергии в энергосистемах. Страны были разделены на три группы в зависимости от уровня использования возобновляемых источников энергии с использованием кластерного анализа, что указывает на важность текущего использования для дальнейшего развития. Исследование показало, что индекс человеческого развития (ИЧР) отрицательно коррелирует с долей возобновляемой энергии в энергосистемах. Увеличение индекса инноваций приводит к развитию возобновляемой энергетики. Это исследование позволяет провести углубленный анализ отдельных стран в выборке и дает значимое представление о текущем состоянии возобновляемой энергетики в мире. В целом, это исследование помогает понять факторы, влияющие на использование возобновляемых источников энергии, а результаты могут быть использованы для принятия политических решений относительно развития возобновляемых источников энергии.

Ключевые слова: возобновляемая энергетика, регрессия, кластерный анализ, индекс человеческого развития, инновации

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1. Introduction

Humanity's existence is dependent on energy production. Of great interest in the field of energy economics is the relationship between energy use and sustainable development (Khan et al., 2020; Nathaniel et al., 2021; Nawaz et al., 2020). Unfortunately, the increase in energy consumption, led by non-renewable energy sources, has negative environmental impacts (Lv et al., 2021; Wang, 2022). Risks associated with environmental degradation and climate change can in turn affect various aspects of the global economy (Wheeler and Von Braun, 2013; Ye, 2022).

Increasing the share of renewable energy in energy consumption can slow down the negative effects of climate change on the economy (Anwar et al., 2021; Gozgor, 2020). Countries are attempting in various ways, not always successfully (Aguirre and Ibikunle, 2014), to promote RES through policies (Omri and Nguyen, 2014; Shang et al., 2022), financial regulations (Li et al., 2022; Wang and Zhao, 2022) and tax systems (Fang et al., 2022). Despite the impact of the pandemic and rising global commodity prices, the world once again set a record for renewable energy capacity growth in 2021[1].

At the 2021 UN Conference of the Parties serving as the meeting of the Parties to the Paris Agreement, 200 countries signed the Framework Convention calling for accelerating the transition to renewable energy sources and reducing CO_2 emissions by developing more effective strategies in 2022.[2] By the end of 2021, a record number of countries had set zero-emission targets.

The REN21 2022 Global Status Report argues that transitioning from fossil fuels to an energy-efficient economy based on renewable energy sources is a step towards a more affordable, secure and sustainable future[2]. Meanwhile, renewable energy production is highly dispersed across countries, as shown in Figure 1.

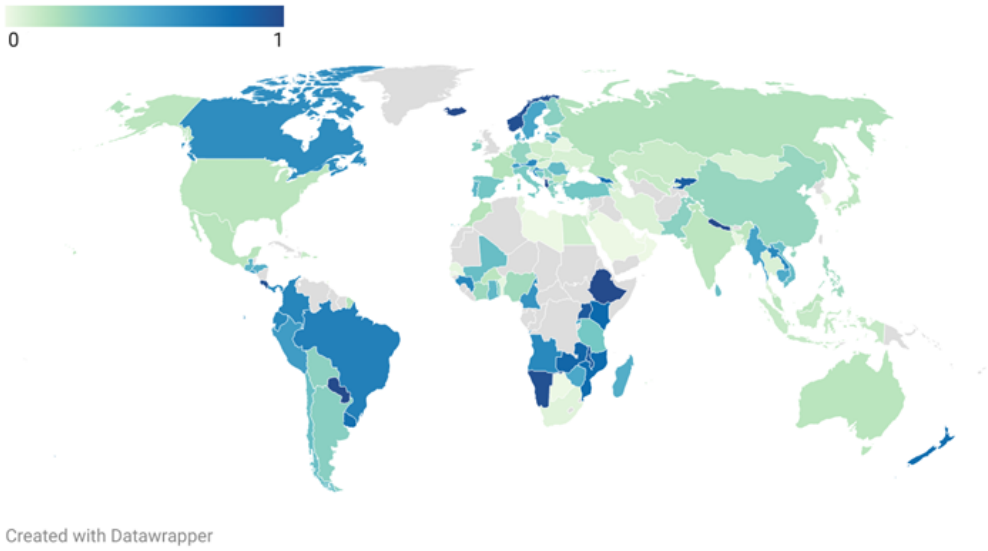

Figure 1. Share of renewable energy, distribution by country.

It is necessary to examine the factors influencing the share of renewable energy in total energy production to understand the trends in renewable energy development. Adjustments were made to the current renewable energy agenda in 2022. In 2014, research showed that respondents were more concerned with environmental threats (rather than security issues) (Sadorsky, 2009), while energy security for fossil fuel-importing countries is now at the top of the list of reasons for promoting renewables[3].

The environmental reasons have not been pressed enough so far. The COP26 convention, the record for zero emissions targets and the record for renewable energy capacity growth in 2021 coexist in the same reality as the record for carbon dioxide (CO2) emissions[3] also set in 2021. Thus, support for

1 Renewables 2022 Global Status Report. URL: https://www.ren21.net/gsr-2022/; Accessed 5 December 2022.
2 Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (2021). URL: https://unfccc.int/sites/default/files/resource/cma2021_L16E.pdf. Accessed 5 December 2022.
3 Renewables 2022 Global Status Report. URL: https://www.ren21.net/gsr-2022/; Accessed 5 December 2022.

renewable energy policies has not been met with the appropriate policies.

Thus, the purpose of this study is to determine the factors affecting the presence of renewable energy in the energy systems of the countries investigated and to describe their influence. This study is significant in its attempt to understand the current state of renewable energy in the world, and it raises questions that could serve as topics for further research.

As energy consumption plays an important role in the existence and development of mankind (Adedoyin et al., 2017), the study of the impact of energy consumption on the economy, progress and ecology occupies a wide niche in the scientific environment (Nawaz et al. 2020; Waheed et al. 2019; Xue et al. 2021). Modern trends make adjustments in the main vectors of such works. More often now the impact of energy consumption is divided (Vo and Vo, 2022), and the impact of traditional (Hussain, et al., 2021) and renewable energy sources (Ehigiamusoe and Dogan, 2022) are considered separately due to the different nature of the impact of these types of energy, for example, EROI (Weißbach, et al., 2013) or the impact on carbon productivity (Adebay, 2022). In addition, the evolution of the energy balance in general (Adams et al., 2018; Shrestha et al., 2022) and the rate of RES adoption (Salim and Rafiq, 2012) are also of interest.

Today's renewable energy sources include[4] hydropower, wind energy, solar energy, geothermal energy, bioenergy and tidal energy; the first three are the most common.

Hydropower can be considered using Russia as an example. At the end of 2020, Russia ranked 5th in the world in terms of energy production by hydropower capacity[4]. Two of the 195 Russian HEPs[5]—Sayano-Shushenskaya and Krasnoyarskaya—are among the 10 largest HEPs in the world; it is the most powerful balancing instrument in Russia's unified energy system and comprises 4.04%[6] of Russian electricity production, with HEP in total covering 20%[7]. At the same time, total RES (HEP excluded) in Russia during 2020 generated 2.194 TWh[4], which is only 0.21% of the produced energy in the country.

Pioneers in RES penetration are Brazil, Canada, Italy, Germany, France and Turkey[6].

The level of renewable energy development for countries is not a definable parameter. It is of interest to researchers as a factor influencing various variables and as a control variable whose influence on factors should be studied.

Considering renewable energy as an influencing factor, the body of research can be divided into groups of studied variables—those related to ecology and those related to economic growth.

CO_2 emissions are often used as an indicator to illustrate the state of the environment. Most researchers agree that the use of renewable energy sources significantly helps to reduce CO_2 emissions and protect the environment (Abbasi et al., 2021; Adebayo et al., 2022; Adebay, 2022; Balcilar et al., 2020; Wang et al., 2022).

Research on the impact of renewable energy on economic growth is less clear (Wang et al., 2022). An analysis of the impact of renewable energy consumption on economic growth using data from OECD countries for the period 1990–2010 found that for every one percentage point increase in renewable energy consumption, the economy grows by 0.105% (Inglesi-Lotz, 2016). In contrast, consuming renewable energy in 27 EU countries has hurt economic growth, explaining the reasons for Europe's poor performance in terms of climate impact (Sharma et al., 2021). Studies on the performance of emerging economies from 1992–2014 found no significant effect of renewable energy consumption on economic growth (Bayar, Y., Gavriletea, M. D., 2019). The above results show that renewable energy consumption can limit the growth of carbon emissions, but the impact of renewable energy consumption on economic growth is inconclusive (Wang et al., 2022).

The reasons for this inconsistency in the relationship between renewable energy consumption and

4 Renewables 2021. Global status report, REN21. URL: https://www.ren21.net/wp-content/uploads/2019/05/GSR2021_Full_Report.pdf. Accessed 1 December 2022.
5 Annual report on the activities of the "NP Market Council" association '20. URL: https://www.np-sr.ru/sites/default/files/1_go_itog.pdf. Accessed 1 December 2022.
6 RusHydro http://www.rushydro.ru. Accessed 1 December 2022.
7 Russian energy 'NP Market Council' association. https://www.np-sr.ru/ru/market/cominfo/rus/index.htm. Accessed 1 December 2022.

economic development have also been highlighted in the scientific literature. Some researchers attribute the divergent effects to the existence of a threshold for renewable energy consumption. When renewable energy production and consumption are below the threshold, renewable energy consumption is of little importance for economic development. Renewable energy indicators above the threshold will positively affect economic growth (Ozcan and Ozturk, 2019; Samoilova, 2022). There are also assumptions about the relationship between the impact of renewable energy on the economy and the degree of the country's dependence on non-renewable energy sources. If the country's non-renewable energy contributes most to economic growth, if it is available and relevant, the relationship between economic development and renewable energy will be weak (Dogan, E., Altinoz, B., Cohen, Y., Taskin, D., 2020).

In identifying the factors influencing renewable energy as a target variable, researchers operate on a broader spectrum, affecting the indicators characterising all the major spheres of society. The groups of factors can be summarised along the following broad lines: economic, environmental, social, political and technological.

Among economic indicators, GDP growth rate and GDP per capita are most often considered; in the economic models of the International Energy Agency, GDP growth rate is the main factor of energy demand. CO_2 emissions (which belong to the group of environmental indicators) are often included in the studied model due to their close relationship with GDP and the economy. Studies of renewable energy consumption in the G7 (Sadorsky, 2009) and E7 (Wang et al., 2022) countries have shown that, in the long run, the increase in real GDP per capita and carbon dioxide emissions per capita are the main factors determining the per capita consumption of renewable energy sources. A study of six major emerging economies—namely Brazil, China, India, Indonesia, the Philippines and Turkey, which are actively accelerating the transition to renewable energy—found similar results: a 1% increase in GDP leads to a 1.228% increase in renewable energy consumption, while a 1% increase in pollutant emissions leads to a 0.033% increase in renewable energy consumption (Salim and Rafiq, 2012). In contrast, a study of EU countries found that increases in CO_2 emissions constrain the development of renewable energy (Marques et al., 2010). Using data separately for the US, economic growth is ineffective in stimulating renewable energy (Shang et al., 2022).

At the intersection of economic and social variables, the level of income is considered an influencing factor; in different samples of countries, its positive impact on RES was found (Marques et al., 2010; Omri et al., 2014; Rodionov et al, 2022; Sadorsky, 2009; Shrestha et al., 2022).

Another economic factor with a political and social dimension is economic openness. Trade openness hurts the development of renewable energy in ASEAN countries, whereas foreign direct investment positively affects it (Huang et al., 2022).

The interest in energy security (i.e., energy independence) resonates with the openness of the economy in terms of the breadth of connections in the factor fields. The energy security indicator is significant for developing renewable energy in EU countries (Marques et al., 2010). Global sample analysis (Omri et al., 2014) shows no impact of energy security problems on renewable energy; on the contrary, it emphasises the importance of public interest in environmental protection. In the example of ASEAN countries, environmental degradation causes the reduction of renewable energy (Huang et al., 2022).

A study of the effect of flexibility in policy priorities on the rate of renewable energy deployment in the EU finds a threshold effect for greenhouse gas emissions, suggesting that public awareness of climate change can only positively affect renewable energy up to a certain level (Oosthuizen and Inglesi-Lotz, 2022). Nevertheless, public opinion as a factor—in one interpretation or another—is given serious attention. A social study conducted in Vietnam shows that respondents concerned about air quality and utility profitability support increases in energy tariffs in case of transition to RES, which can lead to renewable energy development (Yu et al., 2022).

A study of renewable energy impact indicators in the US found that social interests play a primary role in state adoption of clean electricity policies. Population characteristics—as reflected in levels

of participation in environmental advocacy groups, income levels and education levels— appear to be determinants of state clean power policies (Vachon and Menz, 2006). A study of the 53 most hydropower-consuming countries also found that human capital has a stronger significant impact on renewable energy than on non-renewable energy consumption (Ponce et al., 2020).

The influence of the political environment stands out as a factor. Uncertainty about climate policy has a positive effect on the use of renewable energy but only marginally, suggesting that any climate change mitigation policy in the US does not encourage people to use clean energy (Rodionov et al., 2022; Shang et al., 2022). Some government policies discourage developing renewable energy (Aguirre and Ibikunle, 2014), which may indicate poor management or competent political lobbying by traditional non-renewable energy industries (Omri and Nguyen, 2014). In the case of EU countries, lobbying for non-renewable energy industries also hinders introducing renewable energy (Marques et al., 2010).

An attempt has been made to assess the relationship between US public policies promoting and developing renewable energy. The results are ambiguous: no relationships were found. In several states promoting renewable energy policies, there is some progress. One of the most promising ideas is that green energy policies should control the share, volume and growth of renewable energy in the state's energy system and the amount of non-green energy purchased from neighbouring states (Carley, 2009).

Political factors are also used to cluster countries. For example, the influence of democratic institutions on the development of renewable energy has been studied; in countries with a higher level of democracy, the development of RES is positively influenced by economic growth, while rising oil prices and increased trade openness in renewable energy are neutral factors. In less democratic countries, economic growth hurts the development of RES, and this influence is exacerbated by the negative impact of increasing economic openness and rising oil prices (Chen et al., 2021; Rodionov et al., 2021).

An empirical analysis of the influence of political factors on using renewable energy in the EU has shown that lobbying in the manufacturing industry hinders the development of renewable energy, standard indicators of governance quality have a positive effect, and left-wing parties have a more positive effect on renewable energy than right-wing parties (Cadoret and Padovano, 2016).

Studies have paid particular attention to normative regulation. For example, China is now actively developing a system of green finance. Introducing green finance positively affects the volume of investment in renewable energy. At the same time, indirectly, developing green finance hurts non-green finance, which implicitly creates a secondary negative effect of green financial instruments on renewable energy (Wang and Zhao, 2022). However, the study of the impact of financial inclusion on green finance confirms the relationship but defines it asymmetrically and heterogeneously (Sadorsky, 2009). In the Belt and Road Initiative countries, a 1% increase in the green tax would lead to a 1.201% increase in renewable energy consumption (but the effect is non-linear) (Fang et al., 2022).

A study of technology's impact on renewable energy growth through economic development showed that high-tech exports and GDP determine renewable energy production in developed countries; however, high-tech exports are not statistically significant in explaining the use of energy sources in developing countries. GDP and CO2 emissions are the main drivers of RES production in developing countries (Bamati and Raoofi, 2020). A higher degree of economic globalisation also contributes to the demand for renewable energy in developed countries (Gozgor et al., 2020; Rodionov et al., 2022).

In one way or another, clustering is becoming one of the main techniques for dealing with global samples of renewable energy data. The heterogeneity between countries in the stages of the implementation process and the role of renewable energy in influencing economic growth is confirmed by research (Shahbaz et al., 2020). Studies have examined the influence of using renewable energy on its further expansion. In the groups of countries with similar indicators of the level of development of renewable energy, there are no significant differences in the rate of further development; however, the difference in the rates increases significantly when comparing countries belonging to the groups with different levels of renewable energy expansion (Li et al., 2022).

Thus, in the studied theoretical array, the following variables can influence RES: GDP, CO_2 emissions, income level, economic growth, trade openness, energy security, environmental protection, political uncertainty, lobbying of traditional energy sources, democratic institutions, globalisation, green finance, financial accessibility and technological development.

2. Materials and Methods

The following indicators are used for the research. The HDI[8] based on three indicators (GDP at PPP, life expectancy and literacy rate) will serve as a composite reflection of the social environment in the model.

Two indicators are used to reflect technological development: the global innovation index[9] and the index of development of information and communication technologies (ICT)[10]. The first is more detailed and informative; the second contains fewer variables. It is assumed that both indices will be included as factors in the model, even though they partially overlap, and the most significant one will be used on the optimized equation.

It is also assumed that the share of non-renewable energy sources in the world reserves[11] by country is a significant indicator of the development of RES, partly explaining the energy dependence/independence of the country and the prospects of its energy efficiency and economic growth.

To understand the information environment, which is an important factor in describing the state of society today, we will use Google Trends data[12], the presence of RES topics in internet queries (as a factor of interest) and the presence of RES topics in the news (as a factor of coverage).

For the control values, despite their presence in the HDI, we will use GDP per capita[13] to test the hypothesis of the non-influence of other GDP factors.

The actual indicator reflecting the presence of RES is an index obtained by weighing the amount of electricity produced from renewable sources against the total amount of energy produced.

The resulting equation (1) contains 7 variables (x_i):

$$y = c + a \times x_1 + a \times x_2 + a \times x_3 + a \times x_4 + a \times x_5 + a \times x_6 + a \times x_7 \quad (1)$$

Table 1 summarises the data on the indicators.

Table 1. A summary array of indicators

Indicator	Designation	Source
RES	y	EES EAEC. World Energy (Electronic resource)[14]
Share in world reserves of traditional energy sources	x_1	EES EAEC. World Energy (Electronic resource)[14]
HDI	x_2	HDI (Electronic resource)[15]
GDP per capita, $	x_3	Rating of countries by GDP (Electronic resource)[16]

8 HDI. URL: https://nonews.co/directory/lists/countries/index-human. Accessed 8 November 2022.
9 Global Innovation Index. URL: https://nonews.co/directory/lists/countries/global-innovation-index. Accessed 17 November 2022.
10 GtMarket ICT Development Index. URL: https://gtmarket.ru/ratings/ict-development-index/. Accessed 10 December 2022.
11 EES EAEC. World energy industry. URL: https://www.eeseaec.org/ees-eaec-мировая-энергетика. Accessed 8 November 2022.
12 Google Trends. URL: https://trends.google.ru/trends/?geo=RU. Accessed 17 November 2022.
13 GDP ranking. URL: https://nonews.co/directory/lists/countries/gdp. Accessed 17 November 2022.
14 EES EAEC. World energy industry. URL: https://www.eeseaec.org/ees-eaec-мировая-энергетика. Accessed 8 November 2022.
15 Human Development Index (HD). URL: https://nonews.co/directory/lists/countries/index-human. Accessed 8 November 2022.
16 GDP ranking. URL: https://nonews.co/directory/lists/countries/gdp. Accessed 17 November 2022.

ICT Development Index	x_4	Information and Communication Technology Development Index—Humanitarian Portal (Electronic resource)[17]
Global Innovation Index	x_5	Rating of countries on the level of innovation (Electronic resource)[14]
Presence in the news	x_6	Google Trends (Electronic resource)[18]
Presence in Google search	x_7	Google Trends (Electronic resource)[18]

Hypothetically, the share of traditional energy sources in the world's reserves would have a negative impact because the higher the share, the more energy secure and energy efficient the country is.

HDI would have a negative impact because as people's quality of life increases, their energy costs increase, which can be offset more cheaply with non-renewable energy sources.

GDP would have a positive impact, as investment in RES is directly related to the availability of money in the economy.

ICT/GI would have a positive impact on renewable energy, as technological progress contributes to the improvement and reduction of the price of the equipment necessary for the introduction and development of renewable energy.

Interest would also have a positive influence, based on the analysis of the theoretical basis, as public opinion is statistically significant for RES development.

Coverage, potentially reducing interest, would in turn have a negative effect.

Figure 2 shows a working conceptual model. It assumes the influence of 7 variables on the indicator reflecting the phenomenon under study—electricity production by RES, weighted by total electricity production.

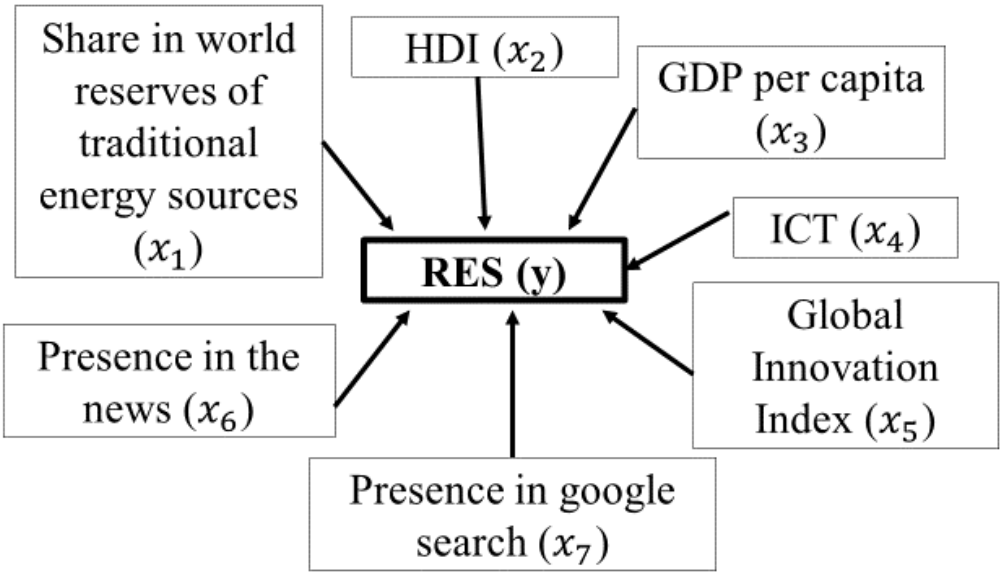

Figure 2. Hypothetical conceptual model

The model was tested for the absence of linear relationships. We then tried to build a significant re-

17 ICT Index – Humanitarian portal. URL: https://gtmarket.ru/ratings/ict-development-index. Accessed 17 November 2022.
18 Google Trends. URL: https://trends.google.ru/trends/?geo=RU. Accessed 17 November 2022.

gression model (in the framework of this study p<0.3 and R>0.6). An equation meeting our requirements was not obtained at the initial stage with the initial sample.

We then divided the data set into clusters, sequentially—by the share of resources, HDI and ICT. The clusters considered did not significantly improve the model.

The research is limited to a sample of 179 countries.

3. Results

Initial analysis of the data did not yield meaningful results. As a result, we therefore used KNIME cluster analysis methods. The sample was divided by RES(y) into three correlated clusters. Figure 3 shows a world map with the resulting distribution of countries by cluster.

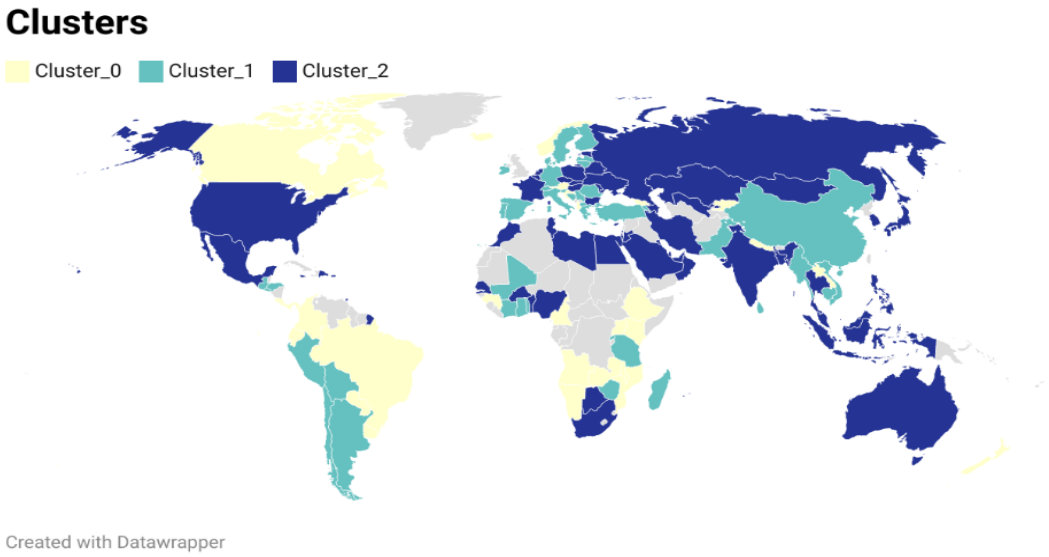

Figure 3. Country cluster distribution

The zero cluster included the countries with the highest indicators of RES; the first cluster included the average values, and the second cluster included the lowest.

The following equations were obtained for clusters 0, 1 and 2, respectively:

$$y_0 = 0,8868 - 0,2306x_2 + 0,0024x_5 + 2,51\times10^{-5}x_7 \quad (2)$$

$$y_1 = 0,4466 - 0,2306x_2 + 0,0024x_5 + 2,51\times10^{-5}x_7 \quad (3)$$

$$y_2 = 0,1607 - 0,2306x_2 + 0,0024x_5 + 2,51\times10^{-5}x_7 \quad (4)$$

The significant variables in the equations remain x_2, x_5, x_7. They explain the variance of RES (y) by 0.9034 (coefficient of determination) (i.e. 90%).

A 1% increase in the HDI (x_2) causes the RES (y) to decrease by 0.2306%. A 1% increase in the innovation index (x_5) leads to a 0.0024% increase in RES (y). Interest in RES topics (x_7) has a weak positive effect on RES (y)—a 1% increase is associated with a 2.51×10^{-6} percent increase in RES (y).

Figure 4 shows the relationship between theoretical and actual values. In the figure, we can see the cluster division.

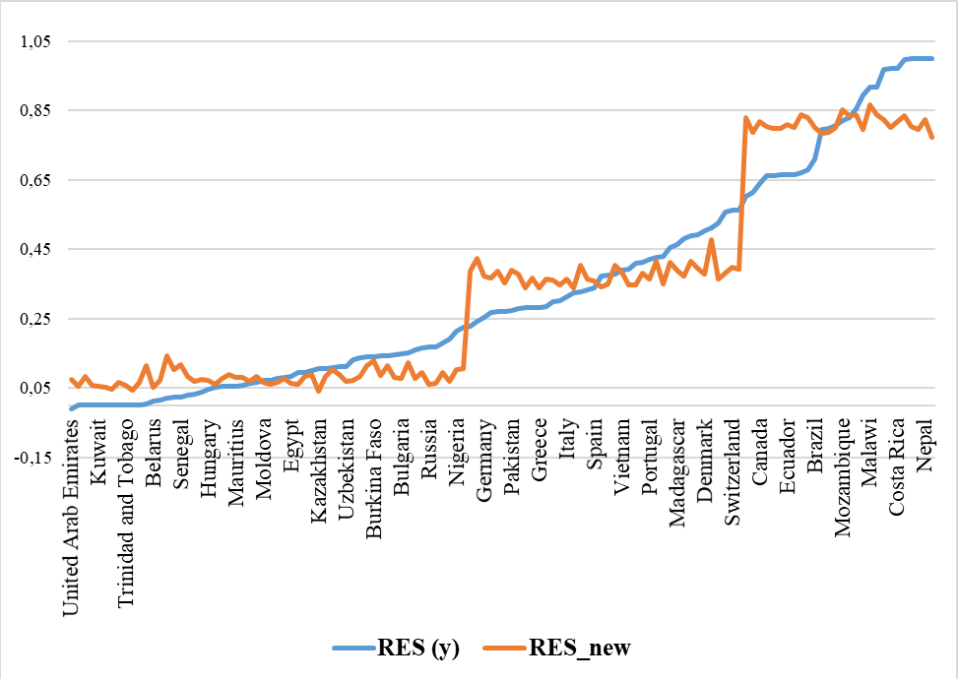

Figure 4. Actual and calculated values of RES (y)

Figure 5 (residuals not described by the model) shows the difference between the control values and the calculated values, distributed by the actual values of the indicator.

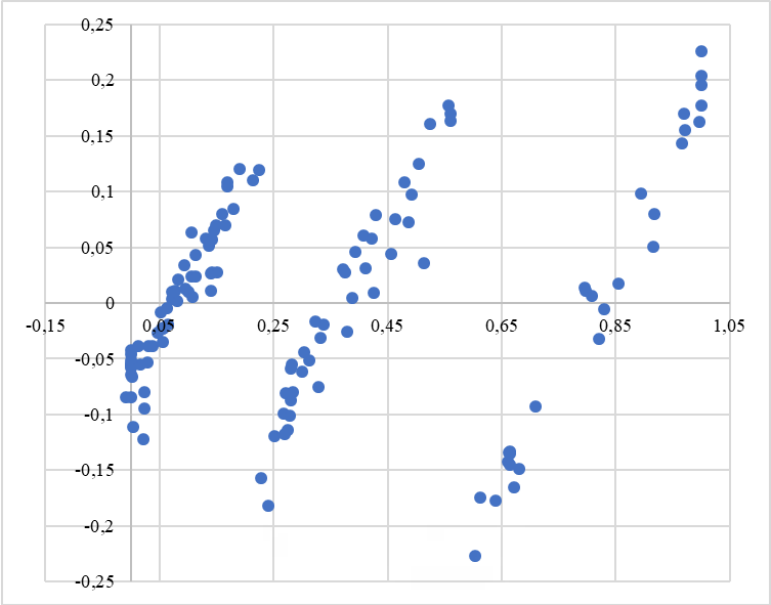

Figure 5. Residuals between the initial and calculated indicators

Figure 6 shows the ratio of the lower and upper bounds of the elasticity coefficient for the indicators of the confirmed model. Accordingly, the closer the bounds of the indicator's elasticity coefficient are to each other, the more we can interpret its impact on the result.

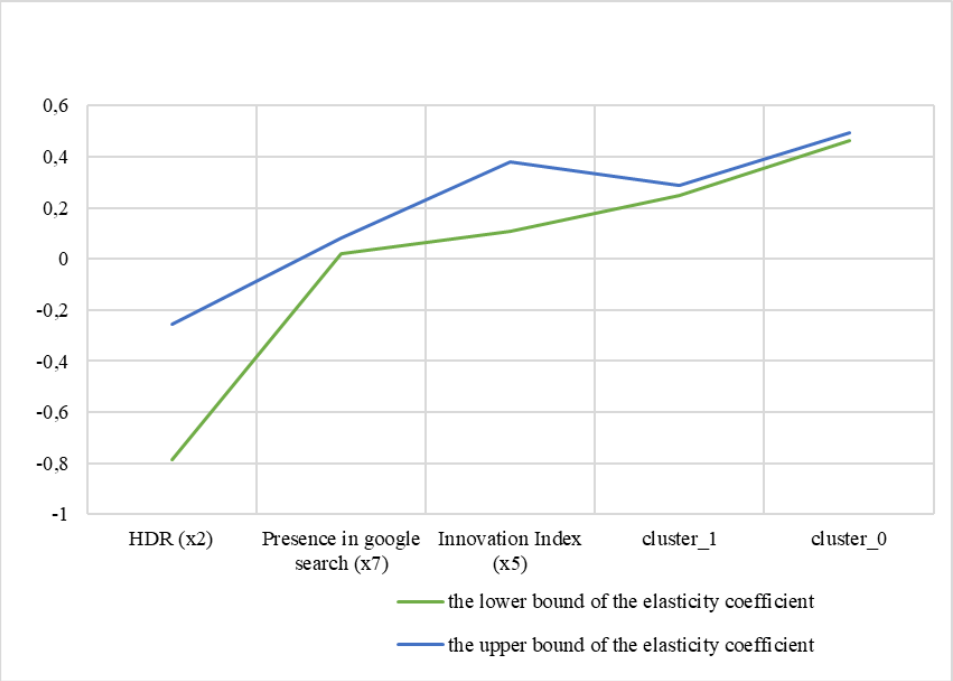

Figure 6. Elasticity bounds

Figure 7 shows the validated conceptual model. Of the 7 variables considered, the influence of 3 variables on the indicator under study—HDI, Global Innovation Index and interest—has been proven.

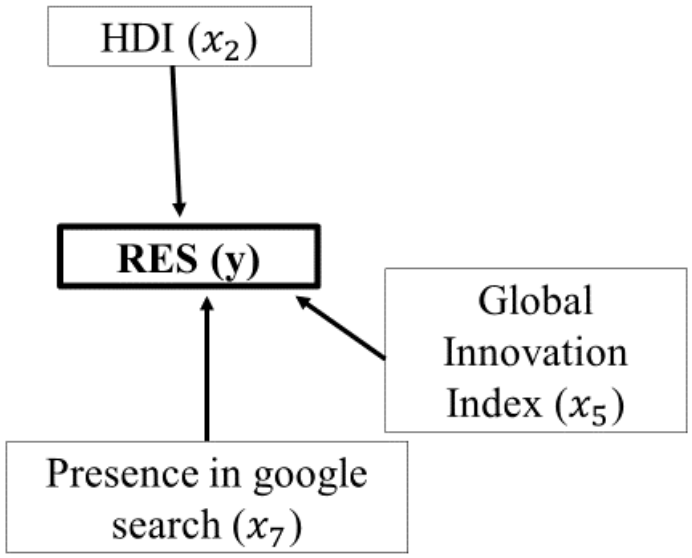

Figure 7. Validated conceptual model

4. Discussion

Three of the six proposed hypotheses were not justified; the statistical significance of their reference indicators was not proven. Of the two indices determining technological development as it was conceived, the more significant remained in the model: the Global Index of Innovation. Thus, we have confirmed the following hypotheses:

1. HDI has a negative impact;

2. The Global Innovation Index has a positive impact;

3. The interest rate also has a positive impact.

HDI's negative impact on RES can be explained by the fact that its growth directly leads to an

increase in energy costs; each of the three indicators used to calculate the HDI confirms this (i.e., life expectancy, the longer a person lives, the more energy is consumed; the education coverage rate, the more people study, the greater the total energy consumption for education; and GDP at PPP does not need any comment). This surplus of energy costs must be covered by additional energy; non-renewable energy often wins here both in terms of economic efficiency and energy availability (Weißbach et al., 2013).

Such reasoning, however, is far from obvious. And from the point of view of the studied theoretical material, an alternative logical chain emerges. If a country has a higher level of human development, then society should be more involved in global problems (e.g., environmental problems) and promote green energy policies (Ponce et al., 2020; Vachon and Menz, 2006; Yu et al., 2022). The will of the people should also have more power in such countries, since the more developed a person is, the more difficult they supposedly are to manage—that is, such a society can seriously influence environmental policy.

Why, then, does the indicator reflect the HDI with a negative coefficient value in the resulting model? First, the tendency of the RES indicator to decrease as the HDI increases does not mean that the absolute values of RES are decreasing, as it only shows the relative values. Second, a study's results on the determinants of RES growth (Aguirre and Ibikunle, 2014) show that countries are likely to reduce their commitment to renewable energy sources under energy supply pressure. At the same time, the authors also argue that if the cost of using fossil fuel generators becomes high enough due to creating emission-limiting conditions, renewables will become competitive without the need for any other policy support mechanism.

The positive correlation between the Global Innovation Index and RES is explained by technological development, which stimulates energy production methods, promotes alternative sources and increases the efficiency of traditional sources. The increase in the innovation index indicates the growth of knowledge-intensive human activity, which allows renewable energy to become more relevant.

Based on the value of the HDI coefficient, why, according to the HDI's logic, the innovation index does not hurt the model? An increase in innovativeness and living standards logically implies an increase in energy costs.

The Global Innovation Index is calculated based on 81 indicators[19]. It consists of two subindices: the innovation costs and the innovation results. Each contains several blocks of data. The innovation costs subindex includes indicators weighted to reflect the following areas: institutional structure of the economy, human capital and research, infrastructure, market sophistication and business sophistication. The innovation output subindex is based on knowledge, technology and creative output.

Developing the potentially positive development indicators included in these blocks requires increasing energy consumption. However, the infrastructure block (innovation cost subindex) includes a coefficient based on the average value of electricity generation. The model's RES index is weighted by electricity production. Therefore, the net increase in innovativeness—reflecting only technological improvement—positively affects diffusing renewable energy.

The results on the presence of renewable energy in the Internet queries, reflecting the population's involvement in the issue of renewable energy, correlate with the results of previous studies (Oosthuizen and Inglesi-Lotz, 2022; Ponce et al., 2020; Vachon and Menz, 2006; Yu et al., 2022). As the population becomes more interested in producing electricity from renewable sources, the RES share in the energy system increases a little (1% of interest, 2.51×10^{-5} % RES), indicating the complexity of the implementation system.

Difficulties accompanying the implementation can partially explain the resulting division into clusters. The cluster division of the data set—carried out by the RES indicator (i.e., by the y-value of the model)—gave significant results within this study's framework. This indicates the fundamental importance of the current level of presence of renewable energy in the energy system for predicting this

19 Global Innovation Index. URL: https://nonews.co/directory/lists/countries/global-innovation-index. Accessed 17 November 2022.

indicator by the model.

Our data set was divided into three clusters. Cluster 0 included the countries with the highest indicators of RES development. Figure 8 shows the countries in cluster 0.

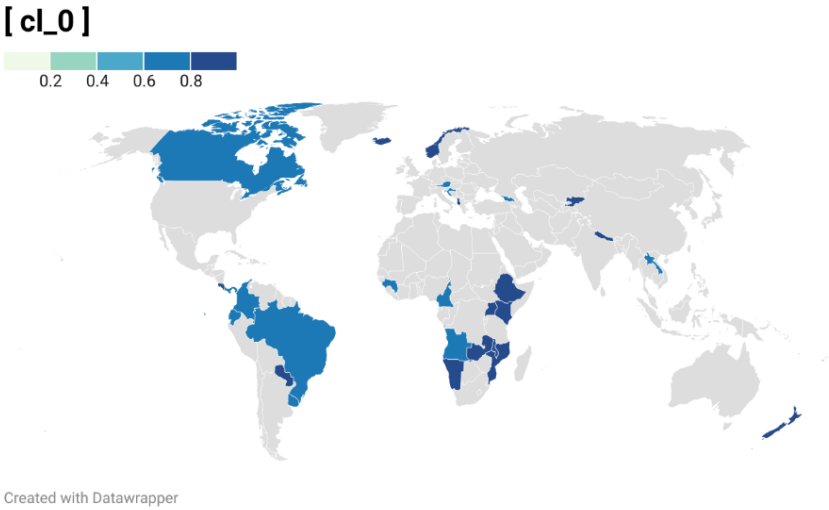

Figure 8. RES development in cluster 0 countries

Cluster 0 includes countries that collectively or individually lack natural fossil fuels, are unable to purchase them, have low total electricity generation, have highly developed green energy policies or have high potential for implementing renewable energy sources.

The countries in the 2nd cluster, assigned to the middle of the data set on the RES development indicator, are visualised in Figure 9.

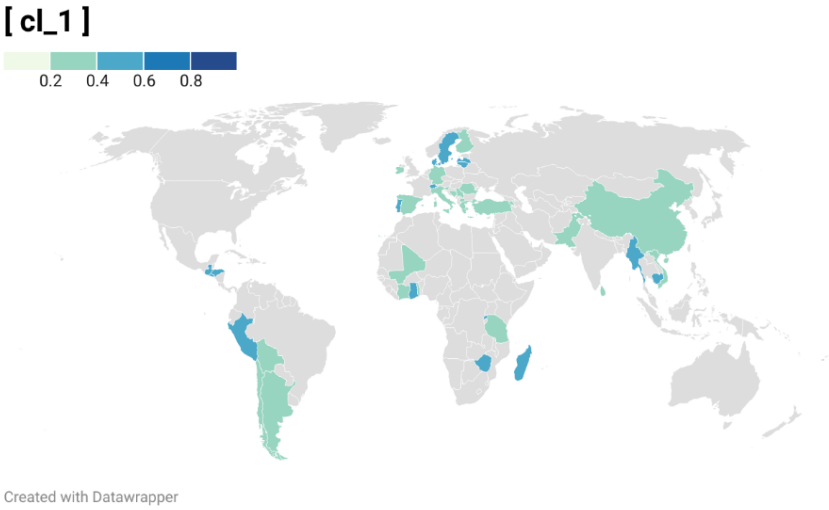

Figure 9. RES development in cluster 1 countries

Cluster 1 comprises countries with favourable economic and geographic conditions for RES development, EU countries supporting the policy of introducing renewable energy, countries satisfied with a low level of electricity generation and China, which is characterised by a high rate of information, policy and technological implementation of RES.

Figure 10 shows the countries with the lowest level of RES presence.

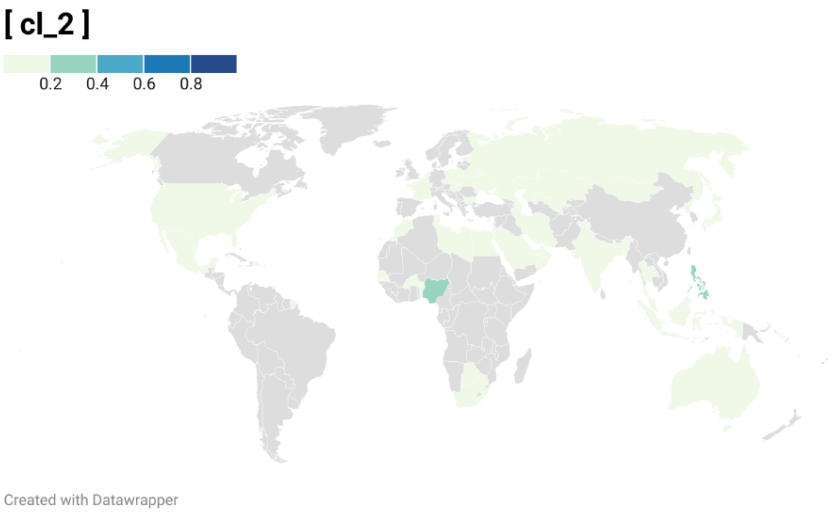

Figure 10. RES development in cluster 2 countries

Countries in cluster 2 include those with the largest quantities of fossil fuels, those with the financial capacity to purchase resources on a large scale and those with a catastrophic need for large-scale power generation but no capacity.

Thus, developing renewable energy is an atypical process, which is currently not a necessary growth stage. Therefore, the clusters of countries when trying to describe unambiguously by indicators of third-party RES may not be obvious. The current level of renewable energy should be considered as a factor reflecting that the country has already adopted a certain RES functionality, which is now being improved in pace, scale and parameters, partially explained by the rule common to the model.

5. Conclusions

This paper examines the influence of several variables on the share of renewable energy in the countries' energy industries. It analyses the relationship between fossil fuel reserves and the share of renewable energy, the impact of technological and human development on green energy policies and the correlation between public interest, news coverage and the share of renewable energy. The conceptual model uses the HDI, the Global Innovation Index, the Information and Communication Technology (ICT) Development Index, GDP per capita and the presence of renewable energy in Google searches and news coverage as explanatory variables. The dependent variable is the share of electricity produced by RES in total electricity production. That is, the causal relationship between the global position of countries and their participation in renewable energy is examined. The following conclusions are drawn:

1. The HDI hurts the development of RES, which is explained by the increase in energy and economic costs.

2. The Global Innovation Index has a positive impact, contrary to the logic of the impact of the HDI, which is due to the presence of weighted data on electricity production in the indicator.

3. The interest indicator also has a positive (but small) correlation with the outcome variable, which is conceptually consistent with previous research on the importance of public opinion.

Cluster membership (in terms of RES(y)) has the greatest impact on the resulting model. This means that renewable energy is heterogeneously distributed in the world. The current improvement, according to the stages of development, occurs at almost equal rates. But the initial data, which are polarly different, and the reasons for the initial differences are cost-effective or unprofitable for renewable energy economic and geographic conditions; a favourable or unfavourable position in terms of fossil fuels, the climate, higher or lower energy requirements and the country's level of development are also reflected in the amount of energy required.

So far, renewable energy has not become vital compared to non-renewable energy. Therefore, its diffusion is not so large. Perhaps, in the future, when coal, oil and gas are exhausted and the issue of RES transition becomes more urgent, the transition to renewable energy will be—not unlike the Industrial Revolution—an energy revolution, marking, for each country, a new stage of development.

The results give an idea of the functioning of RES in the world today—within the limitations of the 179-country sample. Further research is recommended using narrow groups and chronological data, specifying more substantially the level of development of renewable energy in the systems of interest to the researcher.

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A Methodology for Assessing the Harmonisation Level of Industrial and Trade Policies

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Abstract

The paper examines the existing approaches to developing a methodology for determining the level of policy harmonisation. The author suggests a methodology based on the rating method for assessing the level of harmonisation of the components of the industrial and trade policy of St. Petersburg at the institutional level. A scale for quantitatively and qualitatively assessing the harmonisation of industrial and trade policies at the institutional level has been developed. An assessment of the harmonisation of institutional support for industrial and trade policies of St. Petersburg at the federal and regional levels was made. The author developed criteria for harmonising industrial and trade policies which are based on the mutual orientation of the goals and objectives of industry and trade development, the comprehensiveness and systematic use of support measures and the effectiveness of the pursued policies. The principles of uniformity, goal setting, consistency, rationality and mutual socio-economic conditionality can be used to harmonise the industrial and trade policies of the constituencies of the Russian Federation. To assess the level of harmonisation of industrial and trade policies, the indicator of the 'the share of locally produced goods in the region's trade turnover' has been proposed and a scale of qualitative characteristics of the level of harmonisation has been developed. The author suggests a list of indicators for assessing the socio-economic effect of the harmonisation of St. Peterburg's industrial and trade policies based on the light industry sector.

Keywords: methodology for assessing harmonisation, policy harmonisation, trade policy, industrial policy, institutional support for industrial and trade policy, light industry

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Методика Оценки Уровня Гармонизации Промышленной и Торговой Политики

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Аннотация

В статье рассмотрены существующие в современной литературе подходы к разработке методики определения уровня гармонизации проводимой политики. Предложена авторская методика оценки уровня гармонизации компонентов промышленной и торговой политики региона (г. Санкт-Петербурга) на институциональном уровне, на основании бально-рейтингового метода. Разработана шкала количественной и качественной оценки уровня гармонизации промышленной и торговой политики институционального уровня. Проведена оценка гармонизации институционального обеспечения промышленной и торговой политики Санкт-Петербурга федерального и регионального уровня. Сформулированы критерии гармонизации промышленной и торговой политики, заключающиеся во взаимной ориентации целей и задач развития промышленности и торговли; комплексности и системности использования мер и инструментов поддержи; результативности проводимой политики. Определены принципы гармонизации промышленной и торговой политики, состоящие во единообразии, целеполагании, согласованности, рациональности, взаимной социально-экономической обусловленности, экономическом эффекте для бюджета субъекта Российской Федерации. Для оценки уровня гармонизации, реализуемой промышленной и торговой политики, предложен показатель «удельный вес товаров собственного производства в товарообороте региона» и разработана шкала качественной характеристики уровня гармонизации. Предложен перечень показателей оценки социально-экономического эффекта гармонизации промышленной и торговой политики Санкт-Петербурга на примере отрасли легкой промышленности.

Ключевые слова: методика оценки гармонизации, гармонизация политики, торговая политика, промышленная политика, институциональное обеспечение промышленной и торговой политики, легкая промышленность

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1. Introduction

This paper studies the level of institutional support for the industrial and trade policies of St. Petersburg at the federal and regional levels. This study's relevance lies in its search for up-to-date methods for assessing the harmonisation of industrial and trade policies during the period of economic sanctions and within the process of import substitution in the industry of the Russian Federation. The existing approaches to developing methods for assessing the level of policy harmonisation do not measure the level of institutional support, which is the industrial and trade policy enshrined in federal and regional regulatory legal acts. This study's research objectives are the following: to propose a methodology for assessing the level of harmonisation of industrial and trade policy in St. Petersburg, to analyse and evaluate the level of harmonisation of institutional support for industrial and trade policy of St. Petersburg and to determine harmonisation criteria to formulate principles of harmonisation and assess the harmonisation level of industry and trade in St. Petersburg.

Approaches to developing a methodology for determining the level of harmonisation of policies are reflected in the works of Russian researchers. I.F. Bogatyrev examines industrial policy harmonisation from the point of view of achieving internal and external harmonisation. Internal harmonisation is the mutual consistency of the elements of the industrial policy mechanism, while external harmonisation involves industrial policy mechanisms and other types of economic policies (Bogatyrev, 2021).

K.A. Doroshenko, L.I. Egorova and M.K. Chuts explore the harmonisation of foreign trade and economic security at the regional level. They examine the indicators reflecting foreign trade relations and indicators of economic security that have certain threshold values. The researchers suggest using a foreign trade multiplier of regional trade, which characterises the relationship between the region's net income and the net export that caused this increase as an indicator, reflecting the analysis of the commodity structure of the region's exports and imports (Doroshenko and Egorova, 2013).

A. N. Kalyuzhny proposes ranking as a means of harmonising the industrial and trade policies of enterprises through assessing the harmonisation indicators of the trade and industrial policies of an enterprise, such as the following: 1) pursuing innovative activities, which implies the consistency of all its constituent elements, properties, internal processes, connections, contradictions and trends; 2) focusing all types of enterprise resources on 'key (root) competencies'; 3) marketing activities of an industrial organisation in an innovative economy; 4) identifying and motivating employees who have important knowledge of industrial organisation; and 5) building an innovative organisational structure. In the second stage of the assessment, the deviation of the sum of ranks by the type of activity from the reference number is calculated. In the third stage, the calculation results are ranked by enterprises. Based on the scale compiled by the author, enterprises are graded according to the level of harmonisation of industrial and trade policies (Kalyuzhny, 2012).

L. L. Tonysheva and T. A. Mezhetskaya propose a system for assessing industrial and trade policies based on indicators characterising the results of their implementation, such as for industrial policy: industrial production index percentage, labour productivity index percentage, index of investment volume in fixed capital percentage, index of growth of high-performance jobs percentage, the share of costly technological innovations in the total volume of shipped goods percentage, the innovative activity of industrial production organisations, level of harmonisation of national quality standards with international ones; for trade policy: share of domestic equipment about imported; share of exports of Russian high-tech equipment; expansion of the portfolio of orders of enterprises percentage, expansion of sales markets of enterprises percentage, increase in the attractiveness of the industry for investment, change in the reputation of enterprises in the market; changes in the amount of advertising. Next, they propose to evaluate specific indicators of industrial and trade policies using an expert-analytical method. The final stage determines the integral indicator of industrial and trade policy using the formula (Tonysheva and Mezhetskaya, 2016).

The methods proposed above by the authors are noteworthy as they reflect the harmonisation at the

level of an industrial enterprise or country; however, only a few works investigate the level of harmonisation of industrial and trade policies at the regional level. It is necessary to adapt existing methods and develop new ones considering the approaches the experts suggested. We propose our methodology for determining the level of industrial and trade policy harmonisation at the regional level.

2. Materials and methods

The information and empirical base of the study is the data obtained from the Federal State Statistics Service of the Russian Federation and the Office of the Federal State Statistics Service for St. Petersburg and the Leningrad Region (Petrostat). The following sources are also used: the laws of the Russian Federation and St. Petersburg in the field of industrial policy and trade, economic development strategies, industry and trade development strategies at the federal and regional levels, government programs aimed at developing industries and trade in the Russian Federation and the city of St. Petersburg and reports from the Federal Tax Service in form No. 1-NOM 'Accrual and receipt of taxes, fees and insurance contributions to the budget system of the Russian Federation for main types of economic activity'.

The methodology of the study is based on general scientific methods. Statistical observation of economic conditions, comparison and grouping and induction made it possible to formulate criteria for determining the level of harmonisation of industrial and trade policies at the institutional level and formulate principles for harmonising industrial and trade policies in the region. Comparative and structural analysis and scientific generalisation allowed for assessing the level of harmonisation of industrial and trade policies of St. Petersburg at the institutional level. Based on the point-rating method, a scale for quantitative and qualitative assessment of the harmonisation of industrial and trade policies at the institutional level was developed. The graphical method made it possible to prove the correlation between the ongoing harmonised industrial and trade policies and the level of economic effect for the region (in the number of tax revenues to the budget).

3. Results and Discussion

To determine the level of harmonisation of industrial and trade policies at the institutional level, the following criteria are proposed:

1. Mutual orientation of the goals and objectives of industry and trade development;

2. Comprehensive and systematic use of a system of support measures and tools at all levels of government;

3. Effectiveness, which is the positive result of support measures and the approximation of harmonisation indicators to the desired results of industrial and trade policy development.

The formulated principles of harmonisation of industrial and trade policies of the region are the following:

1. Uniformity, which is the presence of consistent institutional support for industrial and trade policies and a correlated system for evaluating implemented programs;

2. Goal setting, which is expressed in setting goals aimed at mutual support and development of industries using the region's potential while considering the existing industry problems;

3. Consistency, which implies the mutual orientation of industrial and trade policies through adopting norms and rules aimed at the interconnected development of industry and trade;

4. Efficiency, which means the effectiveness of support measures by achieving a positive socio-economic effect while optimising government spending;

5. Rationality, which is expressed in an economically justified ratio of the volume of resources allocated for developing industry and trade and the effect of their use;

6. Mutual socio-economic conditionality, which assumes that the harmonisation of industrial policy and trade policy is aimed at the socio-economic development of the region as a whole through the development of production and the formation and satisfaction of consumer demand;

7. Economic effect for the budget of a constituent entity of the Russian Federation, which means an economically justified forecast of an increase in tax revenues received by a constituent entity of the federation from the industrial sector of the economy and trade due to the harmonisation of industrial and trade policies.

At the institutional level, We propose using the point rating to assess the harmonisation of the components of the industrial and trade policy of St. Petersburg enshrined in federal and regional regulations:

1 point is assigned if a subject of the federation has adopted a normative legal act approving the policy;

2 points are assigned if there is a partial orientation of the components of industrial and trade policy towards each other (mention of related industry/trade while considering interests);

3 points are assigned if there is a significant orientation of the policy components towards each other (consolidating the goals, objectives and target indicators of the document of orientation and consideration of the interests of the related industry/trade and the presence of measures and actions aimed at the complementary development of industries).

Table 1. Assessment of the harmonisation level of industrial and trade policies of St. Petersburg at the institutional level

Industrial policy	Number of points		Trade policy	Number of points		Total
Federal level						
Federal Law of 31 December 2014 No. 488-FZ: On Industrial Policy in the Russian Federation	1		Federal Law of 28 December 2009 No. 381-FZ: On the Fundamentals of State Regulation of Trade Activities in wthe Russian Federation	3		4
Strategy for developing the economic security of the Russian Federation for the period until 2030, approved by decree of the president of the Russian Federation of 13 May 2017 N 208	2		Strategy for developing the economic security of the Russian Federation for the period until 2030, approved by decree of the president of the Russian Federation of 13 May 2017 N 208	2		4
Consolidated strategy for the development of the manufacturing industry of the Russian Federation until 2024 and for the period until 2035, approved. by order of the Government of the Russian Federation of 6 June 2020 N 1512	3		Trade development strategy in the Russian Federation for 2015–2016 and Trade development strategy until 2020, approved by order of the Ministry of Industry and Trade of the Russian Federation dated 25 December 2014 No. 2733	3	3	6
			Draft strategy for the development of trade in the Russian Federation until 2025	3		
State enterprise: Development of industry and increasing its competitiveness 2013–2030	2	2.75	State enterprise: Economic development and innovative economy 2013–2030	3		5.75
State enterprise: Development of the pharmaceutical and medical industry, approved by decree of the Government of the Russian Federation of 28 December 2017 No. 1673.	3					
No. 374 state enterprise: Development of shipbuilding and equipment for the development of offshore fields, approved by the decree of the Government of the Russian Federation of 31 March 2017 No. 374	3					
State enterprise: Development of the pharmaceutical and medical industry, approved by decree of the Government of the Russian Federation of 28 December 2017 No. 1673.	3					

Total	8.75		**11**	**19.75**
		Regional level		
Law of St. Petersburg dated 13 May 2009 No. 221-47: On the Fundamentals of Industrial Policy of St. Petersburg	1	Law of St. Petersburg dated 27 October 2010 No. 582-139: On State Regulation of Trade Activities in St. Petersburg	1	2
Law of St. Petersburg dated 19 December 2018 N 771-164: On the Strategy for the Socio-economic Development of St. Petersburg for the Period until 2035	2	Law of St. Petersburg dated 19 December 2018 N 771-164: On the Strategy for the Socio-economic Development of St. Petersburg for the Period until 2035	1	3
State enterprise of St. Petersburg: Development of industry, innovation and agro-industrial complex in St. Petersburg	1	State enterprise of St. Petersburg: Development of entrepreneurship and consumer market in St. Petersburg	2	3
Total	4		4	**8**

To interpret the assessment results using the point-rating method, a scale to quantitatively and qualitatively assess the level of harmonisation of industrial and tradwe policies at the institutional level was developed (Table 2). The value of the harmonisation coefficient is calculated as the ratio of the number of points corresponding to the reflection of mutual interests of industrial and trade policies in the document and the number of analysed documents.

Table 2. Assessing harmonisation at the institutional level of industrial and trade policies

Characteristics of the harmonisation level	The value of the harmonisation coefficient
No harmonisation	1–2
Low level of harmonisation	2–3
Average level of harmonisation	3–4
High level of harmonisation	4–5
Full harmonisation	5–6

The analysis revealed elements of harmonisation of industrial and trade policy components at the federal level of government. (The value of the coefficient as of 2022 is 4.93, which corresponds to a high level of harmonisation.) The regulatory framework governing activities in the field of industry and trade has a greater degree of consistency between the components of industrial and trade policy, namely in defining goals, objectives and mutual consideration of the interests of producers, trade representatives and consumers when approving and consolidating the course of industrial and trade policy within the framework of federal legislation and strategic planning documents, which indicates harmonisation.

At the same time, an insufficient level of harmonisation of the components of the industrial and trade policy of the region has been revealed. (The value of the coefficient as of 2022 is 2.6, corresponding to a low level of harmonisation.) At the legislative level of the federation, which forms the legal basis for industrial development, there is no consideration of the interests of trade in industrial enterprises, and there is no orientation towards changing consumer demand. State programs determining the formation and implementation of industrial and trade policies in St. Petersburg do not reflect the industries' consistency and mutual orientation towards each other in the programs' assigned goals, objectives and target indicators.

Analysing the components of the federal-level regulatory framework in industrial and trade policy showed greater harmonisation than at the level of the federal subject of St. Petersburg. This fact is due to the responsibility of the Ministry of Industry and Trade, which approves documents that determine the direction and formation of industrial and trade policy.

To assess the harmonisation level of the implemented industrial and trade policy, we proposed the indicator 'the share of locally produced goods in the region's trade turnover, and we developed a scale of qualitative characteristics of harmonisation level (Table 3).

Table 3. Scale for assessing the harmonisation of industry and trade in the region

Level of harmonisation	Assessment of harmonisation	Share of locally produced goods in the region's trade turnover, %
Absence or low level of harmonisation	No harmonisation	0–30
Average level of harmonisation	Partial harmonisation	30–60
High level of harmonisation	Harmonised	60–100

As of 2020, the level of harmonisation of the automotive and light industries of St. Petersburg has been assessed. Calculations were based on data from analytical reports from Auto-Dealer-SPb on sales of new passenger and light commercial vehicles in St. Petersburg in 2020, and the turnover of St. Petersburg in the textile group of goods for 2020 (in US dollars).[1,2]

Table 4. Assessing harmonisation level of industrial and trade policies of St. Petersburg in the passenger car and light industries as of 2020

Industry sector	Import	Self-produced goods	Level of harmonisation
Passenger cars (new)	9.62%	90.38%	Harmonised (high level of harmonisation)
Light industry	62.63%	37.37%	Partial harmonisation (average level of harmonisation)

Table 4 shows that the passenger car industry of St. Petersburg has a high level of harmonisation, which is confirmed by statistical indicators and the volume of tax revenues (Figure 1). The light industry of St. Petersburg is at the lower limit of the average level of harmonisation, which is also evidenced by statistical data and volumes of tax revenues (Figure 1).

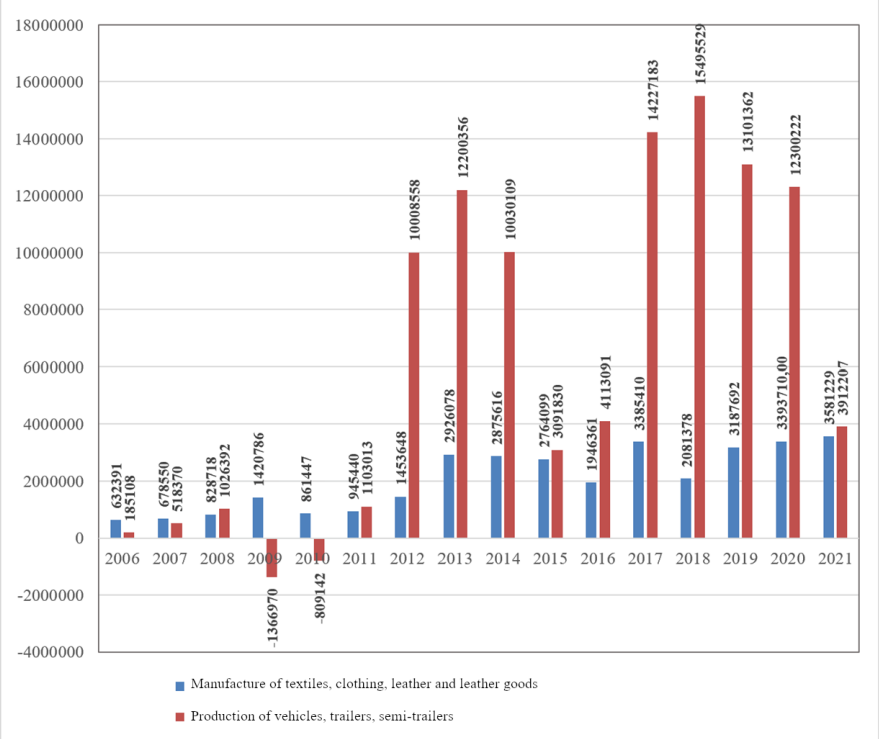

Figure 1. Tax revenues to the federal budget of the Russian Federation from the constituent entities of St. Petersburg for 2006–2021, in thousands of rubles[3]

1 Sales of new passenger cars and light commercial vehicles in St. Petersburg in 2020. URL: http://spb-adlr.ru/articles/analytics.php?id=72384
2 Foreign trade statistics. According to the Federal Customs Service of Russia. Trade turnover of St. Petersburg 'Textiles', URL: https://ru-stat.com/date-Y2021-2021/RU40000/trade/world/11#:~:text=Trade turnover%20 of St. Petersburg%20products%20from %20group,machine%20or%20manual%20knitting"%20(21%25)
3 Accrual and receipt of taxes, fees and insurance contributions to the budget system of the Russian Federation for the main types of economic activity in St. Petersburg. Form No. 1-NOM for 2006–2021. URL: https://www.nalog.gov.ru/rn78/related_activities/statistics_and_analytics/forms/10761488/

Assessing the socio-economic effect of the harmonisation of St. Petersburg's industrial and trade policies using the example of the light industry sector is possible by analysing the dynamics of indicators of socio-economic development in the city (in % of the same period) according to the following indicators:

1. Tax revenues to the budget of St. Petersburg from industry (according to OKVED);

2. Retail trade turnover in the textile product group;

3. Wholesale trade turnover in the textile product group;

4. Foreign trade turnover of St. Petersburg in the textile product group;

5. Number of people employed in textile and clothing production in St. Petersburg;

6. Average monthly wage in manufacturing for certain types of economic activity per employee (in the groups clothing production and textile production).

It is possible to assess the socio-economic effect of harmonisation of industrial and trade policies using this list of indicators in other industries. The works of researchers devoted to this topic do not reflect methods for assessing the institutional support for harmonising industrial and trade policies, and they do not specify the criteria and principles for determining harmonisation. To measure the level of harmonisation of the implemented industrial and trade policy, the indicator 'the share of locally produced goods in the region's trade turnover' was proposed, and a scale of qualitative characteristics of the level of harmonisation was developed. This indicator determines the state of harmonisation and indicates critical points in the implementation of the policy and is also important for determining the industrial and economic security of the country.

4. Conclusion

This study obtained the following results:

1. The criteria for harmonisation comprise the mutual orientation of the goals and objectives of the development of industry and trade; comprehensive and systematic use of support measures; and effectiveness of the policy being implemented.

2. The principles of harmonisation of industrial and trade policies comprise uniformity, goal setting, consistency, rationality, mutual socio-economic conditionality and economic effect for the budget of a constituent entity of the Russian Federation.

3. A methodology is proposed for assessing the harmonisation of institutional support for industrial and trade policies using the example of St. Petersburg; this method is universal and can be applied to other constituent entities of the Russian Federation. The point-rating method makes it possible to assess the level of harmonisation of the components of industrial and trade policy enshrined in federal and regional regulations. A scale for quantitative and qualitative assessment of the level of harmonisation has been developed.

4. To assess the harmonisation level of the implemented industrial and trade policy, the indicator 'the share of locally produced goods in the region's trade turnover' was proposed, and a scale of qualitative characteristics of the level of harmonisation has been developed.

5. An assessment was made of the level of harmonisation of industrial and trade policies of St. Petersburg in the passenger car and light industries as of 2020.

Updating legislation and a closer focus on industry and trade at the regulatory level and coordinated interaction between industry, trade and state representatives will open opportunities for the state to successfully resolve public issues concerning the expansion and development of the sectoral structure of the industry and the implementation of the import substitution process, which will result in harmonised

industrial and trade policies.

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SECTION 4

MANAGEMENT OF KNOWLEDGE AND INNOVATION FOR SUSTAINABLE DEVELOPMENT

РАЗДЕЛ 4

УПРАВЛЕНИЕ ЗНАНИЯМИ И ИННОВАЦИЯМИ В ИНТЕРЕСАХ УСТОЙЧИВОГО РАЗВИТИЯ

Research article
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Model of Motivation for the Top Management of Regional Government Agencies

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Abstract

The purpose of the study is to create a model of motivation for the top management of regional government agencies under which the non-material motivation of top managers will be made dependent on the achieved strategic potential of the region and their material motivation. For this purpose, it is necessary to solve a three-objective problem of global optimisation for the coefficient of natural population growth using a multi-objective genetic algorithm. Each of the three objectives – the strategic potential of the region and the material and non-material motivations of top managers – depends on three factors in the same coordinate system. The first three of the nine factors characterise the system of non-material incentives for top managers in government agencies, the next three refer to the system of their material incentives, and the last three apply to the available strategic potential of the region necessary for its further successful development. The creation of multiple effective solutions using the Pareto front is performed for two primary objectives, namely, the strategic potential of the region and material motivation of top management; then, as a consequence, a set of optimal solutions for non-material motivation is obtained. The conclusion about the actual remuneration (incentives) of the top managers at government agencies in the regions is as follows. For each of the three objectives in a particular region, the latest actual values of the nine factors under study are compared with the nearest planned (optimum) values of the Pareto front. A positive deviation from the optimum is evaluated positively, which makes it possible to additionally incentivise top managers either materially or non-materially.

Keywords: material motivation, non-material motivation, multi-objective genetic algorithm, pattern search

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Модель Мотивации Топ-Менеджмента Государственных Структур Регионов

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Аннотация

Целью исследования является создание модели мотивации топ-менеджмента государственных структур регионов, что позволит поставить нематериальную мотивацию топ-менеджеров в зависимость от достигнутого стратегического потенциала региона и их материальной мотивации. Для этого решается трехцелевая задача глобальной оптимизации коэффициента естественного прироста населения с помощью многоцелевого генетического алгоритма. Каждая из трех целей – стратегический потенциал региона, материальная и нематериальная мотивации топ-менеджмента - зависит от трех факторов в одной системе координат. Первые три из девяти факторов характеризуют систему нематериального поощрения топ-менеджеров в государственных структурах, следующие три – систему их материального поощрения, а последние три – имеющийся стратегический потенциал региона, необходимый для его дальнейшего успешного развития. Построение множества эффективных решений с помощью Парето-фронта выполняется для двух первоочередных целей – стратегического потенциала региона и материальной мотивации топ-менеджмента, после чего уже как следствие получается множество оптимальных решений для нематериальной мотивации. Вывод о фактическом премировании (поощрении) топ-менеджеров государственных структур регионов делается следующим образом. Для каждой из трех целей в конкретном регионе сравниваются последние фактические значения исследуемых девяти факторов с ближайшими плановыми (оптимальными) значениями Парето-фронта. Положительное отклонение от оптимума оценивается позитивно, что позволяет дополнительно поощрять топ-менеджеров материально либо нематериально.

Ключевые слова: материальная мотивация, нематериальная мотивация, многоцелевой генетический алгоритм, поиск по шаблону

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1. Introduction

It is impossible to create competitive advantages in the national economy without developing and applying the necessary management methods in government agencies. Relevant strategies, such as the National Strategy for the Development of Artificial Intelligence for the Period Until 2030, are aimed at enabling the Russian Federation to achieve such innovative advantages in the global market.

Metaheuristic algorithms are an integral part of artificial intelligence technologies and allow the global optimisation of processes that have a high dimensionality. Such processes include the motivation of the top management of government agencies at both country and regional levels. However, building a rational motivation system for senior managers is a complex task, as they can be motivated both materially and non-materially. In the latter case, we primarily imply the career growth of civil servants occupying important management positions.

It is advisable to start modelling the motivation system for top managers by studying the basic principles of their motivation, which are fundamentally different from the approaches used to motivate average employees.

Khytrova et al. (2020) established that the timely identification and diagnostics of problematic situations that arise during the development and growth of organisations significantly depend on the levels of qualifications and professionalism of their managers. According to Munna (2021), moreover, a manager always has the ability to influence others, and there are three types of management skills: technical skills, interpersonal communication skills, and decision-making skills. Technical skills are ideally related to the ability to use methods and techniques to accomplish a task, and interpersonal skills focus solely on the ability to understand, communicate, and work well with individuals and groups through the development of effective relationships.

In a similar context, Dogar (2020) studied identification of the dynamics of excluding internal stakeholders from the process of making organisational strategic decisions as well as their impact on the effectiveness and sustainability of the organisation. The author proposed a mechanism to prevent such conflicts in social development organisations, in particular, and organisations in general.

The next important stage of building a rational motivation system for top management is to create the necessary models for this purpose. Thus, Kampf et al. (2017) identified significant differences between the needs of senior managers and blue-collar workers using Student's *t*-test with two samples. On the basis of the test results, the researchers concluded that in the field of motivational factors in Slovakia, it was impossible to establish a single motivational programme for the analysed groups of employees. In future, after the needs of employees are satisfied, it is possible that as requirements change, motivation may change as well.

Another successful model is the model of motivation management of executives, formed as a structural and logical scheme based on the systems approach and decomposition, which reflects the interaction of subject and object in the process of forming and implementing the system of motivation of managers at an enterprise (Popadinets et al., 2021). Using the method of linear multiple regression, a system of equations was constructed to describe the economic and mathematical model of motivation of management at oil and gas enterprises, which, after repeated experiments, provided diagnostics of indicators before, during, and after the implementation of the model of management motivation.

Motivation in the public sector deserves particularly close attention in the process of modelling top management. For example, Schwarz et al. (2020) sought to better understand leadership in the public sector by examining the relationships among accountability, compliance, political loyalty, and approaches to network management for leadership and public service motivation (PSM) and individual performance. Using a sample of 300 civil servants and their 64 managers in China, the study showed that accountability, compliance, political loyalty, and network management are highly positively related to employees' PSM levels and performance.

The subject of the current study is the construction of a motivation system for the top management of government agencies in order to align the interests of the population, the state, and its top managers. The purpose of the study is to create a model of motivating the top managers of government agencies in the regions under which the non-material motivation of such managers can be made dependent on the achieved strategic potential of the region and their material motivation.

2. Literature review

Currently, there is a cluster approach to managing the development of the country's regions, which allows the innovation component of industrial planning to be taken into account in this process. Working out a strategy for the development of regions with innovation clusters is the starting point of the research presented in this paper.

At the current stage of economic development, innovation clusters can be considered one of the main elements of the innovation system, since the strategic objective of their functioning is the development and production of innovations. Innovation potential is one element of national competitiveness, and the development of a nation's level of innovation is important for its functioning in the world economy (Andrienko, 2021).

In such a context, Zhang (2021) mainly focussed on innovative industrial clusters and the industrial cluster theory, the development areas of innovative industrial clusters, innovative enterprises, and government policies. In contrast, Ferras-Hernandez and Nylund (2018) studied when and how innovation clusters strengthen innovations at the corporate level. The authors examined the matter from different theoretical perspectives, such as neoclassical economics, evolutionary economics, behavioural economics, strategic management, and open innovations, in search of a comprehensive theoretical foundation that would explain the relationship between a specific innovation and a concentration of innovative activities. The researchers took into account five strengths that stimulate technological changes in innovation clusters: attraction, information, interaction, anticipation, and rivalry.

Héraud and Muller (2022) considered a fundamentally new problem, namely, the interaction between smart cities and innovation clusters. Their approach was strongly influenced by the philosophy of foresight and technology assessment, that is, the construction of a desired consensus future rather than a deterministic technological vision of the problem. For this purpose, the authors investigated the activities of municipal politicians or managers as well as those of people involved in technology clusters, research centres, Fab Labs, living labs, etc.

Bittencourt et al. (2018) argued that most studies on innovation capabilities analyse such capabilities at the corporate level and that little has been done to understand the interaction between inter-organisational agglomerations and the capabilities that such mechanisms preserve. Thus, acquisition capabilities, distribution capabilities, and knowledge management capabilities are the core capabilities that constitute the cluster innovation perspective.

Within the cluster approach, we apply a multi-objective genetic algorithm (MGA), which belongs to the class of metaheuristic algorithms, to model the motivation of the top management of government agencies. Hence, we explore the advantages and recent advances of the MGA in various areas of scientific knowledge.

The MGA is a direct search method for multi-objective optimisation problems. It is based on the process of the genetic algorithm (GA); the population property of genetic algorithm is well applied in MGA. Compared with the traditional multi-objective algorithm, which aims to find a single Pareto solution, the MGA seeks to determine the number of Pareto solutions.

Fita (2014) made it a research goal to find a well-defined and meaningful approximation of the solution set for linear and nonlinear three-objective optimisation problems, since it is important for a decision maker to obtain as much information as possible about the set of possible solutions. This pa-

per uses a continuous variational GA to find an approximate near-optimal solution set. Khan and Baig (2015) presented a method based on the evolutionary algorithm to solve the multi-objective feature subset selection problem. Thus, a feature subset must be selected before creating a classifier. This proposed methodology treats feature subset selection as a multi-objective optimisation problem and utilises one of the recent MGAs.

Das et al. (2017) proposed the cluster analysis method based on the MGA to find the optimal set of overlapping clusters. The overall performance of the method was investigated on some popular sets of data and microarrays, and the optimality of the clusters was measured by certain important cluster checking indices. The experimental results showed the effectiveness of the proposed method.

Li and Jin (2018) presented research on a deadline rescheduling strategy and a new hybrid genetic algorithm (HGA) to include a new processing task. Firstly, the time interval is set according to the timing of the new task, and the optimisation of multi-objective planning is guaranteed. Then, by improving the GA and combining it with the simulated annealing algorithm, the new hybrid algorithm is presented, which implements the optimisation processing in flexible shop floor planning. The experiment showed that the algorithm improves the global optimisation capability. Finally, the modelling results showed that the algorithm can obtain a Pareto solution of higher quality under static planning and new problem insertion.

According to Thananant and Auwatanamongkol (2019), supervised clustering aims to achieve several goals, such as the compactness of clusters, homogeneity of data in clusters with respect to their class labels, and separability of clusters. With these goals in mind, the researchers proposed a new supervised clustering algorithm based on an MGA called SC-MOGA. The algorithm searches for an optimal clustering solution that simultaneously achieves the above three objectives. The experimental results showed that the proposed data sampling method not only helps to reduce the number of data instances to be clustered using SC-MOGA, but also improves the quality of the data-clustering results.

Sardaraz and Tahir (2020) presented a multi-objective scheduling algorithm to plan scientific workflows in cloud computing. The results showed that the proposed algorithm provides an improvement in execution time and reduces cost when using a load-balancing system. Wang et al. (2021) established the mathematical model of multi-objective optimisation based on a GA to design a burnable poison structure in a pressurised reactor. Then, the researchers developed an optimisation programme by combining a parallel multi-objective GA with the Monte Carlo N-Particle Transport Code as a neutronics and depletion solver.

Maghawry et al. (2021) proposed an HGA that uses a GA to perform a global search supported by a particle swarm optimisation (PSO) algorithm to perform a local search. The proposed algorithm was tested on the basis of four benchmark multi-objective optimisation functions, where the maximum balance between the exploration and search exploitation of space was achieved. The algorithm also succeeded in improving the overall performance of an HGA by limiting the average number of iterations until convergence.

Nikseresht and Raji (2021) presented a new MGA-based task mapping and scheduling (abbreviated as MOGATS) for a heterogeneous embedded system. The mapping and scheduling tasks are modelled as a GA-based optimisation approach. Thus, the authors' task scheduling tool is the first multi-objective task scheduling in the design phase of embedded systems to help designers determine which scheduling set will achieve their desired outcome.

However, the solutions of an MGA must be checked at the extreme points of the obtained Pareto front, for which the present study will use the direct search (pattern search) algorithm due to its high optimisation quality. This algorithm has several advantages, as outlined below.

Under conditions of uncertainty and turbulence, the classical and traditional approaches cannot satisfactorily find a complete solution to real optimisation problems. Therefore, new global optimisation

methods are required to seriously address these problems. One of these methods consists of HGAs and pattern search, a versatile, flexible, robust, and general-purpose framework for solving complex global optimisation and search problems in real-world applications (Vasant, 2012). The performance of the pattern search algorithm was thoroughly tested by Baeyens et al. (2016) with the use of benchmark functions and compared with some well-known global optimisation algorithms. The results of their computational study showed that the algorithm combines simplicity and efficiency and is competitive with the heuristics-based strategies currently used for global optimisation.

Finally, our proposed approach to the need to verify MGA solutions using other global optimisation algorithms has also been applied by authors who used algorithms other than pattern search for this purpose. For example, Giorgio and Sangiorgio (2020) argued that a complete view of the boundary is possible by first solving single-objective problems corresponding to the extremes of the Pareto boundary and then using such solutions as elite representatives of the original solution. Their paper compared this approach to the more familiar initialisation using some classical tests with a variable number of objectives and known analytical solutions.

Yashin et al. (2020) have already solved a simpler problem of the material and non-material motivation of the top management of governing bodies of regions and districts. For this purpose, the efficiency of intercluster interaction within one federal district was assessed using a system of factors of the socio-economic development of Russian regions that directly affect the natural population growth in the regions of the district. An MGA was also used to solve the task, which allowed the Pareto front to be obtained for the two-objective function of the natural increase rate, all solutions of which are equally optimal. One can find at any point of the Pareto front the shares of material and non-material motivation of top managers.

However, the current paper studies the more complex task of the three-objective global optimisation of the motivation of the top managers at government agencies in the regions under which the non-material motivation of such managers can be made dependent on the achieved strategic potential of the region and their material motivation. In addition, the new task is solved for those regions of the whole country that have territorial innovation clusters on the list approved by the government of the Russian Federation.

3. Materials and methods

In order to model the motivation of the top management of government agencies in the regions, we define a three-objective function where the first objective is the non-material motivation of top managers, the second is their material motivation, and the third is the strategic potential of the region. Each of these goals depends on three factors x_1, x_2, x_3 in one coordinate system.

We model the motivation of the top managers of government agencies in the regions, taking into consideration external and internal relations, through an MGA in several stages (Fig. 1).

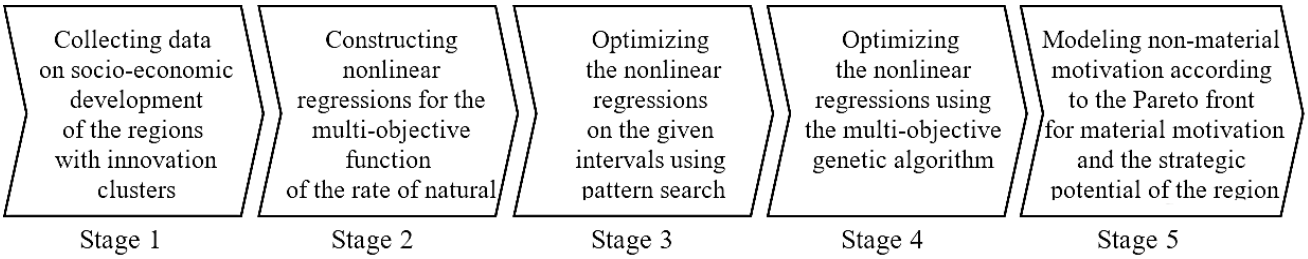

Figure 1. Stages of modelling the motivation of the top managers of government agencies in the regions

Stage 1 - collecting data on the socio-economic development of the regions with innovation clusters. Effective inter-cluster interaction within the country has economic-financial, informational, and logistic aspects. For regions with territorial innovation clusters, inter-cluster interaction refers to

external relations, and for clusters within the region, it refers to internal ones. The regions' external relations with other countries should also be taken into consideration. The effectiveness of such interactions can be assessed through the system of assessment of socio-economic development of the Russian regions using the places they occupy in the Russian Federation in terms of a number of factors:

1. gross regional product (GRP) per capita (x_1);

2. investments in fixed capital per capita (x_2);

3. internal expenditure on research and development (R&D) (x_3);

4. average per capita cash income of the population (per month) (x_1);

5. total living space per capita (x_2);

6. specific weight of hard-surface roads (x_3);

7. tax revenue per capita (x_1);

8. employment-to-population ratio (x_2);

9. number of students per 10 000 population (x_3).

These factors directly affect the value of the rate of natural increase per 1000 people (y) in the regions of the country.

The first three factors characterise the system of non-material incentives for the top managers of government agencies, the next three refer to the system of their material incentives, and the last three refer to the available strategic potential of the region necessary for its further successful development. Thus, the first three factors reflect how effectively top managers solve national tasks and the next three how effectively they solve the tasks that are prioritised by the population. The priorities of the population are more important; therefore, top managers should be materially motivated to meet them effectively. We recommend motivating the realisation of national tasks non-materially.

However, as stated earlier, the non-material motivation of top managers is, first and foremost, an opportunity for their career growth. We define this opportunity depending on how successfully they accomplish the tasks prioritised by the population as well as their success in building up the strategic potential of the region. Thus, constructing a set of effective solutions with the help of the Pareto front will be performed for two priority objectives, namely, the strategic potential of the region and the material motivation of the top management, after which a set of optimal solutions for non-material motivation will be obtained as a result.

Stage 2 - constructing nonlinear regressions for the multi-objective function of the rate of natural increase. At this stage, we obtain the necessary nonlinear regressions for the strategic potential of the region and material motivation of the top management, for example, in the programme *Statistica*, which will then be used for the purpose of the global optimisation of the three-objective function of the rate of natural increase (y).

Stage 3 - optimising the nonlinear regressions on the given intervals using a pattern search. There are 85 constituent entities (regions) in Russia. Therefore, the interval on which we will optimise the three-objective function $y = f(x_1,x_2,x_3)$ will be the values (1; 85). Searching for the global largest values of each nonlinear regression using the pattern search algorithm for this purpose will allow us to check the extreme values of the Pareto front, which we will obtain later by using the MGA.

Stage 4 - optimising the nonlinear regressions using the MGA. This algorithm allows the Pareto front to be obtained for the two-objective function, all points of which are equally optimal solutions. It reflects the set of the largest y as well as the values of its factors x_1, x_2, x_3. Thus, the optimal values of the functions of strategic potential and material motivation, as well as the corresponding values of factors

x_1, x_2, x_3, can be found at any point of the Pareto front.

Stage 5 - modelling non-material motivation according to the Pareto front for material motivation and the strategic potential of the region. While conducting the two-objective optimisation, we simultaneously obtain in the *Matlab* package the value of the third function (i.e., non-material motivation) at each point corresponding to the Pareto front for the first two functions. This allows us to plan the non-financial motivation of top managers depending on how well they achieve the tasks prioritised by the population as well as the increase of the strategic potential necessary for the region's development.

The conclusion about the actual bonuses (incentives) for the top managers of government agencies in the regions is made as follows. For each of the three functions in a particular region, we compare the latest actual values of factors x_1, x_2, x_3 with the nearest planned (optimal) values. A positive deviation from the optimum is evaluated positively, which allows us to additionally incentivise top managers either materially or non-materially. A negative deviation shows that they made poor management decisions in the past, which should surely be reflected in their incentives.

4. Results

Let us consider the process of modelling the motivation of the top managers of government agencies in the regions of the country through an MGA. Thereafter, we will draw conclusions for a specific region.

According to the list approved by the government of the Russian Federation, there are 25 pilot territorial innovation clusters in Russia in the respective regions of the country. For this reason, we will study only those regions (oblasts or republics) in which the clusters from the above list are located.

Stage 1 - collecting data on the socio-economic development of the regions with innovation clusters. Using the indicators of the 'Statistical Review' published by the Federal State Statistics Service, we collect the necessary data for the decade from 2010 to 2019 for the regions under study. A 200 X 10 dimensional matrix is obtained. Table 1 reflects these data for the last year under study, 2019.

Table 1. Data for creating regression models

Region	Place occupied by the constituent entity in the Russian Federation									Rate of natural increase per 1000 people
	Non-material motivation			Material motivation			Strategic potential			
	GRP per capita	Fixed capital investment per capita	Internal R&D expenses	Average per capita cash income (per month)	Total living space per capita	Specific weight of hard-surface roads	Tax revenue per capita	Employment-to-population ratio	Number of students per 10000 population	
	x1	*x2*	*x3*	*x1*	*x2*	*x3*	*x1*	*x2*	*x3*	*y*
					2019					
1. Kaluga region	27	31	20	27	10	65	25	20	59	-5.7
2. Moscow region	16	19	3	9	1	23	22	8	80	-2.5
3. Moscow	6	10	1	4	82	1	6	6	2	1.2
4. Arkhangelsk region	33	47	48	19	28	66	34	70	68	-4.4
5. Leningrad region	17	11	18	24	17	26	16	24	82	-5.3
6. Saint Petersburg	9	23	2	10	47	2	10	7	1	-0.1

7. Republic of Bashkortostan	44	50	16	32	46	10	30	67	38	-1.8
8. Republic of Mordovia	63	65	56	81	30	76	57	19	13	-5.7
9. Republic of Tatarstan	15	14	11	16	37	34	12	17	6	-0.1
10. Perm region	24	28	10	31	65	50	20	71	51	-3.0
11. Nizhny Novgorod region	34	41	4	20	33	49	31	16	29	-5.6
12. Samara region	29	42	9	35	35	82	17	21	21	-3.9
13. Ulyanovsk region	60	70	15	70	23	46	38	60	22	-5.0
14. Sverdlovsk region	22	33	5	14	45	29	32	43	26	-2.6
15. Altai Republic	76	78	40	69	63	53	68	61	47	3.5
16. Krasnoyarsk region	10	17	6	26	55	19	9	22	39	-1.7
17. Kemerovo region	47	27	45	63	57	22	54	63	65	-5.2
18. Novosibirsk region	35	45	7	33	50	44	40	33	8	-2.0
19. Tomsk region	23	43	12	41	62	52	13	39	3	-1.4
20. Khabarovsk region	20	24	38	13	67	11	28	15	12	-2.4

Stage 2 - constructing nonlinear regressions for the multi-objective function of the rate of natural increase. According to the data in Table 1, we can obtain the three most reliable multiple nonlinear regressions in the *Statistica* package:

- non-material motivation (Fig. 2):

$$y = 9,96172 + 0,1769x_1 + 0,3188x_3 - 1,32628\sqrt{x_1} - 4,05206\sqrt{x_3} - 1,04676\ln x_2 + 2,72664\ln x_3,$$
$$R^2 = 0,825;$$

- material motivation (Fig. 3):

$$y = -2,77578 + 0,30824x_2 - 0,01069x_2^2 + 0,00001x_1^3 + 0,00009x_2^3 - 0,00001x_3^3 + 1,18178\ln x_1,$$
$$R^2 = 0,825;$$

- strategic potential (Fig. 4):

$$y = 15,0191 - 0,2383x_1 + 0,1342x_2 + 0,4561x_3 + 8,1069\sqrt{x_1} - 1,4168\sqrt{x_2} - 7,4633\sqrt{x_3} - 13,0338\ln x_1 + 6,8303\ln x_3,$$
$$R^2 = 0,779.$$

Regression Summary for Dependent Variable: Var10 (Regions_3.sta)
R= ,92594578 R?= ,85737558 Adjusted R?= ,84515063
F(6,70)=70,133 p<0,0000 Std.Error of estimate: 1,0057

N=77	b*	Std.Err. of b*	b	Std.Err. of b	t(70)	p-value
Intercept			9,96172	1,784829	5,58133	0,000000
Var3	2,93552	0,692518	0,31880	0,075207	4,23890	0,000067
SQRV3	-3,63084	1,065548	-4,05206	1,189163	-3,40748	0,001090
LN-V3	1,32485	0,497763	2,72664	1,024436	2,66160	0,009638
LN-V2	-0,23202	0,079658	-1,04676	0,359385	-2,91264	0,004806
Var1	1,43075	0,542308	0,17690	0,067053	2,63825	0,010262
SQRV1	-0,94981	0,545310	-1,32628	0,761453	-1,74178	0,085939

Figure 2. Regression of non-material motivation

Regression Summary for Dependent Variable: Var10 (Regions_3.sta)
R= ,90849012 R?= ,82535430 Adjusted R?= ,81038467
F(6,70)=55,135 p<0,0000 Std.Error of estimate: 1,1129

N=77	b*	Std.Err. of b*	b	Std.Err. of b	t(70)	p-value
Intercept			-2,77578	1,445985	-1,91965	0,058979
V4**3	0,41765	0,132844	0,00001	0,000002	3,14391	0,002446
V5**3	5,51764	1,081397	0,00009	0,000018	5,10233	0,000003
V5**2	-6,88600	1,494558	-0,01069	0,002319	-4,60739	0,000018
Var5	1,77997	0,505659	0,30824	0,087565	3,52010	0,000763
LN-V4	0,40928	0,130853	1,18178	0,377837	3,12777	0,002567
V6**3	-0,12534	0,063423	-0,00001	0,000003	-1,97632	0,052060

Figure 3. Regression of material motivation

Regression Summary for Dependent Variable: Var10 (Regions_3.sta)
R= ,88245455 R?= ,77872604 Adjusted R?= ,75269381
F(8,68)=29,914 p<0,0000 Std.Error of estimate: 1,2709

N=77	b*	Std.Err. of b*	b	Std.Err. of b	t(68)	p-value
Intercept			15,0191	2,906653	5,16714	0,000002
Var7	-1,90463	1,940789	-0,2383	0,242775	-0,98137	0,329889
SQRV7	5,93936	3,810889	8,1069	5,201640	1,55852	0,123751
Var9	4,70427	0,887557	0,4561	0,086052	5,30024	0,000001
SQRV9	-7,87952	1,619837	-7,4633	1,534268	-4,86439	0,000007
LN-V9	3,91653	0,976773	6,8303	1,703455	4,00966	0,000154
LN-V7	-3,99155	2,031972	-13,0338	6,635115	-1,96437	0,053575
Var8	1,35475	0,775240	0,1342	0,076766	1,74752	0,085062
SQRV8	-1,32725	0,802079	-1,4168	0,856196	-1,65477	0,102581

Figure 4. Regression of strategic potential

Stage 3 - optimising the nonlinear regressions on the given intervals using a pattern search. Optimising regressions in the *Matlab* package on the interval (1; 85) using a pattern search algorithm yields the following results:

- for non-material motivation:

$$y_{max} = 14,6 \quad \text{when} \quad (x_1, x_2, x_3) = (85;1;85);$$

- for material motivation:

$$y_{max} = 12,9 \quad \text{when} \quad (x_1, x_2, x_3) = (85;85;1);$$

- for strategic potential:

$$y_{max} = 21,9 \quad \text{when} \quad (x_1, x_2, x_3) = (1;1;85).$$

Stage 4 - optimising the nonlinear regressions using the MGA. The MGA approach allows us to obtain the Pareto front in the *Matlab* package for the function of two objectives: strategic potential and material motivation (Figs. 5 and 6).

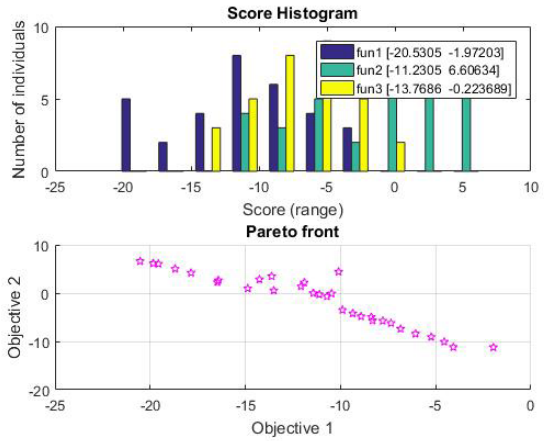

Figure 5. Pareto-front strategic potential (fun1) and material motivation (fun2)

Index	f1	f2	f3	x1	x2	x3
1	-20,531	6,606	-9,209	1,002	1,17	74,763
25	-19,844	6,157	-8,316	1,011	2,666	74,541
4	-19,563	6,057	-8,205	1,033	2,906	74,458
10	-18,69	5,024	-7,217	1,034	5,079	71,066
7	-17,855	4,194	-6,708	1,074	2,888	61,316
19	-16,472	2,267	-4,735	1,041	16,171	59,517
8	-16,414	2,642	-5,039	1,084	17,797	63,568
23	-14,877	0,974	-3,336	1,104	17,069	44,988
31	-14,261	2,833	-5,5	1,459	7,462	60,791
29	-13,621	3,479	-6,218	1,716	3,902	62,026
16	-13,509	0,537	-2,897	1,255	16,782	39,524
14	-12,078	1,401	-4,162	1,675	16,8	56,698
18	-11,91	2,198	-5,076	1,889	12,55	63,303
30	-11,436	-0,009	-1,736	1,537	24,714	25,712
13	-11,115	-0,284	-0,364	1,998	80,293	26,14
32	-10,711	-0,696	-0,224	2,15	80,993	20,844
21	-10,471	-0,074	-2,179	1,744	20,876	34,257
27	-10,103	4,409	-7,233	3,306	3,682	73,935
3	-9,901	-3,508	-13,769	83,951	1,169	80,488
2	-9,36	-4,199	-13,124	83,973	1,477	77,276
28	-8,924	-4,821	-12,709	83,651	1,269	72,825
9	-8,378	-4,946	-11,986	81,659	1,415	69,391
5	-8,315	-5,687	-12,032	83,945	1,415	67,703
24	-7,778	-5,755	-11,213	82,773	2,881	68,12
11	-7,348	-6,216	-10,699	82,868	4,594	67,809
12	-6,843	-7,403	-10,23	84,816	6,029	64,308
20	-6,061	-8,423	-9,345	84,835	10,684	61,603
22	-5,239	-9,085	-8,305	83,66	11,702	53,291
17	-4,555	-10,081	-7,217	84,293	9,74	35,426
26	-4,075	-11,194	-6,715	84,905	17,378	3,199
6	-1,974	-11,23	-6,231	85	18,994	1,352
15	-1,972	-11,23	-6,242	85	18,741	1,348

Figure 6. Coordinates of the strategic potential (f1) and material motivation (f2) Pareto front points

Stage 5 - modelling non-material motivation according to the Pareto front for material motivation and the strategic potential of the region. Figures 5 and 6 also reflect the values of the third function (i.e., non-material motivation), which correspond to the optimal values of the functions of strategic potential and material motivation.

From the analysis of the Pareto front obtained in Figures 5 and 6, we can draw the following conclusions:

1. Maximum population growth will be observed in the case of focusing on the strategic potential. The rate of natural increase per 1000 people here is 20.5.

2. In this case, for the function of non-material motivation, the GRP per capita ($x_1 \approx 1$) and investment in fixed capital per capita ($x_2 \approx 1$) should be maximal, and internal R&D expenditure should be almost minimal ($x_3 \approx 75$). This situation is explained by the fact that investment in fixed capital and R&D expenditures are competing objectives under conditions of limited financial resources.

3. For the function of material motivation, the average per capita cash income of the population (per month) ($x_1 \approx 1$) and the total living space per capita ($x_2 \approx 1$) should be maximal, and the specific weight of hard-surface roads should be almost minimal ($x_3 \approx 75$).

4. For the function of strategic potential, tax revenues per capita ($x_1 \approx 1$) and the employment-to-population ratio ($x_2 \approx 1$) should be maximal. However, the number of students per 10 000 population is allowed to be almost minimal ($x_3 \approx 75$).

So far, preliminary conclusions have been obtained for the 20 regions under study with territorial innovation clusters. To draw conclusions for a specific region, taking the Nizhny Novgorod region as an example, let us compare the actual values in 2019 of the studied factors with the optimal values on the Pareto front (Table 2).

Table 2. Performance assessment of the Nizhny Novgorod region in 2019

Indicators	Place occupied by the constituent entity in the Russian Federation									Rate of natural increase per 1000 people
	Non-material motivation			Material motivation			Strategic potential			
	GRP per capita	Fixed capital investment per capita	Internal R&D expenses	Average per capita cash income (per month)	Total living space per capita	Specific weight of hard-surface roads	Tax revenue per capita	Employment-to-population ratio	Number of students per 10 000 population	
	x1	*x2*	*x3*	*x1*	*x2*	*x3*	*x1*	*x2*	*x3*	*y*
Actual value (2019)	34	41	4	20	33	49	31	16	29	-5.6
Closest optimum 1	2	21	34	2	21	34	2	21	34	10.5
Optimum deviation 1	-32	-20	30	-18	-12	-15	-29	5	5	-16.1
Actual value (2019)	34	41	4	20	33	49	31	16	29	-5.6
Closest optimum 2	1	17	45	1	17	45	1	17	45	14.9
Optimum deviation 2	-33	-24	41	-19	-16	-4	-30	1	16	-20.5
Actual value (2019)	34	41	4	20	33	49	31	16	29	-5.6
Closest optimum 3	85	19	1	85	19	1	85	19	1	11.2
Optimum deviation 3	51	-22	-3	65	-14	-48	54	3	-28	-16.8

As shown in Figure 6, the three closest optima of the Pareto front are located in the lines numbered

21, 23, and 6 (or 15). These are reflected in Table 2 as optima 1, 2, and 3. We consider the deviation from each optimum as the difference between the corresponding values of x_i (i = 1.3) for a particular objective function y. Thus, for the strategic potential function, the closest optimum is 1; then, the sum of deviations of the places for x_1, x_2, x_3 is 39. For the function of material motivation, the closest optimum is 2, and the sum of deviations of places will be 39. For the function of non-material motivation, the closest optimum is 3, and the sum of deviations of places will be 76. Moreover, the deviation of the coefficient of the rate of natural increase (y) is smallest in the case of orientation to optimum 1 and amounts to 16.1.

In this case, according to the results of Table 2, the number of students per 10 000 population and the employment rate roughly correspond to the planned optimal values. However, the specific weight of hard-surface roads should be increased in order for the Nizhny Novgorod region to move from 49th to 34th place; the total living space per capita should also be increased in order for it to move from 33rd to 21st place; and the average per capita cash income (per month) should be significantly increased in order for it to move from 20th to 2nd place.

At the same time, internal R&D expenditures should be reduced for it to move from 4th to 34th place, and investment in fixed capital per capita should be increased for it to move from 41st to 21st place. This is because these two objectives are competing when the budget is limited. In addition, GRP per capita needs to be significantly increased for the Nizhny Novgorod region to move from 34th to 2nd place.

5. Discussion

Comparing our results with the experiences of other researchers, we note that another successful model of managing top managers' work motivation is formalised as a structural and logical scheme based on the systems approach and decomposition and reflecting the interaction between subject and object when the motivation system is formed and introduced at an enterprise (Popadinets et al., 2021). However, our model takes into consideration different aspects of top management motivation.

Moreover, our proposed approach to the need to validate MGA solutions by using other global optimisation algorithms is applied by other authors who use algorithms other than pattern search for this purpose. For example, Giorgio and Sangiorgio (2020) argued that a complete view of the boundary is possible by first solving single-objective problems corresponding to the extremes of the Pareto boundary and later using such solutions as elite representatives of the original solution.

Finally, our results significantly improve the model presented by Yashin et al. (2020). The latter authors solved a simpler problem of the material and non-material motivation of the top management of governing structures in regions and districts. For this purpose, the efficiency of the inter-cluster interaction within one federal district was assessed using a system of factors of the socio-economic development of Russian regions that directly affect the natural population growth in the regions of the district. However, our study has carried out the more complex task of the three-objective global optimisation of the motivation of the top managers of government agencies in the regions, allowing us to make the non-material motivation of such top managers dependent on the achieved strategic potential of the region and their material motivation.

The presented approach can be useful for government agencies to develop a rational system of material and non-material motivation for their top managers.

6. Conclusion

The study results in the following key findings:

1. In order to model the motivation of the top managers of government agencies in the regions, it is advisable to solve a three-objective global optimisation problem under which the non-material motivation of such managers can be made dependent on the achieved strategic potential of the region and their material motivation.

2. Each of these objectives depends on the three factors x_1, x_2, x_3 in the same coordinate system. These factors directly affect the value of the rate of natural increase of population per 1000 people in the regions of the country.

3. The first three of the nine factors characterise the system of non-material incentives for top managers in government agencies, the next three refer to the system of their material incentives, and the last three concern the available strategic potential of the region necessary for its further successful development.

4. A set of effective solutions with the help of the Pareto front should be constructed with two primary objectives, namely, the strategic potential of the region and the material motivation of its top managers, after which a set of optimal solutions for non-material motivation will be obtained as a result.

5. The conclusion about the actual bonuses (incentives) of the top managers of government agencies in the regions is made as follows. For each of the three functions in a particular region, the latest actual values of factors x_1, x_2, x_3 are compared with the nearest planned (optimal) values. A positive deviation from the optimum is evaluated positively, which makes it possible to additionally encourage top managers either materially or non-materially. A negative deviation shows that they made poor management decisions in the past, which, of course, should be reflected in their incentives.

Acknowledgements

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