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Different Approaches to Achieving Sustainable Development of the Territories

The tools for achieving the Sustainable Development Goals of the Territories combine the aspirations and capabilities of management structures, civil society and the private sector. The main idea of implementing initiatives in the field of sustainable development of the territories is to focus on what is realistically achievable based on existing resource constraints. The system of monitoring the sustainability of the development of the territories is a key element in the successful implementation of initiatives in this direction. Monitoring should cover processes (such as quality and coverage of participation and information systems), results and changes in development trends.

In the second issue of the 2023 Sustainable Development and Engineering Economics Journal, the authors examine various aspects of the sustainable development of enterprises and territories and the means to achieve it.

The first section, named Economics of engineering and innovation decisions as a part of sustainable development, is presented in the article 'Development of Instrumental Approaches to Forecasting the Volatility of the Return of Financial Assets' by Guyomey, J. and Zaytsev, A. In this study, the authors consider systematisation as a method for modelling the volatility of financial asset returns and the theoretical foundations of the generalised autoregressive conditional heteroscedasticity model. They also predict and analyse the volatility of US stock indices and stocks using high-frequency volatility estimates (realised volatility indicators).

The Enterprises and the sustainable development of regions section presents the work 'Model of Cross-Financing for Research and Development Costs in a Federal District' by the authors Rodionov, D., Koshelev, E. and Lo, T.H.V. The subject of this article is to develop a model to optimise and plan the cross-financing of R&D costs in a federal district, which takes into consideration the specific technological and economic results of R&D in these regions.

To solve the problem of Sustainable development of regional infrastructure, the authors Ozhgihin, I., Rudskaya, I. and Abdulayeva, I. clarify specific features and principles of the Russian medical equipment market in their article 'Analysis of the Medical Equipment Market of the Russian Federation: Features and Prospects of Its Development'. The essence of the factors that hinder and promote market growth is revealed, and the principles that need to be considered when forming the development vector are listed. The main factors that positively influence the market for innovative medical equipment are the growth of financial resources in healthcare, the expansion of state guarantees of medical care, an increase in the volume of high-tech care and trends in medical science.

The final section, Management of knowledge and innovation for sustainable development, presents two works. The first is the article 'Methodological Justification for the Expediency of Initiating a Programme of Green Innovations in the Oil and Gas Sector' by the authors Lagutenkov, A., Kranina, A. and Ibragimov, B., which addresses the problems of oil and gas innovations. This article takes a systemic approach to the analysis of green innovations in the Russian Federation's oil and gas sector.

The second work – 'Methods and Tools for Harmonisation of Industrial and Trade Policy in the Light Industry' by Sidorenko, Y., Feofilova, T. and Dixit, S. – presents developed and systematised administrative and economic methods and tools of harmonisation in industrial and commercial policy using the example of the light industry in St. Petersburg. These methods and tools are aimed at improving the balance and mutual orientation of the current industrial and trade policy of St. Petersburg in the light industry at the institutional level. They are also intended to improve the effectiveness of their implementation, eliminate problems faced by business entities in their activities and improve the socio-economic situation of the region.

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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Development of Instrumental Approaches to Forecasting the Volatility of the Return of Financial Assets

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Abstract

Measurement and forecasting of volatility and income correlation are achieved by non-parametric methods using high-frequency price data. Due to accurate calculations of conditional volatility and correlation forecasting, it is possible to correctly identify financial derivatives and make risk decisions and relative asset allocation decisions. This article systematises the methods for modelling the volatility of financial asset returns, considers the theoretical foundations of the generalised autoregressive conditional heteroscedasticity model, and predicts and analyses the volatility of US stock indices and stocks using high-frequency volatility estimates (realised volatility indicators). The stock indices studied are the Dow Jones Industrial Average (DJI), Standard and Poor's 500 (SP500), and the Nasdaq Composite Index (NASDAQCOMP). Stocks analysed include stocks in Microsoft, Bank of America, and Coca-Cola. The results of the study support conclusions regarding the effectiveness of volatility estimators within two Bank of America volatility forecasting models, the superiority of the HAR-RV model for trading options in a specific market, and the best model for Microsoft. Thus, systematic analysis of news information is useful for predicting the volatility of returns on financial assets, but its effectiveness depends on the individual company. Future studies should explore the usefulness of the systematic analysis of news information in predicting the volatility of returns on financial assets in other markets and for other asset classes.

Keywords: volatility, high-frequency volatility estimates, modelling and forecasting methods, yield volatility, financial assets, stock indices, US stocks, information environment

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Развитие Инструментальных Подходов к Прогнозированию Волатильности Доходности Финансовых Активов

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Аннотация

Измерение и прогнозирование волатильности и корреляции доходности активов осуществляется непараметрическими методами, для которых используются высокочастотные ценовые данные. Благодаря точным моделям прогнозирования условной волатильности и корреляции возможно корректное определение производных финансовых инструментов, управление рисками и принятие решений относительно распределения активов. В данной статье проведена систематизация методов моделирования волатильности доходности финансовых активов, рассмотрены теоретические основы общей модели GARCH, а также спрогнозированы и проанализировали волатильность фондовых индексов и акций США при помощи высокочастотных оценок волатильности (показатели реализованной волатильности). Изучаемыми фондовыми индексами являются индексы Dow Jones Industrial Average (DJI), Standard and Poor's 500 (SP500) и Nasdaq Composite Index (NASDAQCOMP). Акции, с другой стороны, включают акции Microsoft, Bank of America и Coca-Cola. Результатами исследования стали выводы касательно эффективности оценщиков волатильности в рамках двух моделей прогнозирования волатильности акций Bank of America, превосходство HAR-RV модели для торговли опционов определенного рынка, найден наилучшая модель для акций Microsoft. В свете приведенных выше результатов был сделан вывод о том, что систематический анализ новостной информации полезен для прогнозирования волатильности доходности финансовых активов, однако его эффективности зависит от конкретной компании. Было рекомендовано, чтобы в будущих исследованиях изучалась полезность систематического анализа новостной информации для прогнозирования волатильности доходности финансовых активов на других рынках и для других классов активов.

Ключевые слова: волатильность, высокочастотные оценки волатильности, методы моделирования и прогнозирования, волатильность доходности, финансовые активы, фондовые индексы, акции США, информационная среда.

Цитирование: Гайомей, Д., Зайцев, А., 2023. Развитие Инструментальных Подходов к Прогнозированию Волатильности Доходности Финансовых Активов. Sustainable Development and Engineering Economics 2, 1. https://doi.org/10.48554/SDEE.2023.2.1

1. Introduction

The trend towards measuring and predicting volatility and correlation of asset returns using non-parametric methods has two directions for study: continued research and development of methods for using volatility information in high-frequency data, and modelling and forecasting volatility in a multidimensional environment that is relevant to practical financial economics. The realised volatility approach, which is the most obvious nonparametric measure of volatility, deals with both directions. The benefit is the lack of modelling of intraday observations of returns, which allows for the accurate measurement and prediction of volatility in multidimensional environments. The inherent problem with modelling and forecasting conditional volatility turns is that volatility is unobservable—what is found—modelling what should be indirect. The problem of lagging returns volatility is frequently addressed by inferring volatility based on characteristic assumption parameters, using, for example, autoregressive conditional heteroscedasticity–generalised autoregressive conditional heteroscedasticity "ARCH-GARCH" or a stochastic volatility model. Therefore, it is necessary to develop alternative approaches that would allow for expanding the available price indicators with additional data available for prompt receipt and research. Such data are indicators of the news, information, and digital components that have an impact on financial market participants (Kulakov, 2004a; Kulakov, 2004b).

The main aim of this study is to develop instrumental approaches to forecasting the volatility of return on financial assets. In common parlance, volatility refers to fluctuations observed in a phenomenon over time. This is the change in the results of an uncertain variable, such as the return on assets. Volatility is a statistical measure of the degree to which a trading price changes over a given period. In terms of returns on financial assets, volatility is the standard deviation of returns on investments on an annualised basis. Alexander (2008) defined volatility as "an annual measure of dispersion in a stochastic process that is used to model logarithmic returns". Andersen et al. (2010) classified approaches to the empirical quantification of volatility into two categories: procedures based on the evaluation of parametric models (parametric measurement and volatility modelling), and direct non-parametric measurements (non-parametric measurement and volatility modelling).

Table 1 summarises the various methods for empirically quantifying return volatility within parametric and non-parametric approaches.

Table 1. Approaches to measuring and modelling the volatility of returns on financial assets

Source: compiled by the authors

Parametric measurement and volatility modelling	**Non-parametric measurement and volatility modelling**
Discrete-time parametric volatility models **Continuous time parametric volatility models** **Implied volatility based on a parametric model**	**Measures of instantaneous volatility,** $h \to 0$: 1. ARCH filters and smoothers (ARCH filters and smoothers are used to measure instantaneous volatility; filters only use information up to time $\sigma_t^2 . \tau = t$ while smoothers are based on $\tau > t$. **Implemented measures of volatility, h > 0** 1. The implemented volatility methods directly measure conditional volatility over fixed time intervals. 2. They can be classified based on whether the notional volatility measurement uses only the price data contained within the [t-h,t] interval itself, or whether filtering/smoothing techniques are used to also include returns outside [t-h,t]. 3. The most obvious non-parametric measure of volatility is the "ex-post return squared spanning the time interval [t-h,t], that is, measures of realised volatility".
Methods for parametric measurement of volatility	
Volatility models in continuous time	**Discrete Time Models**

Continuous diffusion along the sampling path 1. Invariant diffusion in time 2. Ornstein-Uhlenbeck (OU) and Cox-Ingersoll-Ross (1985) processes (CIR) 3. Square root volatility model **Hopping diffusions and processes controlled by the levy**	**ARCH-GARCH models** 1. ARCH (m) (Engle, 1986) 2. GARCH (1,1) (Engle, 1986) 3. GARCH (p,q) 4. Symmetric normal GARCH Model 5. Asymmetric GARCH models 5.1 GJR-GARCH (Glosten, 1993) 5.2 Exponential GARCH (E-GARCH) (Nelson, 1991) 5.3 Asymmetric power ARCH model ("apARCH") (Ding, 1993) 5.4 Component sGARCH model ('csGARCH') (Lee and Engle, 1999) 5.5 GARCH family model ("fGARCH") (Hentschel, 1995) 6. Abnormal GARCH models 6.1 Student tGARCH (Bollerslev, 1987) 6.2 Normal mixture GARCH 6.3 Markov switching GARCH (Hamilton and Susmel, 1994) 7. Multivariate GARCH models 7.1 The VECH model presented by Bollerslev et al. (1988) 7.2 Baba-Engle-Craft-Kroner (BEKK) model formalised by Engle and Kroner (1995) 7.3 Factorial and orthogonal GARCH models 7.4 The class of constant conditional correlation (CCC) models proposed by Bollerslev (1990) 7.5 Dynamic conditional correlation (DCC) proposed by Engle III and Sheppard (2001) **Stochastic volatility models** 1. Autoregressive volatility model, or SARV(p) model: 1.1 Lognormal stochastic autoregressive volatility model 1.2 Stochastic autoregressive square root model or SR-SARV

Approaches to Modeling Financial Asset Return Volatility Using High-Frequency Data	
Method/Evaluator	**Description**
Realised variance or realised volatility (rRVar) (Andersen, 2003)	This estimator calculates daily realised variance or realised volatility (RV)
Realised covariances using subsample averaging (rAVGCov)	It calculates realised variances by averaging RV over partially overlapping grids (Zhang et al., 2005)
Modulated realised covariance (rMRCov)	The modulated realised covariance computes a univariate or multivariate pre-averaged estimator by Hautsch and Podolskij (Hautsch and Podolskij, 2013).
Two-time scale of covariance estimation (rTSCov)	It calculates the covariance matrix on a two-time scale (Zhang et al., 2005; Zhang, 2011).
Reliable estimation of covariance on a two-time scale (rRTSCov)	It calculates the robust two-time covariance matrix (Boudt and Zhang, 2015)
Implemented kernel estimator (rKernelCov)	It calculates the realised covariance using the kernel estimator
Realised two power covariance (rBPCov)	It calculates the realised BiPower covariance (rBPCov) (Barndorff-Nielsen and Shephard, 2004)
Minimum realised variance (rMinRVar)	It calculates rMinRVar (Andersen et al., 2012)
Median realised variance (rMedRVar,)	It calculates rMinRVar (Andersen et al., 2012)
Threshold Covariance (rThresholdCov)	It calculates the threshold covariance matrix (Mancini and Gobbi, 2012)
Hayashi-Yoshida Covariance (rHYCov)	It calculates the Hayashi-Yoshida covariance estimate (Hayashi and Yoshida, 2005)

Realised appearance weighted covariance (rOWCov)	It calculates the realised distance weighted covariance (rOWCov) (Boudt and Zhang, 2015)
Realised semi-dispersion of high-frequency reciprocal series (rSVar)	It calculates the realised semivariances (Barndorff-Nielsen et al., 2008)
Realised range based variance (RRV)	It computes a range-based realised estimator (Christensen and Podolskij, 2007)
Quantile-based realised variance (QRV)	It calculates the quantile realised variance (Christen et al., 2010)
Estimating duration based realised variance (DRV) in Andersen, Dobrev, and Schaumburg (2009)	It calculates the long-term realised variance (Andersen et al., 2009)

Let σ_n^2 and σ_n be the variance and volatility of the market variable on day n, respectively. Let ***S*** denote the value of the variable at the end of the *i-th* day. For σ_n, there will be dispersion and volatility will rush to day n respectively. Let ***S*** denote the value of the variable at the end of the *i-th* day. Let u_i be the continuously added variable returns during the *i-th* day:

$$u_i = ln\frac{S_i}{S_{i-1}}(1) \tag{1}$$

An objective estimate of the daily variance, σ_n^2, based on the most recent observations at u_i is:

$$\sigma_n^2 = \frac{1}{m-1}\sum_{i=1}^{m}\left(u_i - \underline{u}\right)^2 \tag{2}$$

Let's make the following changes to the above formula for estimating the variance, σ_n^2 ,:

- u_i is defined as the percentage change in the market variable between the end of day *i*-1 and the end of day *i*, so that

$$u_i = \frac{S_i - S_{i-1}}{S_{i-1}} \tag{3}$$

- $u_i = 0$;

- m-1 is replaced by m**.**

The above changes simplify the original variance formula to:

$$\sigma_n^2 = \frac{1}{m}\sum_{i=1}^{m}u_{n-i}^2 \tag{4}$$

However, there is still a problem with this. The problem with the above simplified formula for calculating the variance is that it gives a high weight density $u_{n-1}^2, u_{n-2}^2 \ldots., u_{n-m}^2$.,,, (i.e. profitability). Our goal is to conditionally estimate volatility, and predictively assign large amounts of losses. The model that adopts this is:

$$\sigma_n^2 = \sum_{i=1}^{m}\alpha_i u_{n-i}^2 \tag{5}$$

The variable α_i is the amount of weight assigned to the observation ***i*** days ago. α_i are positive and must sum to one, that is:

$$\sum_{i=1}^{m}\alpha_i = 1 \tag{6}$$

An extension of the idea in the above weighting schemes is to assume that there is a long-term average variance and that some weight should be given to it. The result is a model that takes the following form:

$$\sigma_n^2 = \gamma V_L + \sum_{i=1}^{m} \alpha_i u_{n-i}^2 \tag{7}$$

where V_L is the unconditional variance and γ is the weight given to V_L . The sum of the weights must be equal to one, so we have

$$\gamma + \sum_{i=1}^{m} \alpha_i = 1 \tag{8}$$

The above model is called the ARCH(m) model. It was introduced by Engle (1982). It estimates the variance based on the long-term mean variance, V_L , and ***m*** observations. If we $\omega = \gamma V_L$, the ARCH(m) model becomes

$$\sigma_n^2 = \omega + \sum_{i=1}^{m} \alpha_i u_{n-i}^2 \tag{9}$$

A generalisation of the above model is the GARCH model. The GARCH model generalises Engle's (1982) ARCH model. In GARCH (1,1), σ_n^2 is calculated based on the following equation:

$$\sigma_n^2 = \lambda V_L + \alpha u_{n-1}^2 + \beta \sigma_{n-i}^2 \tag{10}$$

where λ is the weight assigned to V_L , α is the weight assigned to u_{n-1}^2 , and β is the weight assigned to σ_{n-i}^2 . The sum of the weights must be equal to one, so it follows that:

$$\gamma + \alpha + \beta = 1 \tag{11}$$

If we set $\omega = \gamma V_L$, GARCH(1,1) becomes:

$$\sigma_n^2 = \omega + \alpha u_{n-1}^2 + \beta \sigma_{n-i}^2 \tag{12}$$

The given estimated values ω,α and β, γ can be calculated as:

$$\gamma = 1 - \alpha - \beta \tag{13}$$

The long-term variance V_L will then be given as:

$$V_L = \frac{\omega}{\gamma} \tag{14}$$

To ensure a stable GARCH (1,1) process, it is required that:

$$\alpha + \beta < 1 \tag{15}$$

"(1, 1)" in GARCH (1,1) indicates that σ_n^2 is calculated based on the most recent observation u^2 and the most recent variance estimate, that is, σ_n^2 is calculated u_{n-1}^2 and σ_{n-i}^2 . The general GARCH (p, q) model computes σ_n^2 using the most recent p observations on u^2 and the most recent q variance estimates (Hull, 2018). The main difference between parametric and non-parametric approaches is related to the choice of the time interval to which the measure of volatility refers, for example, a discrete interval, where h > 0, or a point in time (instantaneous) measure, where h → 0.

Considering the ARCH-GARCH models, there are times when volatility is unusually high, and there are times when volatility is unusually low. There is extensive empirical evidence for the clustering of volatility in financial markets, dating back to Mandelbrot (1963). Volatility clustering has significant implications for option pricing, hedging, and risk measurement (Andersen et al., 2006.; Kornikov et al., 2002). A big shock to markets leads to changes in volatility and further increases the likelihood of another big shock. This must be considered when pricing options and assessing portfolio risks (Egorova, 2002; Senko, 2001).

GARCH models have been introduced to capture the clustering of returns volatility (Chekulaev et al., 2004). Given that GARCH models reflect volatility clustering, their predictions are not equal to the current estimate. GARCH volatility can be above or below average in the short term, but as the forecast horizon increases, GARCH volatility forecasts converge towards long-term volatility. The advantage of GARCH is that it calculates short- and medium-term volatility forecasts based on a robust econometric model. GARCH models have been very successful in predicting notional return volatility. They have been finalised and expanded to include additional features. Traditional GARCH models have been extended by incorporating implemented measures into the GARCH equation to enhance their predictive capabilities. Important works in this direction include Engle and Gallo (2006), Hansen (2012), Shepard and Sheppard (2010).

2. Materials and Methods

We estimated, predicted, and analysed the volatility of US stock indices and stocks using existing high-frequency volatility estimates (realised volatility measures). The stock indices studied are the Dow Jones Industrial Average (DJI), Standard and Poor's 500 (SP500), and the Nasdaq Composite Index (NASDAQCOMP). Stocks include stocks in Microsoft, Bank of America, and Coca-Cola. We also valued call and put options on Bank of America, Coca-Cola, and Microsoft using various high-frequency volatility forecasts. The study used both primary and secondary data sources. Daily and intraday data on the prices of the studied stocks and indices, as well as data on option contracts, were obtained from official foreign sources that are participants in the US financial market. Secondary data were obtained based on an in-depth study of scientific periodicals, as well as reference books, monographs, and textbooks in the subject area of research.

To evaluate and predict the volatility of the above stocks and stock indices, we downloaded historical closing price data (data for 5 minutes) for these assets from Finam (Broker Finam, 2022)1. The sample data covered the period 2020.02.06–2021.09.02. We also downloaded option chains for Microsoft (MSFT), Bank of America (BAC), and Coca-Cola (KO) at the end of each trading day from Yahoo Finance2. Option chains covered the period from 2021.08.02 to 2021.09.02. To estimate the volatility of stocks underlying option contracts, this study used the recently proposed high-frequency volatility estimates available in the volatility literature. Table 1 provides data to describe these volatility estimates. To keep tabular presentations simple, we have abbreviated the above high-frequency volatility estimates as follows: RV, AV, MRC, TS, RTS, Epa, Par, mTH, BP, MiRV, MeRV, Thr, HY, OW, SV.do, SV.up, RRV, QRV, and mQRV.

To predict realised volatility, this study used Corsi's (2009) heterogeneous autoregressive model of realised variance (HAR-RV model). The dynamics of the HAR-RV model are represented by:

$$RV_{t+1d}^{(d)} = c + \beta^{(d)} RV_t^{(d)} + \beta^{(w)} RV_t^{(w)} + \beta^{(m)} RV_t^{(m)} + \varepsilon_{t+1d}^{(d)} \quad (16)$$

$RV_t^{(d)}$ is the realised volatility for day *t*.

$RV_t^{(w)}$ is the average realised volatility for the last week (last 5 trading days), calculated as follows:

$$RV_t^{(w)} = \frac{1}{5}\left(RV_t^{(d)} + RV_{t-1}^{(d)} + RV_{t-2}^{(d)} + RV_{t-3}^{(d)} + RV_{t-4}^{(d)}\right) \quad (17)$$

$RV_t^{(m)}$ is the average realised volatility for the last month (last 22 trading days), calculated as follows:

$$RV_t^{(m)} = \frac{1}{22}\left(RV_t^{(d)} + RV_{t-1}^{(d)} + \ldots + RV_{t-20}^{(d)} + RV_{t-21}^{(d)}\right) \quad (18)$$

The HAR-RV model was estimated using the ordinary least squares method, assuming that at

[1] Broker Finam. URL: http//finam.ru/. Access date 04/10/2022

[2] Information about financial instruments. URL: https://finance.yahoo.com/. Access date 04/10/2022

time *t* the conditional mean value ε_(t+1d)^((d)) is zero. For our study, we used a HAR-RV model with the following characteristics: Type, HAR; Lags, 1 5 22; Window Type, "rolling"; and Maximum lags, 22.

We used a 5-minute series of returns (30,808 5-returns) to estimate and predict stock volatility. We were of the opinion that almost all information from high-frequency data is contained in 5-minute data, so we decided to estimate and predict stock volatility using a 5-minute sampling rate. To value option contracts, this study used the Black–Scholes–Merton formulas for the prices of European call and put options in determining the price of option contracts.

3. Results and Discussion

The most popular stock indices for tracking the dynamics of the US stock market are the Dow Jones Industrial Average (DJIA), the Standard and Poor's 500 (S&P500), and the Nasdaq Composite (NASDAQCOM). We estimated the realised volatility of these stock indices for the period 2020.01.06-2021.10.15 using high-frequency volatility estimates. The figures below show volatility estimates obtained for the period under review (Figure 1) (Gayomey, 2022).

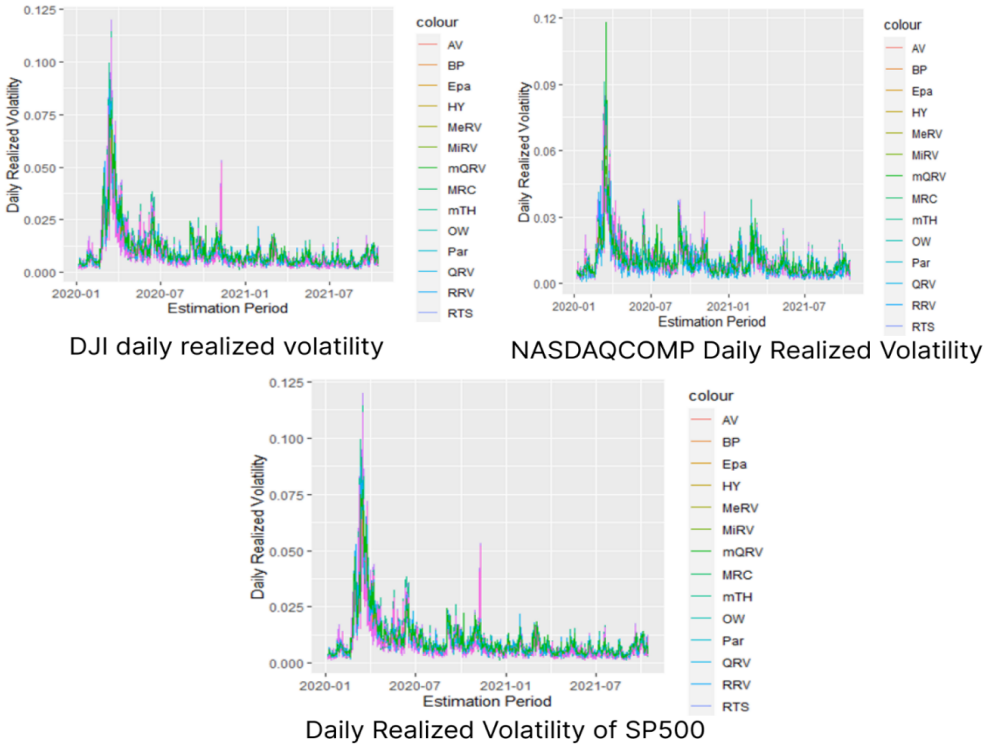

Figure 1. DJI daily realised volatility, NASDAQCOMP Daily Realised Volatility, Daily Realised Volatility of SP500

The realised volatility of all three stock indices shows that the US stock market was volatile towards the end of the first quarter of 2020 (volatility of 10% and above). The figure also shows that from the beginning of the second quarter of 2020 until the end of the evaluation period (2021.10.15), realised volatility has consistently been below 5%, indicating a stable price level in the market. Estimates, however, show that volatility changes over time. Volatility clustering was also observed. We then projected volatility for the Dow Jones Industrial Average, S&P 500, and Nasdaq Composite for the next 30 days (2021.10.18–2021.11.26) using high-frequency volatility estimates. We also compared the volatility forecasts with the CBOE Volatility Index (VIX) for the next 30 days (2021.10.18–2021.11.26) to assess the accuracy of the forecast. The CBOE Volatility Index (VIX) is a popular measure of expected stock market volatility based on S&P 500 index options. It is based on the prices of options on the SPX index with the nearest expiration dates and thus gives a 30-day forecast of volatility in advance (Gayomey,

2022a).

Figures 2-4 show the expected annual change in the Dow Jones Industrial Average, Nasdaq Composite, and S&P500 over the next 30 days: 2021.10.16–2021.11.26, according to the realised volatility approach.

Expected annual change in the DJIA over the next 30 days: 2021.10.16-2021.11.26

Implemented measures	Volatility forecast	CBOE Volatility Index	Forecast Loss
RV	16.2897	16.3000	0.0103
AV	12.3653	16.3000	3.9347
MRC	8.8899	16.3000	7.4101
TS	10.7024	16.3000	5.5976
RTS	9.4100	16.3000	6.8900
Epa	14.8305	16.3000	1.4695
Par	14.8305	16.3000	1.4695
mTH	14.8305	16.3000	1.4695
BP	12.4816	16.3000	3.8184
MiRV	11.5836	16.3000	4.7164
MeRV	11.2091	16.3000	5.0909
Thr	10.2701	16.3000	6.0299
HY	10.9682	16.3000	5.3318
OW	8.7731	16.3000	7.5269
SV.do	9.9558	16.3000	6.3442
SV.up	12.4042	16.3000	3.8958
RRV	13.7790	16.3000	2.5210
QRV	12.9370	16.3000	3.3630
mQRV	12.7933	16.3000	3.5067

Note: The highlighted cell indicates high-frequency volatility estimators whose volatility forecast was close to that of the CBOE Volatility Index (VIX).)

Figure 2. Expected annual change in the DJIA over the next 30 days: 2021.10.16–2021.11.26

Expected annual change in the NASDAQ COMP over the next 30 days: 2021.10.16-2021.11.26

Implemented measures	Volatility forecast	CBOE Volatility Index	Forecast Loss
RV	16.2312	16.3000	0.0688
AV	22.6563	16.3000	-6.3563
MRC	11.5679	16.3000	4.7321
TS	12.3602	16.3000	3.9398
RTS	10.9333	16.3000	5.3667
Epa	16.9672	16.3000	-0.6672
Par	16.9672	16.3000	-0.6672
mTH	16.9672	16.3000	-0.6672
BP	11.1340	16.3000	5.1660
MiRV	10.5268	16.3000	5.7732
MeRV	10.4024	16.3000	5.8976
Thr	9.6806	16.3000	6.6194
HY	11.0299	16.3000	5.2701
OW	8.7697	16.3000	7.5303
SV.do	10.3777	16.3000	5.9223
SV.up	12.1616	16.3000	4.1384
RRV	13.4633	16.3000	2.8367
QRV	10.3678	16.3000	5.9322
mQRV	11.8126	16.3000	4.4874

Note: The highlighted cell indicates high-frequency volatility estimators whose volatility forecast was close to that of the CBOE Volatility Index (VIX).)

Figure 3. Expected annual change in the NASDAQ COMP over the next 30 days: 2021.10.16-2021.11.26

Expected annual change in the SP500A index over the next 30 days: 2021.10.16-2021.11.26

Implemented measures	Volatility forecast	CBOE Volatility Index	Forecast Loss
RV	14.8594	16.3000	1.4406
AV	20.4546	16.3000	-4.1546
MRC	9.2252	16.3000	7.0748
TS	10.2678	16.3000	6.0322
RTS	9.0695	16.3000	7.2305
Epa	15.2176	16.3000	1.0824
Par	15.2176	16.3000	1.0824
mTH	15.2176	16.3000	1.0824
BP	9.9485	16.3000	6.3515
MiRV	9.5236	16.3000	6.7764
MeRV	9.3557	16.3000	6.9443
Thr	8.6203	16.3000	7.6797
HY	9.5312	16.3000	6.7688
OW	7.9498	16.3000	8.3502
SV.do	8.9054	16.3000	7.3946
SV.up	11.4562	16.3000	4.8438
RRV	11.6070	16.3000	4.6930
QRV	8.6699	16.3000	7.6301
mQRV	10.1537	16.3000	6.1463

Note: The highlighted cell indicates high-frequency volatility estimators whose volatility forecast was close to that of the CBOE Volatility Index (VIX).)

Figure 4. Expected annual change in the SP500A index over the next 30 days: 2021.10.16-2021.11.26

According to Figures 2–4, for the DJI and NASDAQCOMP indices, the realised volatility (RV) estimate had the lowest forecast error compared to the CBOE Volatility Index, while for the SP500 index, the realised core estimates (Epa, Par, and MTH) performed the best. The results in the tables also show that the projections for the realised volatility and the realised core estimates for the three indices are, in most cases, very close to the forecast for the CBOE volatility index; that is, the forecast of these two estimates is very similar to the CBOE Volatility Index forecast. The tables also show that more high-frequency volatility estimators provide lower volatility forecasts for the US stock market during the period under review. Consider specific examples (Gayomey, 2022b).

Estimating and predicting the volatility of Bank of America, Coca-Cola, and Microsoft stocks

We predicted and analysed the annual volatility of these stocks. The figures below show the implemented volatility estimates for Bank of America, Coca-Cola, and Microsoft for the period 2020.01.06–2021.10.15 (fig. 5).

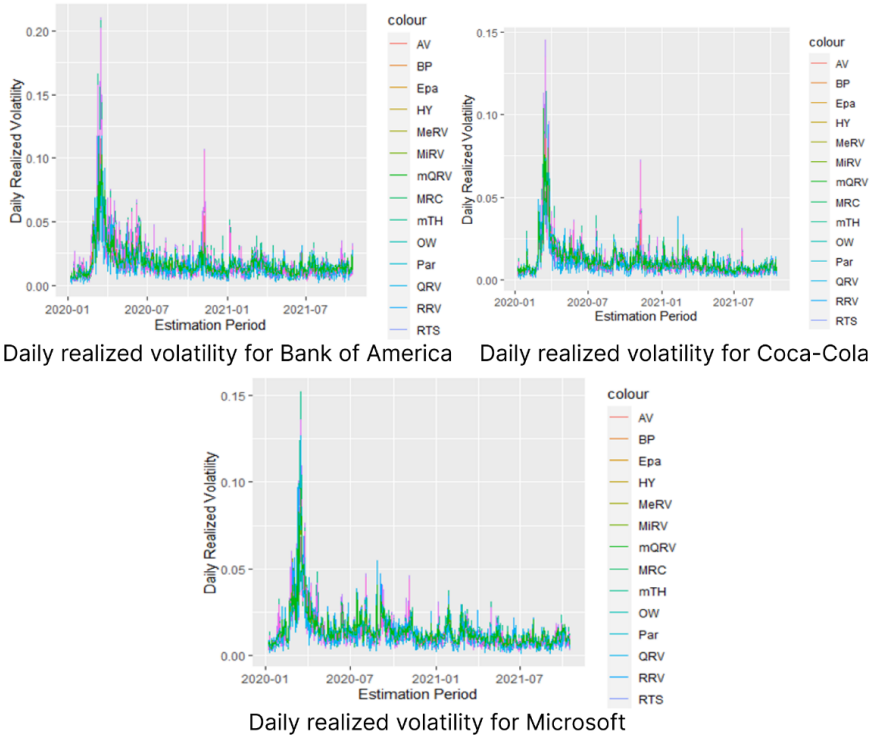

Figure 5. Daily realised volatility for Bank of America, for Coca-Cola, and Microsoft

The charts above show the realised volatility, confirming the volatility situation in the US stock market at the end of the first quarter of 2020, which remains relatively stable during the remainder of the forecast period. Of all three stocks, Microsoft shares experienced the least volatility during the remainder of the forecast period (Gayomey, 2022a).

Figure 6 shows the annual volatility forecast for Bank of America, Coca-Cola, and Microsoft.

Annual Volatility Forecast for BAC, KO and MSFT: Realized Volatility Metrics

Implemented measures	BAC	KO	MSFT
RV	0.2922	0.1802	0.2145
AV	0.2327	0.1454	0.1816
MRC	0.1955	0.1045	0.1385
TS	0.2213	0.1352	0.1809
RTS	0.2069	0.1174	0.1516
Epa	0.2945	0.1689	0.2094
Par	0.2945	0.1689	0.2094
mTH	0.2945	0.1689	0.2094
BP	0.2377	0.1567	0.1833
MiRV	0.2372	0.1546	0.1828
MeRV	0.2294	0.1474	0.1788
Thr	0.2194	0.1309	0.1667
HY	0.2245	0.1432	0.1814
OW	0.2060	0.1147	0.1517
SV.do	0.2030	0.1335	0.1653
SV.up	0.2060	0.1248	0.1453
RRV	0.2608	0.1708	0.2227
QRV	0.1961	0.1438	0.1762
mQRV	0.2397	0.1639	0.1939

Note: Cells highlighted in blue indicate the minimum volatility forecast, while cells highlighted in pink indicate the maximum volatility forecast

Figure 6. Annual volatility forecast for BAC, KO, and MSFT: Realised volatility metrics

Figure 6 shows that the minimum volatility prediction for all three stocks is given by a modulated realised covariance (MRC) estimate. The table also shows that the maximum volatility forecast for Bank of America, Coca-Cola, and Microsoft was derived using realised variance (RV), realised core (Epa, Par, and mTH), and realised range (RRV) volatility estimates, respectively. Table 5 further confirms that all volatility estimates project high volatility for Bank of America (annualised volatility forecast of at least 19% and a maximum of 29%). It can also be seen that Coca-Cola's year-on-year volatility forecast across all volatility estimates is less than 19%, with a minimum volatility forecast of 10%. For Microsoft's stock, the year-on-year volatility forecast ranges from 13.8% to 22%. The forecast above clearly shows that Bank of America is expected to be more volatile over the coming year compared to other stocks, while Coca-Cola is expected to remain more stable over the same period (Gayomey, 2022b).

4. Conclusion

The purpose of this article was to develop methods for modelling and forecasting the volatility of financial asset returns based on the assessment of high-frequency data and the dynamics of the information environment. To this end, we reviewed and systematised theoretical and methodological approaches to measuring and forecasting the volatility of return on financial assets. We also estimated, predicted, and analysed the volatility of stock indices and US stocks using existing high-frequency volatility estimates (realised volatility measures). The stock indices studied are the Dow Jones Industrial Average (DJI), Standard and Poor's 500 (SP500), and the Nasdaq Composite Index (NASDAQCOMP). Stocks, on the other hand, include stocks in Microsoft, Bank of America, and Coca-Cola. We also valued call and put options on Microsoft, Bank of America, and Coca-Cola using various high-frequency volatility forecasts.

The results of the analysis and systematisation of theoretical and methodological approaches to measuring and forecasting the volatility of the profitability of financial assets have shown that the existing approaches and methods for assessing and forecasting the volatility of the profitability of financial assets have some limitations that make the use of these methods for predicting volatility unsatisfactory. In particular, within the framework of the GARCH model and stochastic volatility, the following are salient:

- Volatility is usually derived from daily returns squared, which are objective but noisy estimates of daily conditional volatility.

- High-frequency data are rarely used.

- Evaluation of GARCH and stochastic volatility models is difficult.

- Evaluation of these models often gives unsatisfactory results. Forecasts are inaccurate.

- Standardised returns usually have fat tails, which leads to the search for suitable error distributions that can adequately reflect the empirical distributions of returns.

- Multivariate modelling of volatility and correlation can be extremely complex, and practical models are often only applicable to very small dimensions.

- These volatility methods do not take into account changes in the news background of the digital information environment.

In the high-frequency volatility approach (HAR-RV model), the realised volatility plotted from the highest frequency data should give the best possible estimate of the cumulative volatility, that is, Iv as $m \to \infty$. However, in practice, the sampling rate is limited by the actual supply or transaction frequency. Moreover, very high-frequency prices are affected by market microstructure, such as supply and demand rebound effects, price discreteness, etc., leading to bias and inconsistency in realised volatility. These methods for assessing volatility also do not consider changes in the news background of the digital information environment.

These findings prompt the conclusion that the systematic analysis of news information is useful for predicting the volatility of returns on financial assets, but its effectiveness depends on the individual company. Future studies are encouraged to explore the usefulness of the systematic analysis of news information in predicting the volatility of returns on financial assets in other markets and for other asset classes.

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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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Model of Cross-Financing for Research and Development Costs in a Federal District

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Abstract

The issue of an optimal amount of funding for research and development (R&D) costs within the Russian regions that have the appropriate scientific potential is investigated. For this purpose, a model is developed to optimise and plan the cross-financing of R&D costs in a federal district, which takes into consideration the specific technological and economic results of R&D in the regions. This model makes different R&D expenditures by type of work dependent on three planning directions of innovative development in the regions of the district: investment, production, and financial. All three processes are considered simultaneously. Investment planning is reflected by investment in fixed capital, production planning (by gross regional product), and financial planning (by indebtedness of legal entities on loans). Nonlinear regressions of R&D costs by type of work are optimised using a genetic algorithm, simulated annealing, and pattern search, which eventually allow calculation of the reserve or deficit of the corresponding R&D costs in each region of the federal district. The results of global optimisation reflect the conclusion that in conditions of saving federal budget funds, the federal district can partially finance all R&D costs in those regions that need it. Identifying such regions more reasonably requires analysing this situation in more detail, that is, in terms of various R&D costs by type of work. For the Privolzhsky Federal District, the findings indicate that the Samara region, the Republic of Bashkortostan, and the Perm region are the most in need of financing various types of R&D expenditures. However, the main donor for the costs of different types of R&D is the Nizhny Novgorod region. The findings of this model can allow considerable savings in the federal budget funds allocated for scientific and, consequently, innovative development of the regions.

Keywords: innovative development, region investment planning, production planning, financial planning, research and development costs

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Модель Перекрестного Финансирования Затрат на Научно-Исследовательские Работы в Федеральном Округе

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Аннотация

Исследуется вопрос оптимального объема финансирования затрат на научно-исследовательские работы (НИР) в пределах регионов страны, имеющих соответствующий научный потенциал. Для этого **р**азработана модель оптимизации и планирования перекрестного финансирования затрат на НИР в федеральном округе, учитывающей конкретные технологические и экономические результаты НИР регионов округа. Данная модель ставит в зависимость различные затраты на НИР по видам работ от трех направлений планирования инновационного развития регионов округа: инвестиционного, производственного, финансового. При этом все три процесса рассматриваются одновременно. Инвестиционное планирование отражают инвестиции в основной капитал, производственное планирование – валовой региональный продукт, а финансовое планирование – задолженность юридических лиц по кредитам. Нелинейные регрессии затрат на НИР по видам работ оптимизируются с помощью генетического алгоритма, имитационного отжига и поиска по шаблону, что позволяет в итоге вычислить резерв или недостаток соответствующих затрат на НИР в каждом регионе федерального округа. Результаты глобальной оптимизации позволяют сделать вывод, что в условиях экономии федеральных бюджетных средств федеральный округ может частично сам профинансировать все затраты на НИР в тех регионах, которые в этом нуждаются. Чтобы более обоснованно определить такие регионы, необходимо анализировать эту ситуацию подробнее, т. е. в разрезе различных затрат на НИР по видам работ. Для Приволжского федерального округа (ПФО) получено, что наиболее нуждающимися в финансировании различных видов затрат на НИР оказываются Самарская область, республика Башкортостан и Пермский край. Но при этом основным донором затрат на различные виды НИР является Нижегородская область. Это позволило бы существенно сэкономить федеральные бюджетные средства, выделяемые на научное и, как следствие, инновационное развитие регионов страны.

Ключевые слова: инновационное развитие, регион, инвестиционное планирование, производственное планирование, финансовое планирование, затраты на научно-исследовательские работы

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1. Introduction

Currently, the cost of research and development (R&D) is an important component of Russian state budget expenditures. The financing of R&D allows the state to solve the problems of global technological challenges, including the problems of implementing the import substitution policy. However, the issues of the optimal amount of funding for R&D expenditures within the country and its regions, which have the appropriate scientific potential, have not been completely resolved. By scientific potential, we refer to both research institutes and universities, and scientists working in these institutes. It seems impossible to solve such problems in isolation from the specific technological and economic results of regional R&D. Planning of these results, as well as the resources necessary to achieve them, is an urgent task to optimise the costs of R&D. In this regard, we distinguish three types of planning: investment, production, and financial. We consider all three processes simultaneously. This will allow us to cover a wide range of tasks to optimise R&D costs in the regions and contribute to their innovative development.

Similar optimisation issues have been studied in detail by many scientists in relation to the business development planning of companies. For example, Kruschwitz and Lorenz (2019) studied the processes of simultaneous investment and financial planning, as well as simultaneous investment and production planning. Limitovskiy (2019) supplemented their results by taking into consideration the systemic financial effects of investment programmes. By such effects, the author referred to cross-financing, cross-subsidization, cross-holding, and cross-hedging. Despite the usefulness of these studies, there is still a need to create programmes of innovative development for manufacturing companies and industrial regions. In this regard, Fabiana et al. (2016) studied how the technological innovation process occurs in small and medium technology companies located in Paraíba Valley Metropolitan Region and Northern Coast, Brazil. The study revealed that the development of innovations depends on the type of economic activity that the company develops and the interactions it undertakes with the internal and external environments. Vasconcellos et al. (2016) argued that the resources invested in research do not guarantee immediate practical application. With the aim of developing and presenting a methodology for evaluating a research portfolio and selecting the best research investment, the author showed that risk and return criteria should be used to manage R&D portfolios when selecting projects.

To this end, the present study explores the issue of the optimal amount of funding for R&D costs within the regions of the country that have the appropriate scientific potential.

2. Literature review

Although the abovementioned findings are of real practical interest for implementing the successful development of commercial firms, we aim to leverage them to optimise and plan national and regional R&D expenditures. Other useful results from various researchers in this field include those of Xu (2018), who found that regional investment in R&D in the area of human resources has a positive effect on the efficiency of the internal R&D of an enterprise. The scientist formulated three policy recommendations: increasing regional investment in R&D, expanding, and consolidating the enterprise as the basis of R&D status, and increasing regional investment in R&D in human resources. Chen et al. (2019) found that the production elasticity of R&D capital in China was much higher than that of R&D personnel, suggesting that R&D capital is the main driver of the research results. The elasticity of substitution between R&D capital and personnel has changed from replacement to additional since 2014. To ensure sustainable growth in research results, the contribution of R&D with positive output elasticity should be increased, or the contribution of R&D with negative output elasticity should be decreased with the necessary compromises made according to the ratio of substitution between the two R&D inputs.

Dobrzanski and Bobowski (2020) determined whether funds spent on R&D are used in the countries of the Association of Southeast Asian Nations (ASEAN). Fifteen countries were examined over the period of 2000-2016. R&D spending efficiency was measured using a non-parametric data envelopment analysis (DEA) methodology, which measures input–output efficiency. Hong Kong and the Philippines were found to be the best performing countries in R&D when analysed using the constant returns to

scale approach. However, Hong Kong, Indonesia, Singapore, and the Philippines are the most efficient ASEAN countries under the variable returns to scale approach. The study also confirmed that increasing spending on innovation leads to disproportionate effects. Dehmer et al. (2019), relying on recent developments in spending on science in countries such as China, Korea, India, and Brazil, have found that global scientific activity is undergoing major shifts. Using the evolving pattern of past R&D expenditures for forward-looking projections and in the absence of notable changes in science policy and spending priorities, the authors predicted the continuation of a major shift in R&D geography towards Asian countries and an ongoing large and, in many respects, growing gap between the scientific haves and have-nots in the world.

Kiselakova et al. (2018) examined the relationship between R&D expenditures and the development of global competitiveness in Slovakia, as well as in member states of the European Union from Central and Eastern Europe (CEE EU (11)). To assess the competitiveness of the CEE EU (11) countries, the researchers used the Global Competitiveness Index processed by the World Economic Forum and found that an increase in R&D spending can contribute significantly to the level of competitiveness of CEE EU (11) countries. All the analyses confirmed the importance of focusing on increasing R&D expenditure, especially in the higher education sector, as it has a significant impact on improving the global competitiveness of the CEE EU (11) countries in the case of a number of Global Competitiveness Index sub-indices.

In this regard, the issue of national and regional R&D expenses is especially important. According to Feoktistova (2014), when planning R&D and its financing, the project approach should be used by selecting the expected results from implementing a research project as one of the key criteria and selecting the results already achieved by the research project by its would-be executor as the key criterion. Gaponenko (2018) considered situations in which it is potentially possible to reduce the actual costs of performing R&D: (1) performing R&D similar to work previously performed by the same contractor—a scientific organisation or a researcher; (2) performing R&D similar to work previously performed by other contractors—scientific organisations; (3) performing (possibly simultaneous) of similar R&D for different customers; (4) using previously obtained research results or previously assembled installations in new research, if the subjects of old and new research are not analogous to each other; and (5) including in the terms of reference of tasks that do not correspond to the goal of R&D, the results of which can be used, for example, in another R&D or a publication, a patent.

Nevertheless, in our opinion, these studies did not sufficiently elaborate on the problem of selecting reasonable quantitative benchmarks for planning the R&D expenditures of the regions. The issue of planning the redistribution of R&D expenditures among regions also remains open. On the contrary, in the work by Yashin et al. (2020), a foresight of the evolution of the innovation system in a federal district based on the use of a multipurpose genetic algorithm revealed that to increase the synergy effect of the federal district, it is planned to redirect investment resources and R&D costs to those regions where resources are scarce. This will eventually increase the average per-capita income in the regions of the federal district, which will lead to population growth. This highlights the necessity of solving the problem of optimising regional R&D expenditures and, above all, selecting the most rational methods for this purpose. Thus, Ildırar et al. (2016) provided new estimates of the impact of R&D expenditures on economic growth. They found that there are different types of R&D expenditures, each of which has a different significance for economic growth. The authors found that all R&D expenditures have a positive and significant impact on economic growth in individual OECD countries, but their importance varies. Therefore, policymakers should develop policies to stimulate R&D based on the characteristics of these countries. Accordingly, countries should allocate more resources to different types of R&D expenditures to achieve sustainable growth rates.

Salimi and Rezaei (2018) pointed out that assigning the same level of importance to different R&D indicators, which is a common approach in existing studies, may oversimplify the R&D measurement process and lead to misinterpretations of effectiveness and, consequently, incorrectly chosen R&D strat-

egies. Their findings showed that assigning different weights to different R&D indicators (as opposed to simple averages) leads to different rankings of firms and allows R&D managers to formulate more effective strategies to improve their firm's R&D effectiveness by applying knowledge of the importance of various R&D indicators. Bina et al. (2015) proposed comprehensive criteria for selecting R&D and innovation projects under conditions of uncertainty and taking into consideration the real constraints applicable to the Brazilian electricity sector using a combination of integer programming formulations and a method based on the PROMETHEE method. The authors identified the best results of the proposed application in solving the regulatory problems of the electricity sector, which emphasises the compliance of companies with R&D and innovation expenditure commitments. Thus, although selecting R&D and innovation projects is not a typical example of optimisation, under certain regional, sectoral, or organisational constraints, it may be the best solution.

Huang et al. (2020), taking into consideration the paradox of the spillover effect of R&D spared from the global supply chain, used a computational general equilibrium model with the GTAP v10 database to analyse the impact of Japanese public investment in R&D on key sectors of the global supply chain—chemical and pharmaceutical, electronic equipment, machinery, and transportation equipment—to assess its output, foreign trade, and welfare. Performance parameters initiated by public investments in R&D are calibrated from the SciREX Policymaking Intelligence Assistance System - Economic Simulator (SPIAS-e). The simulation results showed a significant increase in Japanese production and exports of chemical and pharmaceutical, electronic equipment, and transportation equipment. The study provides a comprehensive global analysis of manufacturing networks and an analysis to assess the spillover effects of R&D investments.

Sadollah et al. (2020) set the main goal of optimisation as improving overall sustainability, including environmental, social, economic, and energy resource sustainability, through the implementation of corresponding target functions. Since energy optimisation is one of the main objectives of sustainable development, it is studied from an energy perspective. Further, the concept, definitions, and elements of sustainability and optimisation were presented, and metaheuristic optimisation algorithms used in recently published papers related to sustainability and sustainable development were reviewed. Hyk (2021) determined the optimal cost structure for innovation and its impact on sales revenues, with a focus on the use of elements of economic and mathematical modelling. The scientific novelty of the work lies in the development of a model that substantiates the relationship between the studied indicators of costs for innovation, enables predicting the amount of revenue from sales, and ensures the achievement of its optimal value. The author also assessed the impact of the economy of innovation on the environment, which results in preserving the potential of natural resources to achieve sustainable economic development.

In the present study, we apply metaheuristic algorithms to optimise R&D costs in the regions of the federal district. This will further allow for planning the cross-financing of R&D within a single district. Of the available metaheuristic algorithms, we use the following three, which have significant advantages: (1) a genetic (evolutionary) algorithm (GA) is a highly effective way to find multiple efficient solutions in a single simulation run (Kalyanmoy, 2001); (2) simulated annealing (SA) makes it possible to avoid "trapping" in the local extrema of the function being optimised and to continue the search for a global extremum (Lopatin, 2005). Compared to GA, adaptive simulated annealing (ASA) does not yield to genetic algorithms in most problems and wins in many (Ingber and Rosen, 1992); and (3) pattern search (PS), a direct search method, can be used to solve problems for which the target function is not differentiable or even continuous (Conn et al., 1991; Conn et al., 1997; Kolda et al., 2006).

1. Materials and methods

Using the above metaheuristic algorithms, we created a model to optimise and plan the cross-financing of R&D costs in a federal district (Fig. 1). The model includes five stages, as shown in Fig. 1.

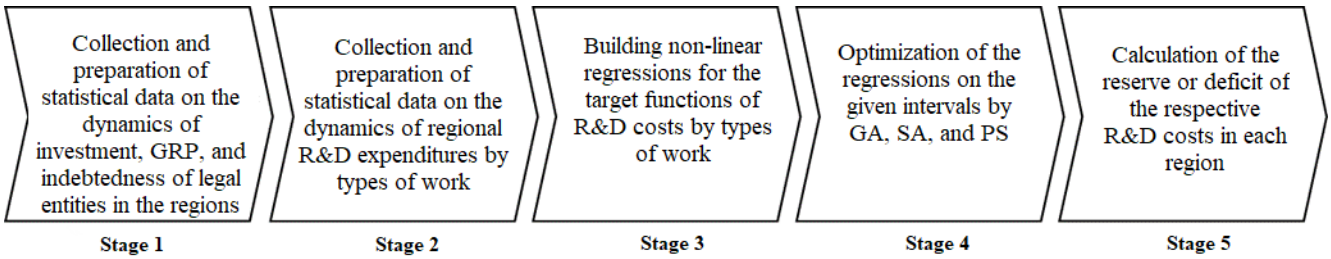

Fig. 1. A model for optimising and planning the cross-financing of R&D costs in a federal district

Stage 1 – Collect and prepare statistical data on the dynamics of investment, GRP, and indebtedness of legal entities in the regions. At this stage, we collect and adjust for inflation data on the dynamics of investment in fixed capital (x1), gross regional product (GRP) (x2), and the debt of legal entities on loans (x3) of the regions of the federal district over a long period spanning 10 years. These data are available on the website of the Federal State Statistics Service1. Here, parameter x1 characterises investment planning, x2 refers to production planning, and x3 captures the financial planning of the district.

Stage 2 – Collect and prepare statistical data on the dynamics of regional R&D expenditures by type of work. Here, we collect and adjust for inflation statistical information on the internal current expenditures on R&D in total (y), as well as by types of work, which are divided into fundamental research (y1), applied research (y2), and developments (y3). These data are collected for the same period of time as in the previous stage.

Stage 3 – Build non-linear regressions for the target functions of R&D costs by type of work. We use multiple non-linear regressions of R&D costs of the form $y = f\left(x_1, x_2, x_3\right)$, which more realistically reflects economic processes in comparison with linear ones. These are constructed using the Statistica software.

Stage 4 – Optimise the regressions on the given intervals by GA, SA, and PS. We perform global optimisation of the regression target functions in MATLAB using the three metaheuristic algorithms: GA, SA, and PS. To refine the results of the GA and SA methods, we supplement the optimisation results of the target functions with the hybrid functions of pattern search and the interior-point method (Babynin and Zhadan, 2008). That is, the GA or SA algorithms are applied first, and then their results are used as a starting point for the subsequent optimisation of the target function. This allowed for obtaining better solutions in each specific case of optimisation of the corresponding R&D costs.

In each particular case, we search for the global maximum of R&D costs in the federal district; that is, we calculate how much funds can be allocated to R&D maximally and on what values of parameters x1, x2, and x3 this maximum depends. We then optimise the obtained regressions for each type of R&D on the segments of parameters x1, x2, and x3, which are typical for each region of the federal district under study.

Stage 5 - Calculate the reserve or deficit of the respective R&D costs in each region. At this stage, we compare the obtained optimum R&D expenditures for each region of the district with its actual maximum value for the period under study and calculate the reserve or deficit of the respective R&D expenditures in each region as a difference between the actual and optimum values. This enables planning the possibilities of cross-financing R&D within the same district in more detail, that is, by region.

3. Results

In what follows, we demonstrate how this model works using the example of the Privolzhsky Federal District (PFD), considering only those regions (regions or republics) in which pilot innovation territorial clusters from the list approved by the government of the Russian Federation are located. These are the industrial regions where PFD's main R&D is carried out.

[1] Federal State Statistics Service. URL: https://www.gks.ru

Stage 1 – Collect and prepare statistical data on the dynamics of investment, GRP, and indebtedness of legal entities in the regions. At this stage, the necessary initial data were collected from the website of the Federal State Statistics Service2 and adjusted for inflation. They are presented in the 2020 prices in columns *x*1, *x*2, and *x*3 of Table 1. Since the above website contains data on domestic current expenditures on R&D only for 2010 and the period 2015–2020, we took the data on investment in fixed capital, GRP, and indebtedness of legal entities on loans for the same years.

Table 1. Initial data on the Privolzhsky Federal District in 2020 prices (million rubles)

Year	Investments in fixed capital	Gross regional product	Indebtedness of legal entities on loans	Internal current costs of R&D by type of work			
				Total	Fundamental research	Applied research	Developments
	x_1	x_2	x_3	y	y_1	y_2	y_3
1. Nizhny Novgorod Region							
2010	354041	1203299	335116	49755.1	2257.5	7763.1	39734.3
2015	286275	1345281	438699	69259.4	2328.5	6359.8	60571.1
2016	268126	1341478	392014	76640.5	2197.6	7618.6	**66824.4**
2017	276481	1422534	356981	72458.5	2283.8	7463.4	62711.2
2018	280429	1478448	361167	71571	2399.5	9863.7	59307.8
2019	309749	1462590	385278	**80671.8**	4970.6	**9972.7**	65728.4
2020	383102	1474561	361554	68750.3	**5220.1**	8560.3	54969.9
2. Republic of Mordovia							
2010	75165	**194177**	80800	884	156.1	267.3	460.6
2015	64242	219641	114539	996.8	147.6	293.9	555.3
2016	60822	233116	97935	896.2	141.2	173.2	581.9
2017	65984	242754	112000	885.7	126.5	212.9	546.4
2018	56551	245720	98970	1049.4	168.1	470	411.4
2019	54751	240875	102512	1009.9	125.3	438	446.6
2020	**48969**	238909	88007	1081.5	107.1	433.5	540.9
3. Ulyanovsk Region							
2010	88464	328536	75419	9242.4	175.8	1451.9	7614.6
2015	96771	370808	96010	9672	228	5190	4254.2
2016	81562	375920	99058	9114.9	262.8	4511.5	4340.6
2017	94796	375951	**71717**	12565.8	230.2	2038.7	10296.8
2018	89649	376064	84054	12206.9	302.8	1267.4	10636.7
2019	75555	339226	78955	9659.3	218.5	1791.1	7649.6
2020	61181	312577	85313	10288.1	265.6	2607.6	7414.9
4. Samara Region							
2010	284644	1282274	390241	22679.8	665.6	1249.4	20764.6
2015	368865	1540461	423126	19921.2	681.9	1616.6	17622.8
2016	296748	1468075	449779	13454.2	641.7	1220.8	11591.5
2017	292574	1520781	453792	15631.9	844.7	1282.3	13504.9
2018	286479	1633018	398565	14861.2	649	1197.6	13014.5
2019	301737	1632825	319233	19929.2	614.4	1020.9	18294
2020	202462	1648019	298558	15492.5	761	713.0	14018.6
5. Perm Territory							
2010	257417	1148574	276981	12308.4	2383.9	1325.1	8599.4
2015	275493	1295517	312592	14528.9	982.9	1873.9	11671.9
2016	276655	1266576	221842	14107	1027.2	1568.8	11511
2017	276337	1343064	215175	15007.6	843.4	1745.3	12418.8
2018	263369	1425398	243162	13788.9	1032.6	1428.7	11327.6
2019	305392	1456557	274316	15591	1090.2	1716.1	12784.6

[2] Federal State Statistics Service. URL: https://www.gks.ru

2020	290460	1467320	306550	15636.3	1148.2	1797.1	12691
6. Udmurt Republic							
2010	94280	506122	121689	821.4	451.2	85.2	285
2015	99676	630842	114739	1297.2	380.9	163.9	752.4
2016	100692	614648	119263	1263	337.2	155.7	770.1
2017	94358	622590	89959	1986	237.5	458.6	1289.9
2018	104844	682300	89920	2481.4	657.3	233.1	1591.1
2019	105451	668360	110349	2332.8	731.4	126.8	1474.5
2020	107187	675545	85536	1846.9	811.5	123.1	912.2
7. Republic of Tatarstan							
2010	606333	1846263	540376	11366.2	1526.8	1864.5	7974.9
2015	**751565**	2274027	660546	13926.5	2495.5	1772.2	9658.8
2016	735575	2234011	**710836**	13841.8	2196.6	1856.1	9789.2
2017	718755	2412123	699269	17574.2	2626.4	2249.4	12698.4
2018	680801	**2669465**	594273	18420.6	2422.4	2444.6	13553.6
2019	672302	2522721	496504	16617.8	2611.1	2232	11774.7
2020	655319	2549636	414215	16878.6	2896.6	2557.3	11424.7
8. Republic of Bashkortostan							
2010	283173	1772189	213167	7236.3	1806	1958.3	3472
2015	386986	1603409	371940	9869.2	1420.5	996	7452.7
2016	410388	1546257	334792	9960.4	1193.1	2229.1	6538.3
2017	314046	1589666	328141	9739.9	1161.9	2568.5	6009.5
2018	289657	1809428	327419	11196.7	1408.7	2582.6	7205.5
2019	337919	1746876	328865	10490.5	1361	2644.6	6484.9
2020	326850	1754979	323670	10527.2	1417.7	2483.4	6626.1

We forecast the missing data on investment in fixed capital and GRP in 2020 prices, using the period from 2009–2018 and the Wolfram Alpha search service3. The results of the forecast are shown in Table 1 in italics.

Stage 2 – Collect and prepare statistical data on the dynamics of regional R&D expenditures by type of work. At this stage, we collected and adjusted for inflation statistical information on the internal current costs of R&D in total, as well as by type of work: fundamental research, applied research, and developments. These data were collected for the same period as in the previous stage. They are presented in the 2020 prices in columns y, y_1, y_2, and y_3 of Table 1.

Stage 3 – Build non-linear regressions for the target functions of R&D costs by type of work. According to the data in Table 1, the following most accurate non-linear regressions were obtained in *Statistica*:

- regression for all R&D costs (Fig. 2)

$y = 82426.01 + 0.06x_2 - 8303.97 \ln x_3$, $R^2 = 0.948$, adjusted $R^2 = 0.938$;

- regression for fundamental research (Fig. 3)

$y_1 = 1782 - \frac{57170107}{x_1} - \frac{73870171}{x_3}$, $R^2 = 0.484$, adjusted $R^2 = 0.444$;

- regression for applied research (Fig. 4)

$y_2 = -58921.7 + 3523.1 \ln x_1 + 1925.2 \ln x_3$, $R^2 = 0.244$, adjusted $R^2 = 0.185$;

- regression for developments

$y_3 = -315317.4 - 0,02542966x_2 - 0.6432493x_3 - \frac{950912100}{x_1} + 981.9057\sqrt{x_3} + \frac{9314139000}{x_3}$, $R^2 = 0.447$,

adjusted $R^2 = 0.392$.

[3] Wolfram Alpha search service. URL: www.wolframalpha.com

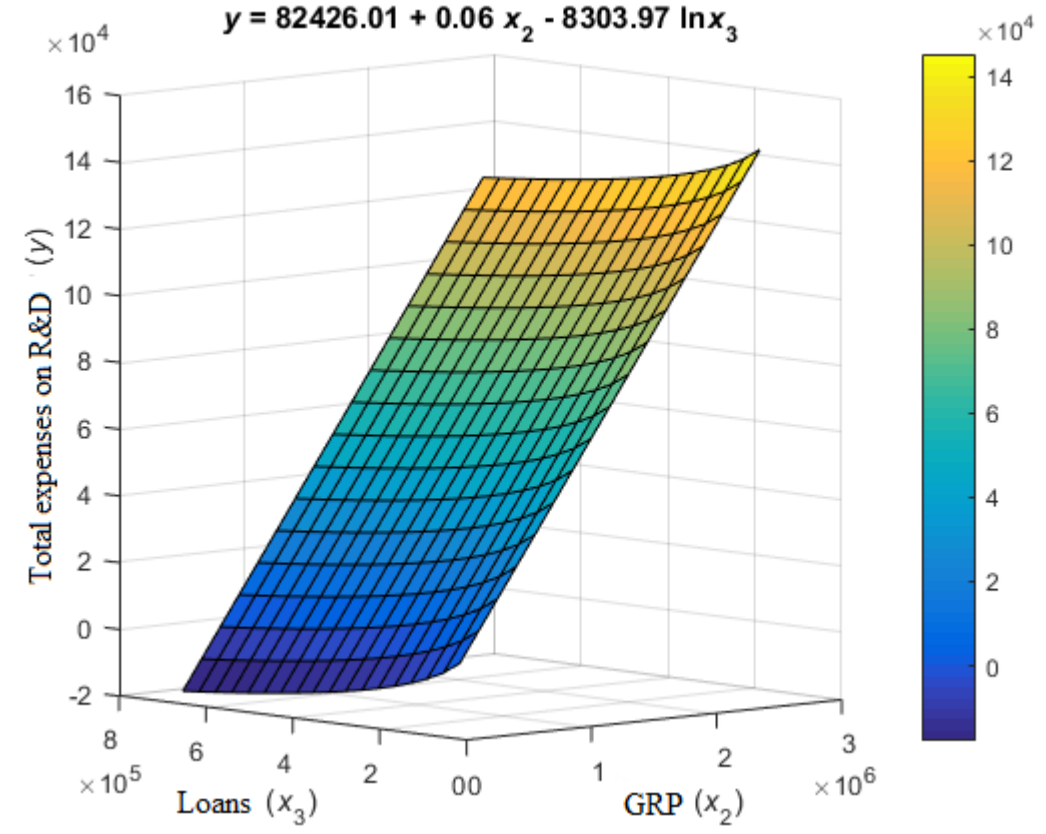

Fig. 2. Regression plot for all R&D costs

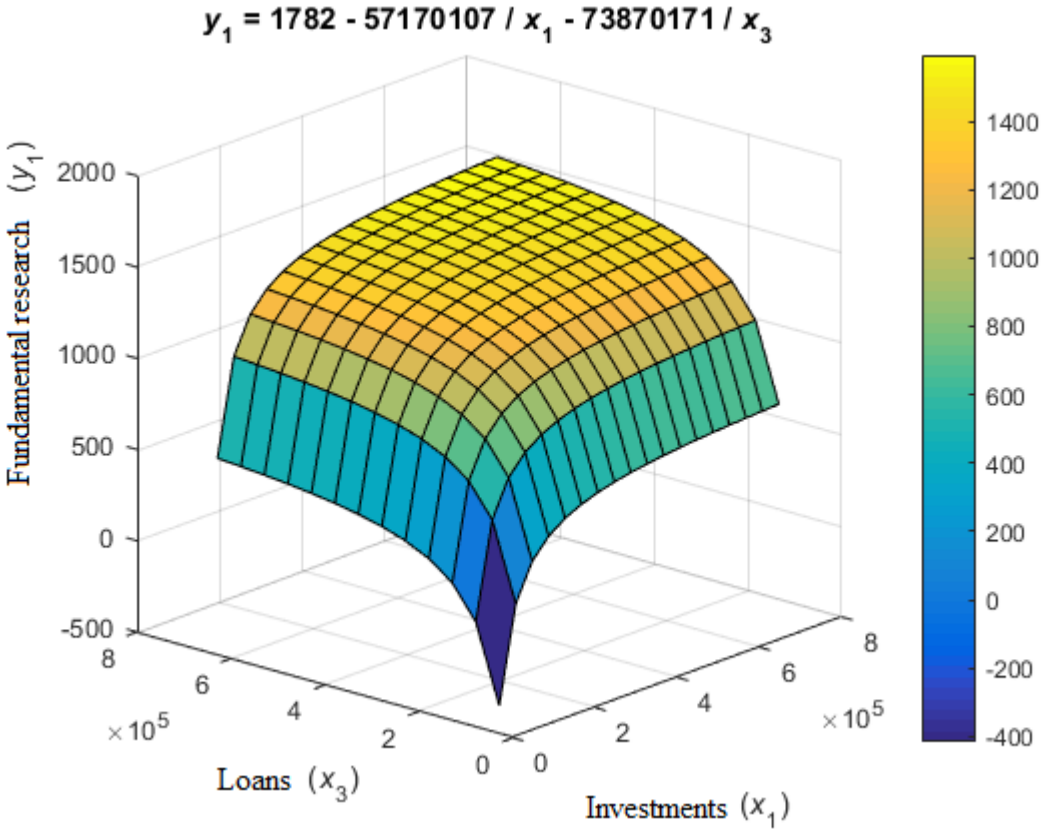

Fig. 3. Regression plot for fundamental research

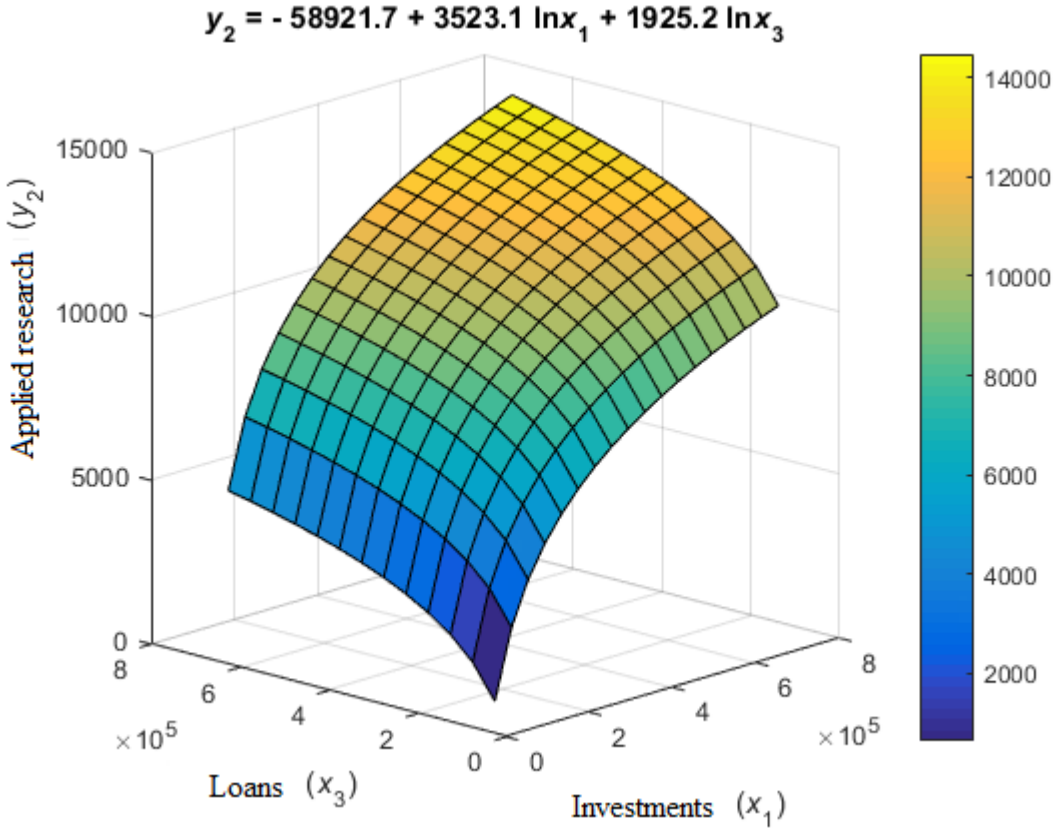

Fig. 4. Regression plot for applied research

Stage 4 – Optimize the regressions on the given intervals by GA, SA, and PS. The global optimisation of the target regression functions was performed using MATLAB. GA, SA, and PS were used for this purpose. To refine the results of the GA and SA methods, the optimisation results were supplemented with hybrid functions of the pattern search and interior-point method (fmincon). All target functions were investigated on the segments of actual values of parameters x1, x2, and x3 for the period under study, according to the data in Table 1, marked in bold type.

As an example, for all the costs of R&D in PFD, the optimisation results are given in Table 2. As shown in the table, the most reliable result is obtained by PS. Adding this algorithm or the interior-point method (fmincon) as a hybrid function for GA or SA also allowed achieving a high-quality solution to the optimisation problem.

Table 2. Results of the global optimisation of the regression for all R&D costs for PFD (million rubles)

Algorithm	Investments in fixed capital	Gross regional product	Indebtedness of legal entities on loans	Total expenses on R&D	Maximum actual value
	x_1	x_2	x_3	y	y
GA	-	2 655 302	84 056	147 583.4	80 671.8
GA + fmincon	-	2 669 465	71 717	149 751.5	
GA + PS	-	2 669 465	71 717	149 751.5	
SA	-	1 474 311	381 367	64 166.1	
SA + fmincon	-	2 669 465	71 717	149 751.5	
SA + PS	-	2 669 465	71 717	149 751.5	
PS	-	2 669 465	71 717	149 751.5	

Table 2 also shows that the maximum actual value of all R&D costs is significantly lower than the maximum possible total costs of R&D with the respective values of GRP and indebtedness of legal entities on loans. This indicates that there are real possibilities for financing R&D in a larger volume. This issue, however, requires a more detailed solution. Thus, we conducted the same global optimisation of

all types of R&D costs for each PFD region separately, applying the same metaheuristic algorithms. The previous target regression functions were investigated for each region on its segments of actual values of parameters x1, x2, and x3 for the period under study, according to the data in Table 1. The results of global optimisation are shown in Tables 3-6.

Table 3. Results of the global optimisation of the regression for all R&D costs by the regions of PFD (million rubles)

Region	Investments in fixed capital	Gross regional product	Indebtedness of legal entities on loans	Total expenses on R&D	Maximum actual value	Reserve (+) or deficit (-) of expenses
	x_1	x_2	x_3	y	y	Δy
1. Nizhny Novgorod	-	1 478 448	335 116	65 487.9	80 671.8	15 183.9
2. Mordovia	-	245 720	80 800	3 336.6	1 049.4	- 2 287.2
3. Ulyanovsk	-	376 064	71 717	12 147.5	12 565.8	418.3
4. Samara	-	1 648 019	298 558	76 621.3	22 679.8	- 53 941.5
5. Perm	-	1 467 320	215 175	68 499	15 636.3	- 52 862.7
6. Udmurtia	-	682 300	85 536	29 058.4	2 481.4	- 26 577
7. Tatarstan	-	2 669 465	414 215	135 189.2	18 420.6	-116 768.6
8. Bashkortostan	-	1 809 428	213 167	89 103.4	11 196.7	- 77 906.7

Table 4. Results of the global optimisation of the regression for fundamental research by the regions of PFD (million rubles)

Region	Investments in fixed capital	Gross regional product	Indebtedness of legal entities on loans	Fundamental research	Maximum actual value	Reserve (+) or deficit (-) of expenses
	x_1	x_2	x_3	y_1	y_1	Δy_1
1. Nizhny Novgorod	383 102	-	438 699	1 464.4	5 220.1	3 755.7
2. Mordovia	75 165	-	114 539	376.5	168.1	- 208.4
3. Ulyanovsk	96 771	-	99 058	445.5	302.8	- 142.7
4. Samara	368 865	-	453 792	1 464.2	844.7	- 619.5
5. Perm	305 392	-	312 592	1 358.5	2 383.9	1 025.4
6. Udmurtia	107 187	-	121 689	641.6	811.5	169.9
7. Tatarstan	751 565	-	710 836	1 602	2 896.6	1 294.6
8. Bashkortostan	410 388	-	371 940	1 444.1	1 806	361.9

Table 5. Results of the global optimisation of the regression for applied research by the regions of PFD (million rubles)

Region	Investments in fixed capital	Gross regional product	Indebtedness of legal entities on loans	Applied research	Maximum actual value	Reserve (+) or deficit (-) of expenses
	x_1	x_2	x_3	y_2	y_2	Δy_2
1. Nizhny Novgorod	383,102	-	438,699	11,382.8	9,972.7	-1,410.1
2. Mordovia	75,165	-	114,539	3,059.7	470	-2,589.7
3. Ulyanovsk	96,771	-	99,058	3,670.3	5,190	1,519.7
4. Samara	368,865	-	453,792	11,314.5	1,616.6	-9,697.9
5. Perm	305,392	-	312,592	9,931.7	1,873.9	-8,057.8
6. Udmurtia	107,187	-	121,689	4,426.6	458.6	-3,968
7. Tatarstan	751,565	-	710,836	14,686.1	2,557.3	-12,128.8
8. Bashkortostan	410,388	-	371,940	11,307.4	2,644.6	-8,662.8

Table 6. Results of the global optimisation of the regression for developments by the regions of PFD (million rubles)

Region	Investments in fixed capital	Gross regional product	Indebtedness of legal entities on loans	Developments	Maximum actual value	Reserve (+) or deficit (-) of expenses
	x_1	x_2	x_3	y_3	y_3	Δy_3
1. Nizhny Novgorod	383,102	1,203,299	438,699	40,998.4	66,824.4	25,826
2. Mordovia	75,165	194,177	80,800	9,503.2	581.9	-8,921.3
3. Ulyanovsk	96,771	312,577	71,717	13,603.7	10,636.7	-2,967
4. Samara	368,865	1,282,274	453,792	39,572.4	18,294	-21,278.4
5. Perm	305,392	1,148,574	312,592	30,065.7	12,784.6	-17,281.1
6. Udmurtia	107,187	506,122	121,689	3,732.2	1,591.1	-2,141.1
7. Tatarstan	751,565	1,846,263	526,041	27,961.4	13,553.6	-14,407.8
8. Bashkortostan	410,388	1,546,257	371,940	27,670.3	7,452.7	-20,217.6

Stage 5 – Calculate the reserve or deficit of the respective R&D costs in each region. The last columns of Tables 3–6 present the results of calculating the reserve or deficit of the respective R&D costs in each region as the difference between the actual and the optimal values. This allowed for planning the possibilities of R&D cross-financing within one district. For example, in Table 3, in the Nizhny Novgorod and Ulyanovsk regions, the actual maximum total R&D costs exceed the optimal costs. This leads to the tentative conclusion that in the conditions of saving federal budget funds, PFD can partially finance all R&D costs in those regions that need it. According to the data in the last column of Table 3 regarding the lack of total R&D costs, we can include the Republic of Mordovia, the Samara region, the Perm region, the Udmurt Republic, and the Republics of Tatarstan and Bashkortostan in such regions. Moreover, according to Table 3, the region in need is the Republic of Tatarstan.

To better identify these regions, the outcome was analysed in more detail—in terms of the various costs of R&D by type of work. The results in Tables 4–6, for example, show that the Republic of Tatarstan, on the contrary, had some reserve in the expenditures on fundamental research, which could be redirected to other regions of PFD. Further, for Tatarstan, the shortage of expenditures on applied research (Table 5) and developments (Table 6) in total was significantly lower than the shortage of all R&D expenditures, as reflected in Table 3. By contrast, according to Tables 4–6, the Samara region, the Republic of Bashkortostan, and the Perm region were the most in need of financing various types of R&D costs. However, the main donor of the reserve of costs for various types of R&D remained the Nizhny Novgorod region, if we again consider the internal cross-financing of R&D costs within the limits of PFD. This would allow significant savings in the federal budget funds allocated for scientific and, consequently, innovative development in the country's regions.

4. Discussion

The present results correlate with the conclusions obtained by Yashin et al. (2020). Namely, for the Samara region, the model revealed the greatest deficit in current R&D expenditures compared to the optimal plan, which amounted to 10,673 million rubles. The region can be partially compensated for at the expense of R&D reserves of the Nizhny Novgorod and Ulyanovsk regions, the Udmurt Republic, and the Republics of Tatarstan and Bashkortostan. In total, such a reserve amounts to 8,412 million rubles, which should be allocated to the Samara region. The synergy effect of such an reallocation would be 86,153.7 million rubles. The reserve of 8,412 million rubles can also be partially allocated to R&D in the Republic of Mordovia and the Perm region, and the remainder should be transferred to the Samara region. However, the synergy effect of the entire PFD in this case will be the same as in the case if the entire reserve is allocated to R&D in the Samara region.

Comparing the obtained results with the experience of other researchers, it can be noted that in planning R&D and its financing, Feoktistova (2014) highlighted the use of the project approach, the choice of the expected results of a research project as one of the key criteria, and the choice of the results

already achieved by a research project by its potential performer as the key criterion. Gaponenko (2018) also considered situations in which it is potentially possible to reduce the actual costs of performing R&D: (1) performing R&D similar to work previously performed by the same contractor—a scientific organisation or a researcher; (2) performing R&D similar to work previously performed by other contractors—scientific organisations; (3) performing (possibly simultaneous) similar R&D for different customers; (4) using previously obtained research results or previously assembled installations in new research terms if the subjects of old and new research are not analogous to each other; and (5) including in the terms of reference tasks that do not correspond to the goal of R&D, the results of which can be used, for example, in another R&D or a publication, a patent.

We propose justified quantitative guidelines for planning the costs of R&D in an industrial region based on global optimisation of the indicated costs. The described approach can contribute to better decision making by state structures and their experts with regard to planning the innovative development of industrial regions of the country.

5. Conclusion

The following points highlight the most important findings of the study:

1. Currently, the issues of the optimal financing of R&D expenditures within the country and its regions, which have the appropriate scientific potential, have not yet been completely solved. It seems impossible to solve such problems in isolation from the specific technological and economic results of regional R&D. Planning of these results, as well as the resources required for their achievement, is an urgent task to optimise R&D expenditures. In this regard, we distinguished three types of planning: investment, production, and financial. We considered all three processes simultaneously. This allows for covering a wide range of tasks to optimise R&D costs in the regions and contribute to their innovative development.

2. The results of global optimisation allow us to draw the conclusion that in the conditions of saving the federal budget funds, the federal district authorities can partially finance all R&D costs in those regions that need it. To identify such regions more reasonably, it is necessary to analyse this situation in more detail—in terms of various R&D costs by type of work.

3. For PFD, the Samara region, the Republic of Bashkortostan, and the Perm region are the most in need of financing various types of R&D expenditures. However, the main donor of the reserve of expenditures on various types of R&D is the Nizhny Novgorod region. This is the essence of the internal cross-financing of R&D costs within PFD. It would allow significant savings in the federal budget funds allocated for scientific and, consequently, innovative development of the country's regions.

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SECTION 3

SUSTAINABLE DEVELOPMENT OF REGIONAL INFRASTRUCTURE

РАЗДЕЛ 3

УСТОЙЧИВОЕ РАЗВИТИЕ РЕГИОНАЛЬНОЙ ИНФРАСТРУКТУРЫ

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Analysis of the Medical Equipment Market of the Russian Federation: Features and Prospects of Its Development

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Abstract

One of the key directions in the development of modern healthcare is tightly concentrated around technological modernisation, the main task of which is to achieve a high quality of life for the population based on sustainable economic growth and the use of advanced technologies. With their help, the priority of national health care will no longer be the treatment of identified diseases but the prevention and maintenance of health. Limited access to advanced achievements in the field of medical equipment and a significant level of competition from foreign manufacturers with significantly greater financial strength have led to a low share of the domestic medical equipment market on a global scale. The lagging behind the world's leading manufacturers in terms of the commercialisation of innovations is accompanied by a high cost of equipment for the production of medical devices, a high level of import dependence in components, the inability of manufacturers to provide services for the integrated equipment of medical institutions, and a shortage of qualified personnel capable of solving the problems of creating new products and organising modern production in the medical industry. This article analyses the medical equipment market of the Russian Federation and reveals specific features and principles. The essence of the factors that hinder and promote market growth is revealed, and the principles that need to be considered when forming the development vector are listed. The main factors that positively influence the market of innovative medical equipment are the growth of financial resources in healthcare, the expansion of state guarantees of medical care, an increase in the volume of high-tech care, and trends in medical science. However, certain institutional factors inhibit the development of the market, particularly those related to regulatory and legal regulation as well as the interaction of market participants.

Keywords: medical equipment, medical equipment market, factors of formation, features of the equipment market, conditions of increased uncertainty

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Анализ Рынка Медицинского Оборудования Российской Федерации: Особенности и Перспективы Его Развития

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Аннотация

Одно из ключевых направлений развития современного здравоохранения плотно концентрируется вокруг технологической модернизации, главной задачей которой является достижение высокого качества жизни населения на основе устойчивого экономического роста и использования передовых технологий. С их помощью приоритетом отечественного здравоохранения станет уже не лечение выявленных заболеваний, а предотвращение и поддержание здоровья. Ограничение доступа к передовым достижениям в области медицинской техники и значительный уровень конкуренции со стороны зарубежных производителей, обладающих существенно большей финансовой силой, привело к низкой доле отечественного рынка медицинской техники в мировом масштабе. Отставание от ведущих мировых производителей в части коммерциализации инноваций сопровождается высокой стоимостью оборудования для производства медицинских изделий, высоким уровнем импортозависимости в комплектующих, неспособностью производителей предоставлять услуги по комплексному оснащению медицинских учреждений и дефицитом квалифицированных кадров, способных решать задачи создания новой продукции и организации современного производства в медицинской промышленности. В данной статье проведен анализ рынка медицинской техники Российской Федерации, выявлены специфические черты и принципы. В рамках работы была раскрыта сущность факторов, препятствующих и способствующих росту рынка, а также перечислены принципы, на которые необходимо обратить внимание при формировании вектора развития. В качестве основных факторов, положительно влияющих на рынок инновационной медицинской техники, можно выделить рост объема финансовых ресурсов в здравоохранении, расширение госгарантий медицинской помощи, увеличение объемов высокотехнологичной помощи, тенденции в медицинской науке и ряд других, в то же время, определенные институциональные факторы тормозят развитие рынка, в частности, связанные с нормативно-правовым регулированием, а также с взаимодействием участников рынка.

Ключевые слова: медицинская техника, рынок медицинской техники, факторы формирования, особенности рынка техники, условия повышенной неопределенности.

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1. Introduction

According to a UN study (Population Prospects, 2019)1, global life expectancy will increase to 77.1 years by 2050. The fastest-growing age group is rightly considered to be people over 65 years old. Notably, 1 in 6 people in the world will be over 65 years old (16%), compared to 1 in 11 in 2019 (9%). This trend will inevitably lead to an increase in the need for medical care and solutions to several social and medical problems, such as the search for additional medical personnel, the expansion of funding for the social and healthcare sectors, and the creation and development of new programmes to promote a healthy lifestyle among the population. With the ageing of the population, medical equipment is required to provide ambulance and care in the hospital while diagnostic equipment needs to be improved.

The projection of the global demographic trend onto the Russian Federation unearths a galaxy of problems. For example, older people experience difficulties in obtaining medical care, thereby highlighting the insufficient level of its availability. The impossibility of obtaining expert advice due to such reasons as low mobility, the presence of queues, and the complicated "path" to a narrow specialist leads to the fact that older people (especially those over 75 years old) with health conditions in Russia seek advice less and less. According to experts, it is possible to develop remote consultations (such as telemedicine), which, of course, requires solving the issue from the point of view of medical technology. A separate area is technical equipment, taking into account advanced innovative developments in geriatric care (outpatient and inpatient), as well as the development of technical means for the rehabilitation of the disabled.

The active use of innovations allows the global medical equipment market to develop, even under conditions of strict government regulation. The innovative development of medical equipment is associated with both the use of advanced technologies and the creation of new medical products that allow for solving existing problems on a fundamentally new basis, and recognised world manufacturers are actively using this in their activities. For example, Philips uses new technological solutions in its manufactured devices for ultrasound diagnostics, computed tomography, and magnetic resonance imaging, which allow for more accurate diagnostics due to enhanced image quality. Experts have also noted an increase in the number of permits issued for domestic medical equipment based on innovative principles of operation.

The final assessment of the quality of medical equipment can be given by direct users—and patients and people who take care of their health and doctors working in various sectors of the economy (physical culture and sports, social services, spa services, etc.). Therefore, an important aspect is not only the quality of the medical equipment itself but also its service and after-sales service. Timely prevention of failures in the operation of equipment and maintenance allows medical institutions to avoid equipment replacement and increase their service life; therefore, offering technical support during operation increases the competitiveness of medical equipment manufacturers.

The relevance of the chosen topic lies in the fact that medical technology is associated with all aspects of ensuring a high level of healthcare: diagnosis, treatment, disease prevention, and rehabilitation. The duration of a healthy life for the population depends on high-tech care, which is determined by innovative trends in medical technology. The aggravation of sanctions changes, the emerging need for import substitution, and fiercer competition with international corporations have complicated the development of the Russian medical equipment market.

The purpose of this article is to characterise the medical equipment market in the Russian Federation, identifying the factors of its formation and features.

Currently, there are two trends in the development of the medical industry, which are reflected in the development of the medical equipment market. One direction is the strengthening consolidation of major market players joining long-term partnerships with enterprises operating in the fields of gene, in-

[1] Population Prospects 2019: Highlights. United Nations: website. URL: https://population.un.org/wpp/Publications/Files/WPP2019_10KeyFindings.pdf (accessed 23/04/2020)

formation, and biological technologies. When entering the markets of other countries (especially developing countries), such companies usually buy local producers to facilitate entry into the national market. The second direction in the development of medical industry enterprises is the division of functional components of activities based on the principles of outsourcing. A number of major players in the medical equipment market leave only the most significant departments (research & development [R&D], marketing, and strategic management) within their own company and transfer functions such as testing, direct production, distribution, promotion, and service to specialised companies.

Further, the number of assembly plants and even development departments in other countries is growing, which erases the national identity of companies and leads to a global division of labour. To produce healthcare products, which are served by the medical and pharmaceutical industries of various countries, the global market is moving towards maximum openness in the field of information exchange and regulation. Separate protectionist measures protect specific developments in a limited area, and finished products are typically not the ones that become innovative but production technology (Melnichenko, 2018; Treshchevsky and Litovkin, 2018).

2. Methods and Materials

The study uses modern general scientific methods: content analysis of modern and domestic scientific literature, synthesis method, and systematisation method. The theoretical basis of the study is made up of articles by domestic and foreign researchers in the fields of healthcare, medical equipment, the world state of the medical equipment market, personalised medicine, telemedicine, and statistical collections. The study analysis the state of the medical equipment market of the Russian Federation and identifies the features of its development and the factors that contribute to and hinder its development. Thus, a diagram that clearly illustrates the confrontation of factors, and a systematising table that reveals the essence of each factor are presented. Factors that hinder the medical industry have been identified based on the strategy for the development of the Russian Federation's medical industry for the period up to 2030.

3. Results and Discussion

We highlight the specific features of the Russian medical equipment market, characteristic of the current stage of development of the socioeconomic system.

1. High level of influence of political risks. These types of risks form a poorly predictable and unfavourable external environment for the functioning of the medical equipment market. The political risks associated with the sanctions policy can significantly worsen the conditions for technical support and maintenance of medical equipment with regard to components manufactured outside the Russian Federation. In addition, these risks may prevent domestic producers from entering foreign markets. The influence of political risks exacerbates the problem of the country's economic security, which makes it necessary to take protectionist measures in relation to the domestic market.

2. The significant impact of the level of development. The medical equipment market affects the quality and efficiency of the healthcare system, and therefore the quality of life of the population, which underscores the high social significance of supporting domestic manufacturers.

3. Regional differentiation of needs for medical equipment. This is due to the different material and technical bases of state medical institutions, as well as differences in the effective demand of the population, which affects the development of private medical organisations and the range of services they offer.

4. The key role of the state. As a consumer of medical equipment, the state's function is associated with the peculiarities of the organisation of the state healthcare system and compulsory medical insurance.

5. A significant level of competition from foreign manufacturers. Players with significantly

greater financial strength can actively penetrate transnational corporations into the domestic market. In some cases, competition is unfair when domestic developments are called into question for political and economic reasons in the struggle for sales markets.

6. Growth in demand for specific types of medical equipment. For example, the COVID-19 pandemic drove the demand for specific equipment, with a relative decrease in demand for other types of equipment. The biggest increase was in the demand for equipment for laboratory analysis and resuscitation equipment. Despite a slight drop, according to experts, a full recovery of the market in terms of volume was expected by the end of 2021, and furthers expansion was predicted. In general, the pandemic has made health care a key concern for everyone, which may increase demand not only from medical institutions but also from private consumers who want to independently control their basic level of health.

7. Large amounts of state participation. The state financially supports medical equipment manufacturers associated with the implementation of national projects. The implementation of the national healthcare project is focused, among other things, on the re-equipment of medical institutions, which contributes to an increase in demand for medical equipment. For example, "in the last three years alone, the market for medical equipment and products in Russia has grown by about 32%, which is due to the high demand for innovative and high-tech medical care, improving the quality of healthcare services".

8. Low share of the domestic market of medical equipment on a global scale (according to the most optimistic estimates, less than 2%). The volume of sales of imported equipment in rubles on the domestic market is almost four times higher than the volume of sales of domestic equipment. This figure slightly decreased in 2020.

9. Potentially high market capacity. This occurs because existing equipment causes user dissatisfaction and needs to be replaced. According to a survey conducted among doctors in 2020 by the Doctors of the Russian Federation Organization, over 30% of those surveyed said that they were constantly dissatisfied with the quality of the equipment they had to work with, and over 20% more—from time to time.

10. Urgent need to introduce innovations. This forms the basis for increasing the competitiveness of domestic producers. However, the realisation of this need is possible only with active state participation and the development of the appropriate infrastructure.

Based on the characteristic features of the Russian medical equipment market, we highlight the features of its formation below (Iashin, 2016; Iashin, 2017).

First, the Russian medical equipment market under conditions of an unstable exchange rate is characterised by a lack of funding for the purchase of modern imported equipment and components for production. The situation during the COVID-19 pandemic showed that with the effective organisation of activities, medical industry enterprises can quickly launch the production of medical products (masks, disinfectant solutions, etc.). However, the production of competitive, innovative medical equipment cannot be established in a short time, as this requires significant time and financial investments. Moreover, the need to obtain registration certificates increases the period required to obtain a return on investment.

Second, a feature of the Russian medical equipment market is the high importance of the state as the main consumer. Despite the adoption of the Decree of the Government of the Russian Federation, which limits participation in the public procurement of foreign goods, over 62% of domestic producers did not notice a difference in demand (Decree of the Government of the Russian Federation of February 5, 2015)2. At the same time, in conditions of a state budget deficit, there may be problems with financing public procurement, which will lead to unstable demand and a lack of working capital for producers (Treshchevsky et al., 2016).

Based on the presented theses, it can be concluded that the export potential of Russian medical

[2] Decree of the Government of the Russian Federation of February 5, 2015 No. 102 (as amended on June 30, 2020) "On restrictions and conditions for the admission of certain types of medical devices originating from foreign countries for the purposes of procurement for state and municipal needs"

equipment has not yet been realised. The inability to compete with the developed distribution system of global manufacturers of well-known brands of medical equipment significantly complicates the export of domestic products. The lack of international registration for Russian medical equipment results in additional time and financial costs.

The following are considered factors contributing to the development of the market for innovative medical equipment in the Russian Federation:

1. The main factor in the growth of the medical equipment market in the Russian Federation can be considered an increase in healthcare financing, both from the state budget within the framework of state policy and from private healthcare organisations. In state programmes for the development of medicine, great attention is paid to raising the level of technical equipment of state medical institutions, from specialised high-tech scientific and medical centres to medical organisations at the local level.

2. The expansion of state guarantees for the provision of quality medical care leads to the development and approval of standards and procedures for the provision of medical care. Maintaining a high level of medical services and compliance with the procedures for the provision of medical care requires large expenditures on the material and technical equipment of healthcare institutions. In this situation, a significant increase in the demand for medical devices in general and medical equipment in particular is required. Due to the existing inequality in the availability of medical care in different regions, in some cases, a sharp increase in the need for medical equipment is required.

3. Development of high-tech medical care based on the use of "complex and (or) unique methods of treatment, as well as resource-intensive methods of treatment with scientifically proven effectiveness, including cell technologies, robotic technology, information technology and genetic engineering methods developed on the basis of the achievements of medical science and related branches of science and technology" (Federal Law No. 323-FZ, "On the Fundamentals of Protecting the Health of Citizens in the Federation")3, leads to the need to provide medical organisations with innovative medical equipment as the basis for the provision of medical services. The provision of high-tech medical care places special demands on the quality of the medical equipment used, often designed specifically for the implementation of a particular method or technology, which provokes the growth of an innovative segment in the medical equipment market.

4. Growth in life expectancy and gradual recovery from the demographic collapse of the 1990s lead to an objective need for an increase in demand for medical equipment due to an increase in the number of clients of medical organisations.

5. An increase in the standard of living of the population leads to an increase in the cost of health-saving measures, which are an important part of maintaining a healthy lifestyle, attractive appearance, and quality of life in general. Investments in one's own health, including the use of medical equipment, are becoming a factor in the growth in demand for equipment that allows for preventive, diagnostic, and rehabilitation procedures.

6. Expansion of the segment of private medicine both by increasing VHI (Voluntary Health Insurance) policies (especially corporate ones) and by increasing the share of treatment payments at the expense of compulsory medical insurance. For organisations of paid medicine, the constant updating of medical equipment is an important factor in ensuring competitiveness. The largest private medical companies recorded a significant increase in the share of services under the compulsory medical insurance policy. In 2018, more than a third of private clinics accepted the compulsory medical insurance policy for payment. The share of such services can be a quarter in total revenue, and for some services (for example, IVF) in a number of organisations, more than half are paid for by compulsory health insurance (Morozova, 2020)4.

[3] Federal Law No. 323-FZ of November 21, 2011 (as amended on July 31, 2020) "On the Fundamentals of Protecting the Health of Citizens in the Federation" (as amended and supplemented, effective from September 1, 2020)

[4] Morozova T. The largest private clinics are growing thanks to compulsory medical insurance. Newspaper Vedomosti: site. URL: https://www.vedomosti.ru/business/articles/2019/09/02/810270-krupneishie-kliniki-rastut (accessed 04/21/2020).

7. The development of telemedicine and remote monitoring systems requires the development of comprehensive proposals for the medical equipment market, combining medical equipment with telecommunication systems and specialised software.

8. An increase in the home medicine sector, leading to an increase in demand for medical technology products that allow:

- Maintaining an acceptable quality of life for difficult-to-transport patients.

- Carrying out diagnostic and rehabilitation measures independently.

- Saving personal time and the doctor's time for visits to a medical organisation.

- Monitoring the condition of both healthy and sick people.

9. The development of personalised medicine requires modern clinical diagnostic equipment to identify the characteristics of a client's health and to identify individual risk factors for each patient.

10. The development of medicine through the active use of innovative technologies and devices is expected to lead to the predicted growth of the market for innovative medical equipment. The development of modern technologies in medicine itself, as well as in biochemistry, electronics, and materials science, especially in the context of emerging Industry 4.0, increases the growth rate of the medical device market.

11. Macroeconomic factors determine the dynamics of the market in monetary and physical terms. Fluctuations in the exchange rate of the national currency directly affect the purchasing power of legal entities and individuals to purchase medical equipment. However, the market may grow in monetary terms but decline in physical terms due to the unfavourable exchange rate of the ruble, which reduces the correctness of comparisons of time indicators.

12. State regulation of the medical industry, given its social significance, is carried out at all stages of value creation, but special attention is paid to controlling the production of medical equipment. In leading countries, such control is carried out by a separate supervisory body.

In what follows, we consider the factors hindering the development of the medical equipment market in the Russian Federation. Even in the "Strategy for the development of the medical industry of the Russian Federation for the period up to 2020" (Order of the Ministry of Industry and Trade of Russia dated January 31, 2013 No. 118 "On approval of the Strategy for the development of the medical industry of the Russian Federation for the period up to 2020"), the main shortcomings hindering the development of the medical products market were identified:

- Technological backwardness and moral obsolescence of products;

- Weak innovative activity;

- Closed industry and weak integration into international markets".

In the draft "Strategy for the development of the medical industry of the Russian Federation for the period up to 2030" (2018)5, systemic problems of industry development are considered for the first time in relation to the life cycle of medical products. Among the main problems are the following:

Lack of communication between manufacturers and consumers in terms of determining priority areas for development and understanding current market needs;

Financial constraints of small and medium-sized businesses do not allow regular investment in research and development;

Prohibition of access of unregistered products to the trial operation process;

[5] The project "Strategy for the development of the medical industry of the Russian Federation for the period up to 2030". Media project "GXP News": site. URL: https://gxpnews.net/2018/08/minpromtorg-razrabotal-strategiyu-razvitiya-medpromyshlennosti-na-period-do-2030-goda/ (Accessed 17.02.2020)

Underdeveloped infrastructure and services market for research and testing of medical devices;

Low level of interaction between the educational infrastructure, institutions involved in fundamental science, applied science, and manufacturers seeking to use actual physical and chemical solutions in production;

High cost of equipment for the production of medical devices;

High level of import dependence in components;

Duration of registration of medical devices;

The need for a new registration when making even minor changes;

Uneven and unstable demand from the public sector

The inability of manufacturers to provide services for the integrated equipment of medical institutions;

Shortage of qualified personnel capable of solving the problems of creating new products and organising modern production in the medical industry (Order of the Ministry of Industry and Trade of Russia dated January 31, 2013 No. 118 "On approval of the strategy for the development of the medical industry of the Russian Federation for the period up to 2020")6.

Table 1 presents the factors that contribute to and hinder the development of the market for innovative medical equipment.

Table 1. Factors influencing the development of the market for innovative medical equipment

Factors affecting the development of the market	Direction of influence
Increased funding for health care both from the state budget within the framework of state policy (national projects and programs in the field of health care and demography), and from private medical organisations.	Growth of financial opportunities for the production of innovative equipment that requires significant costs
Expansion of state guarantees for the provision of quality medical care, development and approval of standards and procedures for the provision of medical care	Growth in the need for material and technical re-equipment of healthcare institutions and the acquisition of advanced medical equipment
Development of high-tech medical care	Growing demand for innovative medical equipment based on the achievements of medical science, growing requirements for the quality of medical equipment and its maintenance
Increase in life expectancy, gradual recovery from the demographic collapse of the 1990s, increase in the share of the elderly population	Increasing the number of patients, including those in need of innovative treatment methods in medical institutions and at home
Growing needs of the population in maintaining a healthy lifestyle, attractive appearance, leading to a willingness to pay for health savings	Growing demand of service organisations for equipment that allows for preventive, diagnostic and rehabilitation procedures (including innovative technologies in the beauty industry), growing demand for household medical devices
Expansion of the segment of private medicine both by increasing VHI policies (especially corporate ones) and by increasing the share of payment for treatment at the expense of compulsory medical insurance.	Growth in demand for innovative medical equipment from commercial medicine organisations, for which the constant updating of medical equipment is an important factor in ensuring competitiveness
Development of telemedicine and remote monitoring systems	Growing demand for comprehensive offerings that combine medical technology with telecommunications systems and specialised software

[6] Order of the Ministry of Industry and Trade of Russia dated January 31, 2013 No. 118 "On approval of the Strategy for the development of the medical industry of the Russian Federation for the period up to 2020".

Increasing the home medicine Sector	Growth in demand for medical equipment products that allows for: - Maintain an acceptable quality of life for difficult-to-transport patients; - Carrying out diagnostic and rehabilitation measures independently; - Saving personal time and the doctor's time for visits to a medical organisation; - Monitoring the condition of both healthy and sick people.
The development of personalised medicine	Growing demand for modern clinical diagnostic equipment to identify the client's health characteristics and individual risk factors
The development of modern technologies in medical science, as well as in biochemistry, electronics, materials science, especially in the context of the emerging Industry 4.0 and the deployment of digitalisation processes	Increasing the growth rate of the market of innovative medical equipment due to the emergence of new technologies and scientific knowledge, for which the commercialisation of innovations is possible
High level of state control at all stages of value creation, including a lengthy registration procedure for new products	Slowdown in the production of innovative medical equipment due to bureaucratisation
Imperfection of the current public procurement mechanism	Slowdown in the production of the innovative medical equipment due to bureaucratisation, inefficient choice of manufacturers
Low level of interaction between the educational infrastructure, institutions involved in fundamental science, applied science, and manufacturers	Lagging behind the world's leading manufacturers in terms of commercialisation of innovations
Inconsistency of existing federal laws, GOSTs, classifiers, lack of comparability with world practice	Limitation of interactions with foreign partners, difficulty in obtaining state support for manufacturers
Adverse changes in the external environment associated with the sanctions policy	Restriction of access to cutting-edge medical technology
Shortage of qualified personnel in the field of creation and operation of innovative technology	Slowdown of innovation processes among manufacturers of medical equipment, decrease in demand from medical organisations due to the lack of personnel to work on modern equipment

For the development of the medical equipment market in the Russian Federation, it is necessary to highlight a number of principles, the main of which are (Ozhgikhin, 2020). The principle of cost reduction is based on the increasing use of disposable devices and tools, as well as the use of new materials. The growth in disposables reduces the cost of sterilisation and eliminates nosocomial infections, the consequences of which can be very costly. New materials, especially polymers, make it possible to create equipment with improved properties as well as fundamentally new products, such as 3D-printed prostheses. Resource conservation is closely related to cost reduction but includes cheaper production and a fundamentally new approach to the use of resources for production by reducing material consumption. The use of recycling materials (where appropriate), weight reduction through the transition to new materials, and product design based on computer simulation (Rodionov and Alferyev, 2020) can reduce resource consumption without compromising product quality.

Further, the optimisation of the nomenclature based on the unification of products and a focus on expanding the functions of complex instruments and apparatus based on the needs of users make it possible to avoid the release of products that are not in demand among consumers. Reducing the duration of the production cycle leads to a faster practical application of innovative materials and technologies in medical technology, which ultimately improves the quality of medical care. The widespread use of digital technologies and the active use of the achievements of biology, pharmaceuticals, radiology, materials science (including nanomaterials), and other sciences significantly increase the possibility of manufacturing medical products with desired properties at the request of the client in a short time. Localisation of production based on import substitution is significant for our country for high-tech equipment and consumables (syringes, catheters, etc.), the total consumption of which is very significant. In recent years, active work has been carried out to organise the production of medical equipment in the Russian Federation, but it is almost impossible to completely eliminate the import of medical devices.

Lastly, the principle of the priority production of innovative medical equipment consists of the possibility of realising the national scientific and technological potential in the production of medical devices precisely through the production of innovative medical equipment, which allows practical application of the advanced achievements of medicine and technology and entry into the global market for the sale of products with high added value (Gorovoy and Zueva, 2018).

In this study, the study of the essence of factors in the formation of conditions for the development of the medical industry market led to the conclusion that the undeveloped infrastructure and the market for services for research and testing hinder development in many respects: lack of qualified personnel, lack of communication between consumers and manufacturers, and low interaction with educational infrastructure. The need to introduce innovative technologies is accompanied by an increase in financial costs, which helps to strengthen the development vector of personalised medicine and telemedicine. However, the introduction of innovation is hindered by bureaucracy, particularly the length of registration of medical devices, which is required for each product, even with the slightest change.

By systematising all the theses above, we formulate a visual scheme that reflects the confrontation between the factors of the medical equipment market (Figure 1).

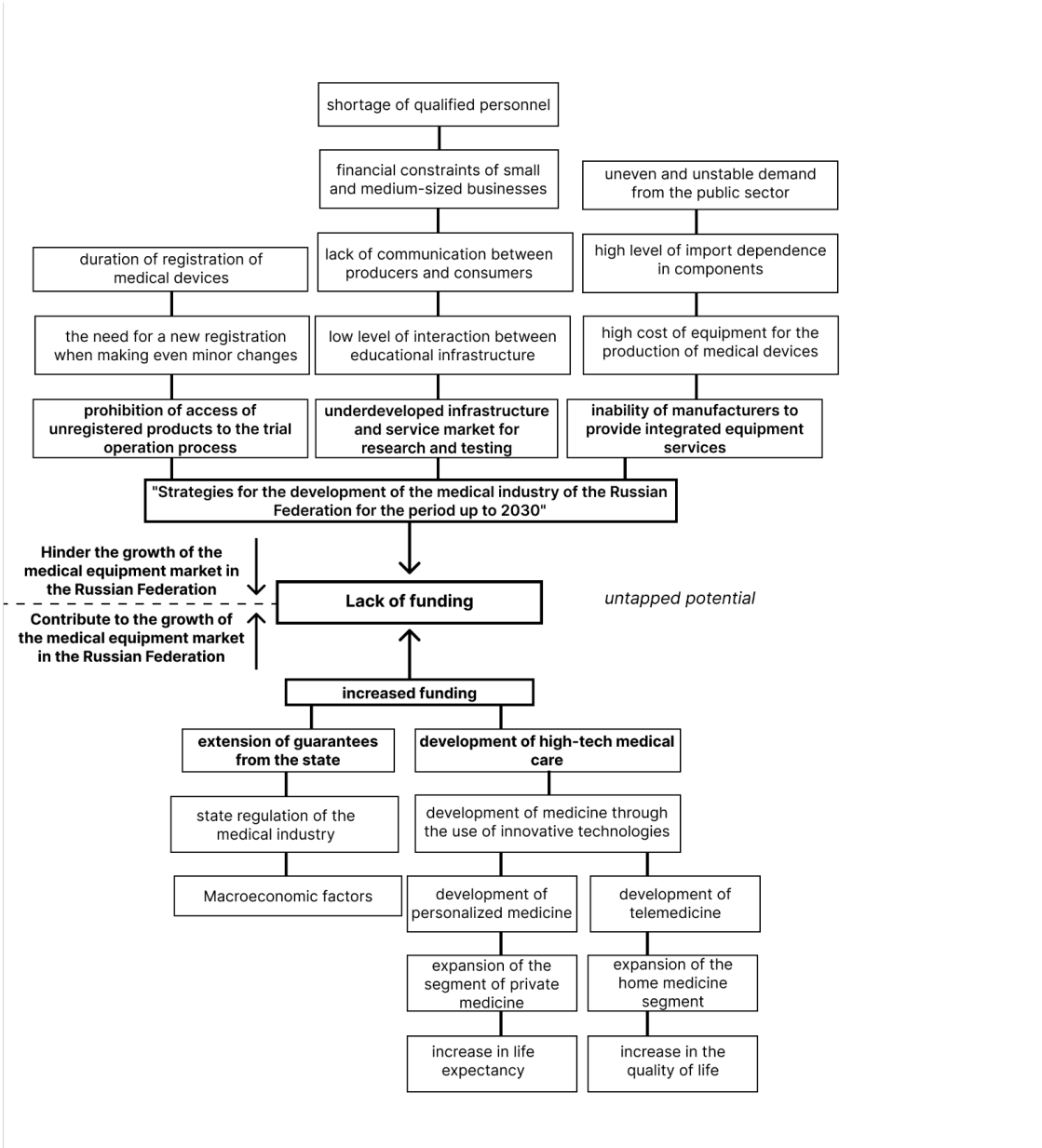

Figure 1. Confrontation between the factors of the medical equipment market

4. Conclusion

In this study, an analysis of the medical equipment market of the Russian Federation was carried out, and specific features and principles were identified. As part of the work, the essence of the factors that hinder and promote market growth was revealed, and the principles that need to be considered in forming the development vector were listed. A summary of the analysis is as follows:

1. Specific features of the Russian medical equipment market:

The negative impact of macroeconomic factors, which result in a high level of political risks, non-competitiveness of domestic goods, and its low share in the world market.

Urgent need to introduce innovations to increase competitiveness. Moreover, the medical staff personnel are not satisfied with the quality of the work equipment.

Growth in demand for specific types of equipment and potentially high market capacity.

2. Based on the characteristics of the market of the Russian Federation, the following features have been formed: turbulent conditions of the past few years and the high role of the state in the medical healthcare system caused by the implementation of national projects.

3. Key factors hindering the development of the medical equipment market:

Restriction of access to advanced achievements in the field of medical technology in connection with the sanctions policy towards the Russian Federation;

The bureaucratic nature of the health care system;

Low level of interaction between the educational infrastructure, institutions involved in basic science, applied science and manufacturers.

4. Key factors that contribute to the development of the medical equipment market

Developing modern technologies in medical science;

Developing personalised medicine and telemedicine;

Developing modern technologies in medical science;

Developing personalised medicine and telemedicine;

Increasing health financing;

Trending towards higher quality of life and longer life.

The analysis of the consequences resulted in identifying key principles for consideration in the development of the medical equipment market in Russia: cost reduction, resource saving, optimisation of the range, reduction of the duration of the production cycle, localisation of production based on import substitution, and priority production of innovative medical equipment.

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SECTION 4

MANAGEMENT OF KNOWLEDGE AND INNOVATION FOR SUSTAINABLE DEVELOPMENT

РАЗДЕЛ 4

УПРАВЛЕНИЕ ЗНАНИЯМИ И ИННОВАЦИЯМИ В ИНТЕРЕСАХ УСТОЙЧИВОГО РАЗВИТИЯ

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Methodological Justification for the Expediency of Initiating a Programme of Green Innovations in the Oil and Gas Sector

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Abstract

A feature of the modern world is the constantly increasing flow of innovation, which has caused a chain reaction of technological, institutional and social changes in all spheres of activity. Increasingly noted examples of this are the 'green' trend, the ecologisation of innovation processes and enterprises following modern trends in sustainable development. In this study, the authors developed an original methodology to risk-assess (probability of success) green innovations based on a decision tree. The authors' solution facilitates making an optimal decision on the expediency of launching projects to implement green innovations in the oil and gas sector, such as carrying out entire innovation programs, launching a pilot projects or suspending current programs, based on the expected income. In this paper, the methodological approach is tested using conditional data. The results obtained form the foundation for developing a framework for innovation activities at oil and gas complex enterprises, providing a new (green) view on solving the problems of oil and gas innovations and taking a systemic approach to the analysis of green innovations in the oil and gas sector in the Russian Federation. The findings can be used in strategic planning by oil and gas enterprises, in particular, when deciding on the expediency of initiating green innovation programmes.

Keywords: green economy, oil and gas industry, green innovations, sustainable development

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Методическое Обоснование Целесообразности Инициирования Программы Зеленых Инноваций в Нефтегазовом Комплексе

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Аннотация

Особенностью современного мира является постоянное нарастание инновационного потока, который вызывает цепную реакцию технологических, институциональных и социальных изменений во всех сферах деятельности. Все в большей степени отмечается «зеленая» тенденция, экологизация инновационных процессов, разворачивающая предприятия в сторону современных трендов устойчивого развития. На основании проведенного исследования была разработана оригинальная методика оценки риска (вероятности успешности) «зеленых» инноваций на основании дерева решений. Авторское решение данного исследования позволяет на основании ожидаемого дохода сделать выбор оптимального решения о целесообразности запуска проекта по внедрению «зеленых» инноваций в нефтегазовом секторе, а именно реализовать всю инновационную программу, запустить пилотный проект либо приостановить действующую программу. В рамках статьи апробация методического подхода была произведена на условных данных. Полученные в ходе исследования результаты создают основу для разработки основ инновационной деятельности предприятий нефтегазового комплекса, формирования нового («зеленого») взгляда на решение проблем нефтегазовых инноваций, формирования системного подхода к анализу «зеленых» инноваций в нефтегазовом комплексе Российской Федерации, результаты исследования могут быть применены при стратегическом планировании нефтегазового комплекса, в частности, при принятии решения о целесообразности инициирования программы «зеленых» инноваций.

Ключевые слова: «зелёная» экономика, нефтегазовая отрасль, «зелёные» инновации, устойчивое развитие

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1. Introduction

At the current stage of global economic development, the transition from traditional hydrocarbons to alternative energy sources, as well as energy resources with a low carbon footprint, is becoming increasingly important. The dynamics of both national and international projects aimed at reducing greenhouse gas emissions are increasing every year, due to the high priority given to this area of activity in connection with the current climate agenda at the national level.

Taking into consideration the fact that the Russian Federation occupies a leading position in the field of hydrocarbon exports, the transition to a green economy, amid the realities of the growing pressure from sanctions by the West in particular, the slowdown of technological development in the economy and the reorientation of sales markets, has become a serious challenge. In addition to existing measures, comprehensive work is required to intensify innovative activity among organisations in the oil and gas sector. This transition, based on breakthrough innovative technologies, should be supported by the state, in particular, by a system of institutional support. To date, there has been a lack of effectiveness at various stages of the innovation cycle.

An indispensable prerequisite for improving the quality and efficiency of energy-saving resources and the innovative activities of oil and gas companies in the green economy, as well as for reducing the duration of the innovation cycle, is to take a complex approach on behalf of all the interested public administration bodies. The coordination and consolidation of research findings is of particular importance in the field of energy efficiency and for reducing the carbon footprint, which has been noted in the policy documents on the decarbonisation of the Russian economy (Lagutenkov, 2022).

In the current conditions of economic uncertainty, the main task of oil and gas companies, when developing innovation policy is to develop strategies, is to take into consideration this this probability and determine priority activities that should be adapted to changing operating conditions. To date, this process has not been backed by appropriate methodological support.

The relevance of the research topic is determined by the fundamental importance of the role of the oil and gas sector in the socioeconomic development of the Russian Federation, the need to increase its technological potential through the introduction of innovations in line with the existing global trends in environmental policy and the low efficiency of mechanisms regulating the activities of participants in the initiation, development and implementation of green innovations in oil and gas.

The objective of the study is to develop a programme for implementing green innovations that will contribute to the sustainable development of oil and gas enterprises in the Russian Federation. The study's scientific significance relates to using expert evaluations to refine the methodological justification for implementing green innovations in the oil and gas sector.

Another goal of the study is to methodologically substantiate the feasibility of implementing green innovations in the oil and gas sector in the context of sanction restrictions. To achieve its goals, the study embarks on the following:

A clarification of theoretical ideas about the essence of green innovation and its impact on the development of a green economy.

A description of the content of the main preparation stages and the work of expert groups.

Taking a methodological approach to develop a procedure for substantiating decisions on the feasibility of initiating programmes to introduce green innovations at oil and gas enterprises (Lagutenkov, 2022).

2. Literature review

Both the main idea for and the importance of the transition to a green economy are described in the work of Biryukov and Ryazanova (2020), with the authors noting the particular relevance of envi-

ronmental and economic issues in the context of global development aimed at the rational consumption of limited resources. The study also noted some ambiguity in the approaches taken to implement the concept of the green economy in practice. In their study, Bondarenko et al. (2018) distinguished the need to form institutions for the ecological transformation of the Russian Federation at a time when it is lagging behind world practices as a means to achieve the ecologisation of socioeconomic reproduction. Farber et al. (2002) provided a comprehensive assessment of human activities aimed at achieving sustainable development within the global ecological–economic system, the purpose of which was to achieve a balance between society and nature. A significant number of researchers and publications on this subject have called for the systematisation of the main trends and methodological approaches to the evolution of the green economy, which is necessary for studying its impact on the development of innovative activities.

Both Borkova (2020) and Zakharova and Krakovetskaya (2018) considered the influence of individual factors on the processes of development, implementation and use of green innovations, including in relation to digital technologies.

A significantly smaller number of studies have been devoted to innovative activity in the oil and gas segment, with that of Lukyanova et al. (2019) among the most interesting of these. Nevertheless, studies describing the problems of green innovation in the oil and gas segment are relatively scarce. Among them, the works of Zubarev and Polaeva (2021) and Sinkov and Cherepovitsyn (2009) integrated the experiences of implementing environmental proposals by oil and gas organisations and the requirements and conditions of the projects and focused on the challenges of the green economy.

Lagutenkov and Dubolazova (2022) stated the following: Porter and Van der Linde (1995) substantiated a new relationship between the environmental goals of an organisation and competitive advantages, proving that there had been a conflict between mandatory compliance with environmental legislation and the costs of compliance, but nowadays, competitive relations are dynamic and based on innovations. The core of the authors' strategy was cross-functional or cross-active integration.

Dorfman and Dorfman (1993) and Pearce and Turner (1990) considered the evolutionary transformation of the green economy in the context of various scientific schools and directions, the main purpose of which was to identify patterns of influence on the formation and development of green investment, affecting the transformation processes in the sectoral and regional contexts.

Analysis of the existing scientific works has enabled the formation of a comprehensive view of the essence of the green economy and green innovations and the importance of transitioning to sustainable development. Most of the existing studies are devoted to general issues concerning the green economy and the processes of modelling to introduce green innovations. There has been significantly less research on the topic of innovation activity in the oil and gas sector, and the studies in this field mainly represent the generalisation of experiences in the implementation of oil and gas companies' initiatives. More specific issues concerning the mechanism of implementing green innovations and the use of modern technologies in green oil and gas innovations have not been given proper attention in scientific research. The lack of unambiguous definitions, principles and sources of transition to green innovation in the oil and gas sector emphasises the relevance of this study.

3. Materials and methods

With the formation and development of the green economy, there have been a number of evolutionary changes, including those associated with the transformation of scientific and technological innovations and the emergence of new threats and challenges (Vasiltsov, 2021). These changes have led to the formation of certain provisions, according to which existing post-industrial societies have focused on the use of resource-saving technologies and placed significant responsibility on all the participants in these, regardless of the size of the available resource base and the degree of influence on management decision-making.

Of particular importance in the transition to a green economy are special innovative technologies (Potapova and Kiryushkina, 2018) and products that can be distinguished as green innovations based on their rational use of renewable natural resources, whose main goal is to ensure the sustainable development (Kuklina, 2018) and economic growth of both the Russian economy as a whole and its individual sectors and industries.

A characteristic feature of developing, introducing and implementing green innovations is its dual focus. On the one hand, the activity is aimed at preserving the existing ecological environment and supporting environmental policies pursued by both the state and individual sectors of the economy. In addition, these innovations allow for a more efficient use of the resource potential for both production and economic activities in such a way as to maintain balance between the existing ecological system and society's ever-growing need for different benefits. In this case, the source of such benefits can be those resources, the need for which up to a certain level has been minimal; thus, their reserves may be relatively high or they have a renewable nature (Polovyan and Yaluner, 2020).

According to Lagutenkov (2022): 'The choice of optimal means and tools for the statistical evaluation of both individual green innovations (Buranova, 2020) and the emerging market for this economic good at various levels (local, national and international) from a socio-economic point of view seems very difficult.'

The following important methodological aspects accompanying the innovation process in terms of the green economy and contributing to the development of green innovation activities in the oil and gas segment should be recognised (Loginova, 2018):

The identification of key types of green innovation in terms of existing classical ideas about the classification of innovations according to certain criteria most relevant to the oil and gas sector.

The formation of methodological approaches to the generalisation of basic areas of green innovation in the oil and gas sector in the context of providing interrelationships with certain selected types of innovation.

The comparison and economic evaluation of the effectiveness of various sources of financing for process of developing green innovations in the oil and gas segment.

In the Russian Federation, the current practice of forming clusters focused on the principles and requirements of the green economy is rather limited. Under the framework of stimulating the development of cluster initiatives in the field of the green economy, the development of comprehensive measures to support the innovative activity of market subjects in terms of their involvement in the clusters and the gradual introduction of green innovations look most preferable. This should allow for the regional specificity of clusters and the sectoral nature of structures; that is, there should be a gradual transition from the existing clusters in the field of environmental protection and waste processing to clusters with any sectoral focus whose participants use green innovations in their production and economic activities (Lagutenkov and Melnichenko, 2022).

On the basis of the analysis of methodological approaches to assess the level of development of green innovations, it would seem most effective to carry out assessment procedures in relation to a set of green innovations within a particular industry or group of industries that can be united in terms of common technological processes and the similarity of the material resource bases they need for the production of end-products, provided that relevant information and analytical data are collected and processed. In addition, it is necessary to take into consideration the importance of the industry to the national economy as well as the prerequisites for increasing the level of innovation activity of organisations and enterprises operating in this industry.

The decision to initiate a development project and/or the introduction of green innovations amid the great uncertainty of the external environment of oil and gas companies significantly depends on

the state of the external and internal environment of the organisation (Kuklina, 2018), the forecasts of instability and the content and effectiveness of the strategy for innovative development. In the national and international practice of project management, various management decision methods, such as SWOT-analysis, the Delphi method, analysis of financial planning on sensitivity to changes in input parameters, the analogy method, scenario forecasting, the Monte Carlo method, the PERT method and the decision tree method, are well-proven.

In conditions of great uncertainty and with a significant likelihood of the wrong choice being made concerning the trajectory of innovative development, statistical methods of management decision-making do not give reliable results. Therefore, to assess the feasibility of implementing 'green' innovations by oil and gas enterprises under these conditions, it is necessary to use methods of decision-making under uncertain conditions based on expert assessments, which will enable the use of information from experts with different competencies, and such an approach will ensure the relevance and adequacy of the decision-making, the preparation for which involves professionals in the subject areas of specific innovations (Lagutenkov and Liukevich, 2022).

The composition of expert groups is defined in the GOST R 57313-2016 innovation management guidelines, which were introduced on 1 June, 2017. This document establishes those responsible for activities according to their level and stage in the innovation process; these can and should be involved as experts to assess the likelihood of the success of green innovations. In this regard, a methodical approach was developed to assess the probability of success for green innovations, in accordance with what had been established in the specified GOST guidelines, as follows:

- Level of innovative project management (strategic, operational).

- Functional area (marketing and commerce, technology, legal/regulatory support, management and organisation).

- Stage of initiation and implementation of an innovative project (research, evaluation and decision making, project management, capitalisation).

- Stakeholders from the organisation who are involved as experts.

The main stages of preparation and the expert group's work are as follows:

1. Initiation of the expert survey by the head of the organisation.

2. Setting the goal of conducting an expert survey.

3. Developing a questionnaire (definition of the object of evaluation).

4. Developing methodological support for the experts (definition of the objects of evaluation, development of a questionnaire, establishment of requirements for the qualifications and experience of the experts, method of processing the results of the expert survey, methods of analysis of the information obtained).

5. Forming and approving the composition of the group of experts.

6. Organising the work for the expert group and the expert survey.

7. Processing the obtained information, interpreting the results and preparing a management decision.

In the context of this study, the purpose of the expert survey is generally formulated from the following question: 'Should a green technology implementation programme or project be initiated and implemented?' (Lagutenkov and Liukevich, 2022). To better consider the factors affecting the reliability of the answer that can be obtained, the group of experts evaluating the probabilities of the strengthening/removal of sanctions should include the top management of companies and external stakeholders, whose

composition is specified in accordance with the current GOST R 57313-2016 innovation management guidelines.

4. Results

Table 1 shows the authors' view on the comparison of assessed risks with the stages of the innovation process for which these risks are significant.

Table 1. Influence of risks at the stage of the innovation process (developed by the authors)

Assessed risk	Impact on the stages of the innovation process
Risk of not achieving the planned effect of the programme of a green innovation while maintaining or increasing sales volumes ($p_1=\alpha p_S+(1-\alpha)p_{Ap}$, $0\leq\alpha\leq1$, where p_S is the probability of the successful completion of strategic-level tasks and p_{Ap} is the probability of maintaining/increasing sales of products, work and services).	Preparation for production at the manufacturing plant Production of the innovation Implementation and promotion of the innovation Assessment of the economic efficiency of the innovation Marketing of the innovation Diffusion of the innovation
Risk of not achieving the planned effect of the programme of a green innovation in the context of declining sales volumes ($p_2=\beta p_S+(1-\beta)p_D$, $0\leq\beta\leq1$, where p_S is the probability of the successful completion of strategic-level tasks and p_D is the probability of reducing sales of products, work and services).	Research and development work Preparation for production at the manufacturing plant Production of the innovation Implementation and promotion of the innovation Assessment of the economic efficiency of the innovation Marketing of the innovation Diffusion of the innovation
Risk of not achieving the planned effect of the pilot project on the implementation of a green innovation while maintaining or increasing sales ($p_3=\gamma p_o+(1-\gamma)p_{Ap}$, $0\leq\gamma\leq1$, where P_O is the probability of the successful completion of the operational-level tasks and p_{Ap} is the probability of maintaining/increasing sales of products, work and services).	Research and development work Preparation for production at the manufacturing plant Production of the innovation Implementation and promotion of the innovation Assessment of the economic efficiency of the innovation Marketing of the innovation Diffusion of the innovation
Risk of not achieving the planned effect of the pilot project on the implementation of a green innovation in the context of declining sales ($p_4=\delta p_o+(1-\delta)p_D$, $0\leq\delta\leq1$), where P_O is the probability of successful completion of operational level tasks and p_D is the probability of reducing sales of products, work and services).	Marketing research Innovation initiation (generation and filtering of ideas)
The probability of reducing sanction pressure and access to the markets of countries that implement economic regulation of the sale of products with a high carbon footprint with the probability of (p_5)	Marketing research Innovation initiation Research and development Technical and economic expertise in projects
The probability of stabilisation of the situation (p_6)	Full cycle of the innovation process
The probability of increased sanctions (p_7)	Marketing market research Initiating the innovation (generation and filtering of ideas) Diffusion of the innovation

The choice of a particular direction of further activity in conditions of great instability, when the results of the decision depend on the consequences of a previously taken action, can be described in the current study with the help of a decision tree. This toolkit was described in detail by Prosvetov and supplemented in this study in accordance with the objective and subject of his research.

In the process of making the optimal decision on the feasibility of launching a project to implement

green innovation in the oil and gas sector, the following activity trajectories are analysed.

The first concerns launching a programme to implement a set of green innovation projects in the products/processes of an oil and gas company. The investment requirement is IC_1 million roubles.

If the number of sales is maintained or increased with probability *p1 (p1=1-(αpS+(1-α)pAp), 0≤α≤1)*, the income from the projects included in the programme of green innovation will be expected to be V1 million roubles, and the effect that the programme provides will be

$$L_{11} = - IC_1 + F_1 + V_{opt} \quad (1)$$

If the number of sales is reduced, the effect of the programme L_1 (million roubles) with probability p_2 will be

$$L_{12} = -IC_1 + F_1 + V_{pes}, \quad (2)$$

where F_1 (million roubles) is the discounted amount of savings due to the reduction of penalties for greenhouse gas emissions for all projects of the green innovation programme; V_{opt} (million roubles) is the net discounted income from the implementation of all programme projects, including income from the sale of products/works/services in new sales markets in countries not participating in the sanctions policy (optimistic estimate); and V_{pes} (million roubles) is the net discounted income from the implementation of all programme projects, including income from the sale of products/work/services in new salesmarkets in countries not participating in the sanctions policy (pessimistic estimate).

The second is to implement a pilot project that is a part of an innovation programme for the transition to a green economy and provides the implementation of an innovative technology in a separate structural unit. The need for *investment* is $IC_2 << IC_1$.

With preserved or increased sales with probability p_3, the planned effect of the project will be L_{21} (million roubles):

$$L_{21} = -IC_2 + F_2 + V_2. \quad (3)$$

With decreased sales with probability p_4, the effect of the green innovation project will be

$$L_{22} = -IC_2 + F_2, \quad (4)$$

where F_2 (million roubles) is the discounted amount of savings due to the reduction of penalties for greenhouse gas emissions provided by the green innovation pilot project and V_2 (million roubles) is the net discounted income from implementation of the green innovation pilot project, including income from sales of products/work/services in new sales markets in countries not participating in the sanctions policy.

The third is to consider the possibility of suspending the innovation programme for a period. The shorter the duration of this, the higher the degree of uncertainty, and the following three scenarios are possible:

- *Reducing* sanction pressure and opportunities to access the markets of countries that implement the economic regulation of sales of products with a high carbon footprint with a probability of p_5.

- *Stabilisation* of the situation with a probability of p_6, $p_5 + p_6 < 1$.

- *Increased* sanctions with a probability of $p_7 = 1 - p_5 - p_6$, $p_5 + p_6 + p_7 = 1$.

In the case of a favourable scenario, a pilot project or an innovation programme as a whole can be implemented; the probability of growth in sales is p_7, and correspondingly, the probability of decline will be $p_8 = 1 - p_7$.

To estimate the probabilities p_{Ap}, p_D, p_5, p_6 and p_7, it is advisable to involve head office employees

as well as specialised consultants and contract research organisations.

The feasibility of making an alternative decision *X* in this situation is based on determining the cost effect, which can be defined as the mathematical expectation of the cost effects of the results of these decisions *M(X)*:

$$M(X) = \sum p_{xi} * C_{xi}, \quad (5)$$

where p_{xi} is the probability of obtaining the ith gain in the result *I* from the implementation of solution *X* and C_{xi} is the profit (gain) projected to be obtained when obtaining the result *i* from the implementation of solution *X*.

From the alternative solutions *X1, X2, ..., Xn*, the one that gives the maximum value of *M(X*)* is chosen:

$$M(X^*) = max\ (M(X_1), M(X_2), ..., M(X_n)). \quad (6)$$

For the decision tree shown in Figure 1, the choice of alternatives is determined by the following conditions:

$$M(A) = p_1 * L_{11} + p_2 * L_{12},$$

$$M(B) = p_3 * L_{21} + p_4 * L_{22},$$

$$M(C) = p_1 * L_{11} + p_2 * L_{12},$$

$$M(F) = p_3 * L_{21} + p_4 * L_{22},$$

$$M(G) = p_3 * L_{21} + p_4 * L_{22},$$

$$M(H) = 0,$$

$$M(D) = 0,$$

$$M\ (2) = max\{M(E), M(F)\},$$

$$M\ (3) = M(G),$$

$$M(C) = p_5 * M\ (2) + p_6 * M\ (3) + M(D),$$

$$M\ (1) = max\{M(A), M(B), M(C)\}.$$

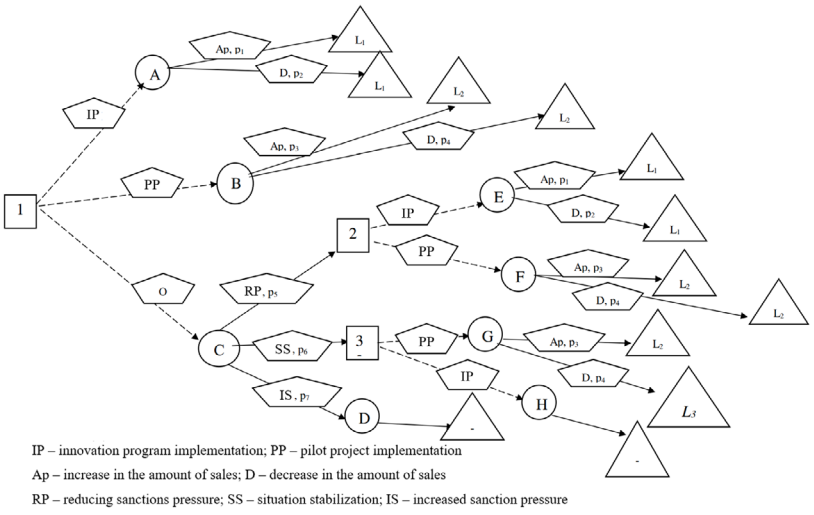

Figure 1. Decision tree for implementing green technologies under sanction pressure (developed by the authors)

Determining the maximum value of the projected income from the implementation of alternatives A, B or C, one of following three innovation strategies is selected: implementation of the entire innovation programme that ensures the transition to green technologies, a pilot project from the list of projects included in the program or the suspension of the program. (Lagutenkov and Liukevich, 2022).

The methodological approach outlined above was tested with conditional data.

In the conditional example, it is assumed that each unit is represented by one expert, and the opinions of the experts are assumed to be equivalent, so the final probability for each question posed to the experts is calculated as the unweighted arithmetic mean. Situations of increasing and decreasing sales are also considered equally probable. The results of the calculations are shown in Table 2.

Table 2. Testing of the model of probabilistic assessment of the effect of the programme and the pilot project of green innovation (developed by the authors)

Model parameter	Unit of measurement	Parameter value
IC_1	(million roubles)	500
p_1		0.606
P_2		0.606
p_S		0.712
P_O		0.817
p_{Ap}		0.5
p_D		0.5
F_1	(million roubles)	30
V_{1opt}	(million roubles)	800
V_{1pes}	(million roubles)	600
L_{11}	(million roubles)	330
L_{12}	(million roubles)	130
IC_2	(million roubles)	100
p_3		0.659
P_4		0.659
F_2	(million roubles)	5
V_{2opt}	(million roubles)	120
V_{2pes}	(million roubles)	105
L_{21}		25
L_{22}		10
p_5		0.2
p_6		0.4
p_7		0.4
A		0.5
B		0.5
Γ		0.5
Δ		0.5
M(A)	(million roubles)	285.78
M(B)	(million roubles)	23.065
M(E)	(million roubles)	285.78
M(F)	(million roubles)	23.065
M(G)	(million roubles)	23.065
M(H)	(million roubles)	0
M(D)	(million roubles)	0
M (2)	(million roubles)	285.78
M (3)	(million roubles)	23.065
M(C)	(million roubles)	66.382
M (1)	(million roubles)	285.78

Testing of the model on conditional data (Table 2) proved its fundamental efficiency and suitability for choosing the green innovation strategy in conditions of high uncertainty. In the given example, such a strategy is a variant for implementing the innovation programme as a whole.

It should be noted that the application of this model in practice requires the careful selection of experts in accordance with the nature of the initiated innovation programme and the requirements of regulatory documents governing the management of the innovation process.

The proposed approach to modelling the feasibility of initiating programmes for introducing green innovations at oil and gas enterprises, based on the procedure for experts to assess the strength of sanctions and opportunities to access the markets of countries that implement the economic regulation of sales of products with a high carbon footprint based on a decision tree, will expand the methodological basis of strategic planning in the field of green innovation and complement the methodological tools of project management for the innovative development of economic systems.

5. Discussion

For the development of green innovations under conditions of sanctions, it is necessary to improve the innovation infrastructure of the oil and gas sector and to create a single information and resource centre for green innovations in this field in Russia (electronic platform of innovations). Attracting state financing is possible within the framework of creating a state fund to support green innovation in the oil and gas segment. In addition to the fund, venture funds with the participation of banks and companies operating in the oil and gas industry and investment from external investors under the framework of public–private partnerships, credit institutions and companies' capital invested in innovative projects can be considered as investment resources. To make decisions on an investment, it is necessary to assess its feasibility.

The proposed algorithm for assessing the development of green innovations and the model that was developed to assess the feasibility of implementing green innovations are recommended for broad practical application in strategic planning for enterprises' innovation activities.

Further research could involve substantiation of the prospects of implementing green innovations in the context of there being increased risk of a negative external impact on the economy as a whole. The transition to the green economy requires a special approach, taking into consideration all the specific aspects of management, especially in the oil and gas sector of the economy. On the one hand, significant financial resources are allocated at the Russian government level for the construction of large infrastructure projects, but on the other hand, this process will require significant investment transfers from the companies themselves. Taking into consideration the current situation in the international market of oil products and energy resources, with increasing supply and demand instability, unpredictability and the current refusal of foreign countries to buy Russian hydrocarbons, the process of implementing green innovation may be inactive for an indefinite period. This requires the study of possible tools and mechanisms to level the risks as well as the use of green innovations themselves as a factor contributing to the effectiveness of economic activity.

Further research could also involve the substantiation of directions and mechanisms of cooperation of the state and businesses in the process of developing, initiating and implementing green innovations in the oil and gas segment under the framework of developing public–private partnerships by determining characteristics of the infrastructure and institutional environment of the interaction between government and business entities in the implementation of green innovations in a negative external environment.

6. Conclusions

In accordance with the goals of this study, the following results and conclusions were obtained:

1. Theoretical aspects of the nature of green investment and its role in the development of the green

economy were specified.

2. The main stages of preparation and the work of an expert group to assess the probability of successfully implementing green innovations were considered.

3. An algorithm for managing green innovations in the oil and gas sector was developed and tested in terms of assessing the feasibility of implementing innovations based on expert interviews, a decision tree and the assessment of probabilities of outcomes; namely, a methodology was formulated to assess the choice of optimal decisions on the feasibility of launching a project to introduce green innovations in the oil and gas sector based on an expert assessment of sanction pressure and potential access to the markets of countries that conduct the economic regulation of energy-intensive products based on a decision tree, which makes it possible to complement the methodological support of strategic planning processes of green innovations and expand the tools for designing the innovation activities of economic entities.

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Research article

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Methods And Tools for Harmonisation of Industrial and Trade Policy in The Light Industry

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Abstract

This study examines the current industrial and trade policy of St. Petersburg in the field of light industry and substantiates the importance and necessity of the development of this sphere of industry in view of its strategic orientation. This paper analyses the approaches mentioned in the literature to determine the methods and tools for harmonisation of industrial and trade policy and state regulation of the conducted policy. The author developed, proposed and systematised administrative and economic methods and tools of harmonisation of industrial and commercial policy using the example of the light industry in St. Petersburg. As an administrative method of harmonisation of industrial and trade policy, the following tools are proposed: regulatory, state programming, state subsidies and public investment. As part of the economic method of harmonisation of industrial and trade policy, the following tools are proposed: state support for investors (monetary policy, tax policy), provision of benefits and tax policy. These methods and tools are aimed at improving the balance and mutual orientation of the current industrial and trade policy of St. Petersburg in the light industry at the institutional level and the effectiveness of their implementation, the elimination of problems faced by business entities in their activities, and improving the socio-economic situation of the region.

Keywords: industrial policy, trade policy, harmonisation, light industry, administrative methods, economic methods

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Методы и Инструменты Гармонизации Промышленной и Торговой Политики Легкой Промышленности

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Аннотация

В рамках исследования рассматривается проводимая промышленная и торговая политика г. Санкт-Петербурга в области легкой промышленности, обосновывается важность и необходимость развития данной сферы промышленности ввиду ее стратегической направленности. В статье проанализированы существующие в литературе подходы к определению методов и инструментов гармонизации промышленной и торговой политики, и государственного регулирования проводимой политики. Автором разработаны, предложены и систематизированы административные и экономические методы и инструменты гармонизации промышленной и торговой политики на примере легкой промышленности города Санкт-Петербурга. В качестве административного метода гармонизации промышленной и торговой политики предложены следующие инструменты: нормативно-правовой, государственного программирования, государственного субсидирования, государственных инвестиций. В рамках экономического метода гармонизации промышленной и торговой политики предложены такие инструменты, как: государственная поддержка инвесторов (денежно-кредитная политика, налоговая политика), предоставление льгот, налоговая политика. Данные методы и инструменты направлены на повышение сбалансированности и взаимной ориентации проводимой промышленной и торговой политики г. Санкт-Петербурга в отрасли легкой промышленности на институциональном уровне и эффективность их реализации, устранение проблемных моментов с которыми сталкиваются хозяйствующие субъекты в сфере своей деятельности и на улучшение социально-экономического положения региона.

Ключевые слова: промышленная политика, торговая политика, гармонизация, легкая промышленность, административные методы, экономические методы

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1. Introduction

The light industry, having a large domestic consumer market and a stable, growing demand for civilian and dual-use goods, is experiencing significant pressure from foreign manufacturers but also has internal difficulties. St. Petersburg in Russia has preserved its competencies and has intra-regional potential for light industry development. However, more than 60% of the sales of light industry products in the consumer market are provided by deliveries from foreign producers. Additionally, the production of consumer goods and other products of light industry enterprises has significantly decreased compared to the last century, i.e. the region has lost part of its sales market and significantly reduced industrial output.

The modern period is characterised by a high level of economic turbulence. The national economy is influenced by factors that fit into global trends. However, apart from them, the economic system is influenced by the restrictions imposed by other states, the increased volume of state expenditures to ensure strategic national interests in the defence sphere, and the sovereignty and integrity of the territory and state. At present, the development of domestic production, especially in terms of processing industries, is of particular importance. Such industries include the light industry. The search for tools for the development of industries under the conditions of unpredictable changes in global and national economies is a subject of scientific interest for various countries and researchers in various branches of the economy (AL-Saadi et al., 2022; Ch'ng et al., 2021; Mahnkopf, 2019; Mamedov et al., 2019; Yang et al., 2019)

Researchers have noted that in the regions, the light industry, as a traditional sector, is experiencing difficulties in its development. Thus, the limitations of the existing model of production are pointed out by Koszewska (2018)business people and authorities. The importance of the transition towards a more circular economy has also been noticed in the European Union. The new regulations provide the enabling framework for the circular economy to flourish. At the same time, although there is no standardized approach to creating a circular economy, while defining appropriate policies, care must be taken that they are suitable for particular industries. The limits of the present linear economy model (take-make-waste. Gomel'ko et al. (2020) noted that there is "insufficient investment in the absence of prospects and attractiveness of light industry and its constituent enterprises for investors". The technical and technological backwardness of production is highlighted by Ibragimova (2019). The increasing restrictions and the withdrawal of foreign manufacturers from the domestic market, on the one hand, create the risks of reducing the output of the light industry in the market and causing consumer demand dissatisfaction. On the other hand, the new conditions of economic activity create opportunities for the development of the light industry in the region.

Many researchers consider the development of the industry in the practical application of various forms of state support, for example, state subsidies (Ibragimova, 2019), increasing the state order (Yakovenko, 2015). However, our analysis of state target programmes has shown that the instruments of state policy for supporting the development of industries need to be improved. This is due to a number of reasons. In particular, the target indicators are not fully achieved; during the implementation of the programme, their quantitative values often decrease, while maintaining or increasing the amount of budget transfers.

We have identified a scientific problem that lies in the fact that the traditional ways of supporting manufacturing industries through subsidies, benefits and tax incentives, for example, do not meet the expectations of the state and do not satisfy the needs of society to the full extent, which determines the scientific search for ways to improve the existing methods and tools of state policy aimed at developing industries in the region (using the light industry as an example). At the current stage, the search, development and implementation of effective direct and indirect methods and tools of state regulation of the economy at the regional level are of particular relevance.

As one of the tools for the development of industries focused on satisfying consumer demand, we can consider harmonisation of the interests of interrelated industries achieved through harmonisation of industrial and trade policies in the region. Harmonisation in the economy is analysed in the national

and international literature from different points of view. For example, Moy and Godefroy consider harmonisation in the food industry to be an instrument for the unification of requirements for product quality in European countries (Barrie and Schröder, 2022; Moy and Godefroy, 2023). In a closely related context, the harmonisation of EU policies has been investigated by Magar et al. (2011) in terms of the standardisation of biomass trade requirements. The analysis showed that international researchers use harmonisation as a tool to coordinate the different components of a single industry (Dansie et al., 2019; Marques, 2019; Schmidt and Steingress, 2022).

The need for harmonisation of national and international industrial standards among the tools of harmonisation of industrial policy was considered by Klimenko et al. (2019). The harmonisation of industrial policy and state policy in the sphere of economic security was considered by Kanoat (2021).

The harmonisation of strategic plans at the national and regional levels was the subject of the study by Plotnikov et al. (2015). In national publications, the harmonisation of industrial and trade policy is most often analysed at the microeconomic level (e.g. Barmashov, 2018). The harmonisation of industrial and trade policy at the regional level is mostly studied as a tool to ensure productive and efficient interactions between enterprises and representatives of various industries (Roslyakova, 2021). Thus, harmonisation at the stage of development of sectoral components of state regional policy as a tool of state stimulation and support of industry development is not fully applied and studied, which determined the goal of this study. The aim was to develop the tools of harmonisation during the formation of institutional support for industrial and trade policy in the region using the example of the light industry.

2. Literature review

To develop measures for the harmonisation of industrial and trade policy, it is important to determine a set of methods and tools for state policy.

Shpak (2009) considered methods and tools of harmonisation of industrial and trade policy in terms of indicators of economic security in the region. Undoubtedly, when carrying out industrial and trade policy, it is necessary to consider the level of economic security in the region, but this approach does not fully reflect the existing problems in balancing the industrial and trade policy being conducted. It is aimed at increasing the values of economic security indicators, some of which are not directly related to the sphere of industry and trade, such as life expectancy and housing (Smirnova and Feofilova, 2018).

Mysachenko (2009) divided the forms and methods of state regulation of industry into four groups: the first group, macroeconomics, is the successful activity of state agencies to optimise the sectoral structure of industry, optimise the ratio of accumulation and consumption, rationalise all industrial sectors, stimulate demand for products, and promote exports (methods: forecasting, programming, regulatory, protectionist measures, differential taxation, development and implementation of a system of priorities, state investment, direct subsidies and other methods of investment policy, differential customs tariffs, export concentration and coordination, import restrictions, state guarantees and investment insurance, state subventions, targeted loans); the second one, microeconomics, is the method of state regulation of restructuring the primary production link, the withdrawal of inefficient industrial production from the economic turnover (methods such as forecasting, indicative programming, taxation, bankruptcy, state subventions, state investment, preferential loans, state order and price regulation); the third group of methods allows public authorities of the federal centre to reorganise the economic structure of industry in the country and the regulation of the regional industrial structure (forecasting, programming, legal framework for development of federalism, taxes, state investment, mixed financing of scientific and technological priorities, creation of free economic zones); and the fourth group is related to institutional changes that complement the first, second and third groups (methods such as regulatory methods for regulating investment flows, antimonopoly methods, state guarantees and information support). This classification is quite meaningful and detailed, but it also seems rather generalised, as it is proposed for use in all regions (Smirnova and Feofilova, 2018). It is worth agreeing with the statement of Erofeeva (2011)

that an industrial policy, as a set of measures and actions, should respond to the problems and challenges of the real industrial state and development. It should provide solutions to the most acute actual problems of industrial development, as well as mechanisms for their implementation.

The example of foreign countries that are leaders in the light industry demonstrates the effectiveness of measures aimed not only at developing the industrial complex but also at supporting trade. Many studies have been conducted in the field of increasing competitiveness in the light industry. For example, Epanchintseva (2012) provided a scheme of measures to achieve competitiveness in the light industry, in which at the industry and micro levels, measures were indicated that were equally aimed at stimulating industry and improving trade, such as "product quality improvement", "technical modernisation of production facilities", "marketing improvement", "optimum price policy" and "production organisation and logistics" at the micro level; and "creation of industry associations", "creation of industry procurement structures", "creation of industry added value chain", "creation of training organisations" and "trade network expansion" at the industry level.

Relying on the expert opinion of the largest apparel retailers in Russia, marketing research on the textile and apparel market, and empirical and statistical data on the light industry and the textile and apparel market, we offer a developed set of measures aimed at the harmonisation of industrial and trade policy in the light industry of St. Petersburg. Developing the ideas of Mysachenko (2009), we propose systematised, specific administrative and economic methods and tools for the harmonisation of industrial and trade policy, focused on the development of the light industry in St. Petersburg.

3. Materials and methods

The informational and empirical basis of the study consisted of data from the Federal State Statistics Service of the Russian Federation (Rosstat), the Office of the Federal State Statistics Service for St. Petersburg and the Leningrad region (Petrostat), federal and regional legislative and regulatory acts of the Russian Federation in the field of industrial and trade policies, industrial and trade development strategies at the federal and regional levels, and state target programmes aimed at supporting and developing the industry and trade of St. Petersburg.

The study used the method of analysis of institutional (regulatory and legal) support of industrial and trade policy at the federal and regional levels of St. Petersburg, the method of comparison at the federal and regional levels of the programme, and goal-oriented planning in the field of industrial and trade policy. The method of analogy allowed the federal experience of strategic planning and the formation of state programmes to be adapted to the regional level and clarified the functions and tasks of state authorities of constituent entities responsible for the formation and development of industrial and trade policy. The method of induction allowed for the formulation and identification of specific methods and tools for the harmonisation of industrial and trade policy of the light industry in St. Petersburg. The method of systematisation and grouping allowed them to be summarised and systematised using administrative and economic methods.

4. Results

During the study, a number of factors were identified as limiting the development of the industry (exemplified by the light industry) in the region. In addition to the factors related to the sources of risks formed by the technical and technological backwardness of industrial production, lack of investment, loss of the sales market for products, and the high level of competition, the limited effectiveness of support measures by public authorities was revealed.

Analysis of the state target programmes of the region showed that, for industry and trade, there were measures that when implemented did not lead to the achievement of the target indicator values. We developed the tools of administrative and economic methods to use the resources of industry and trade to stimulate the development of the respective sectors of the region's economy. In developing the instruments of the state policy in the region, we relied on mutual consideration of the interests of the

sectors - industry and trade, which, according to our calculations, will form a synergistic effect for the socio-economic system in the region by including coordinated measures to support sectoral enterprises.

The tools of the administrative method for the harmonisation of industrial and trade policy of the region are presented in Table 1.

Table 1. Administrative tools of the harmonisation of industrial and trade policy in St. Petersburg using the example of the light industry

Administrative methods of harmonisation		
Harmonisation tools	**Form of implementation**	**Estimated effect**
Regulatory Adoption of the Regulation on the Committee Clarification of the functions of the committees responsible for the development of industry and trade / or merging these committees by analogy with the federal level of government (implemented)	Interaction of the committees when developing state programs, development of joint programs; approval of a passport of the state programme (in its area of activity) to clarify the goals, objectives and target indicators.	Increasing communication and interaction between the committees; it will allow coordinated decisions, enhance mutual orientation and integration of the conducted industrial and trade policy, and streamline the list of activities being carried out.
Regulatory Based on sub-clause 7, clause 1, Article 9 of Law No. 221-47 of 08.06.2009 “On foundations of the industrial policy of St. Petersburg” (establishment of coordination and advisory bodies in the sphere of development of industry in St. Petersburg) Adoption of the Regulation on the Advisory Board	Creation of the Advisory Board (under the Committee on the Industrial Policy, Innovation, and Trade of St. Petersburg), the function of which is to expand communication channels between government and business to make balanced decisions when forming and implementing policies and government programs for the development of industry and trade.	Creation of a negotiation platform for making coordinated, mutually oriented decisions, increasing the level of communication between the authorities and business entities of the industry and trade in St. Petersburg.
Regulatory Improvement of the legislative and regulatory framework of documents constituting the institutional support of industrial and trade policy in St. Petersburg	Introduction of amendments and additions to legislative and other legal acts of St. Petersburg regulating the activities of industrial and trade policy in terms of setting goals and objectives aimed at the mutual orientation of the development of industries and considering the interests of trade industries (in particular: 1) St. Petersburg law of 13.05.2009 No. 221-47 “On the basis of the St. Petersburg industrial policy”; 2) St. Petersburg law of 27.10.2010 No. 582-139 “On state regulation of trading activities in St. Petersburg ...”; 3) St. Petersburg law of 19.12.2018 No. 771-164 “On the Strategy for Social and Economic Development of St. Petersburg for the period until 2035”; 4) SP SPb “Development of industry, innovation, and agro-industrial complex in St. Petersburg”; 5) SP SPb “Development of entrepreneurship and consumer market in St. Petersburg”.	Increasing the mutual orientation of industries towards one another; coherence, uniformity, integrity of the goals and objectives of industrial and trade policy.
Regulatory Specification of target indicators of state programmes for industrial and trade development	Explanation of the goals, objectives and specification of target indicators of state programmes for industrial and trade development, considering the mutual interests of the development of industries. The formation of the goals requires the consideration of the mutual interests of industries. Targeting tasks to solve problems in the industry in the interests of economic entities.	Making the evaluation of effectiveness of target indicators and implementation of the programs homogeneous. Updating and focusing on the solution of problem areas in industries. As a result, solving the problem areas hinders the development of industry and trade.

Regulatory Fixing the development of the light industry as a priority for St. Petersburg	Supplementing the strategy for socio-economic development in St. Petersburg until 2035 with provisions on the inclusion of the light industry into areas of industry ensuring sustainable economic growth, aimed at import substitution (item 3.3, clause 6.3)	Development of the light industry in the territory of St. Petersburg (historically traditionally established industry for St. Petersburg). Interregional cooperation with the Ivanovo region. Creation of additional production in the territory of St. Petersburg, which contributes to improving the business climate in the region. Creation of additional jobs, filling the revenue part of the budget. Increasing the competitiveness of products. Reducing the cost of production for the end consumer. Stimulating sales of regional products in the region, country and export development. Additional funding for business entities.
Regulatory, State programming Development of a state subprogramme for the development of the light industry in St. Petersburg in the framework of the SP Development of industry, innovation, and agro-industrial complex in St. Petersburg (similar to the subprogramme "Light industry and folk arts and crafts")	Orientation of the goals and objectives of the program to meet consumer demand of the population of the region, involvement and interest of trade entities in the promotion of regional products, and solving existing problems in the sectors of light industry. Targeting of state support. Popularisation and promotion of the "Made in St. Petersburg" brand, maintaining the image of St. Petersburg as the capital of the fashion industry. Formation of consciousness of environmentally friendly consumption; popularisation of purchasing high-quality products made of natural fabrics. Conclusion and execution of the agreement on interregional cooperation with the Ivanovo region, increase of localisation, and construction of the cluster development of the industry.	
State subsidies, Government investment Increasing state support measures to improve the competitiveness of regional products	Reducing administrative barriers when participating in state programs (expanding the scope of grants and subsidies). Popularisation of state measures to support manufacturers, increasing the level of communication and counselling. Increase in the volume of budget funds allocated for the renovation of fixed assets within the framework of the state programme. Stimulation and assistance in the digitalisation of production. Co-financing of projects for the development of light industry production infrastructure (up to 50% of the project cost).	

The following groups of tools have been developed as the tools of the economic method of harmonisation of industrial and trade policy in St. Petersburg using the example of the light industry: state support for investors, provision of benefits and tax policy measures (Table 2).

Table 2. Economic methods and tools for the harmonisation of industrial and trade policy in St. Petersburg using the example of the light industry

Economic methods of harmonisation		
Harmonisation tools	**Form of implementation**	**Estimated effect**
State support for investors **(monetary policy, tax policy)** Encouraging the placement of production facilities in the territory of St. Petersburg	Construction of modern factories and modernisation of existing ones to develop competitive products, leasing production areas for contract manufacturing, outsourcing to SMEs and the self-employed. Organisation of production in the territory of St. Petersburg of the largest foreign retailers of the Russian apparel market, Inditex, GloriaJeans and Adidas, and the largest Russian retailers, Oodji, Incity and MelonFashionGroup	Development of small and medium businesses. Increase the investment attractiveness of the region. Create additional jobs. Reduce the cost of goods for the end consumer.

Sustain. Dev. Eng. Econ. 2023, 2, 5. https://doi.org/10.48554/SDEE.2023.2.5

Provision of benefits for the use of land plots and property owned by St. Petersburg Provision of benefits for the use of land for the construction of production and storage facilities	Provision of benefits for the use of land for the construction of storage facilities, namely: - provision of state-owned land plots for leases without tender; - reducing the rent for the provision of land for construction to 1.5% of its cadastral value; - possibility of redeeming a land plot obtained for designated purposes at a reduced price; - establishment of preferential rent rates for the use of property owned by St. Petersburg.	Support and development of small and medium businesses. Distribution of the regional product. Increase business loyalty to state authorities. Increase the region's investment appeal and improve the region's business climate. Reduce the cost of goods for the end consumer.
Tax policy Establishment of special preferential tax regimes	Providing tax benefits for 5 tax periods in accordance with the law of St. Petersburg of 28.06.1995, No. 81-11, the subjects conducting activities under OKVED 2: in industry: class 13 – Manufacture of textile products; class 14 – Manufacture of clothing; class 15.2 – Manufacture of footwear. in commerce 47.51 – Retail trade in textile articles in specialised stores; 46.11.35 – Activities of agents in wholesale trade in textile raw materials and semi-finished goods; 46.16 – Activities of agents in wholesale trade in textile articles, clothing, footwear, leather and fur products; 46.42 – Wholesale trade in clothing and footwear; 47.71 – Retail sale of clothing in specialised stores; 47.82 – Retail sale in non-stationary trade objects and markets with textiles, clothing and footwear.	Reduce the tax burden on business entities, reducing the cost of production for the end consumer. Increase the investment attractiveness of the region, improving the business climate in the region – a synergistic socio-economic effect.

The light industry of the region was chosen as the object, the factors of the development and the current state of which were identified and evaluated during this study. As a result, tax incentives for the light industry were developed (Table 3).

Table 3. Regional tax incentives for entities operating in the light industry and trade in textile and clothing products

Tax type	General conditions	For St. Petersburg SEZ / Industrial zones	Tax incentives for investment projects	Proposed tax incentives (for the light industry and trade in textile and clothing products)
Transport tax	10 – 150 r./h.p.	0 r./h.p. for 5 years from the date of vehicle registration	-	5/70 r./h.p. during the program but not more than 5 tax periods
Income tax	20%	15.5% for the entire period of the Special Economic Zone's existence	13.5 for 7 years	15% during the program but not more than 5 tax periods

Property tax	2.2%	0% for 10 years from the date of property registration	0% for 5 years	1% during the program but not more than 5 tax periods
Land tax	1.5%	0% for 5 years from the date of emergence of ownership of each land plot	renting a land plot without tender; the possibility of redeeming the plot at a reduced price; reduction of the rent for the provision of land for construction up to 1.5% of its cadastral value	1% during the program but not more than 5 tax periods

When developing tax incentives for light industry enterprises in the region, the experience of state support of the automotive industry was adapted. Over a 10-year period (2010–2020), the automotive industry in the region was created through the successful implementation of state industrial policy measures. We chose the coefficient of capital intensity of enterprises as the main indicator to adapt measures of state support in value terms, which allowed us to compare the amount of resources required to invest in fixed production assets at the initial stage of development of industrial enterprises.

5. Discussion

The analysis identified the inconsistency of elements in industrial and trade policy, expressed in the lack of mutual orientation of goals and objectives of industry and trade, embodied in the normative legal acts of the Federation's constituent entity, limiting the development and implementation of measures to stimulate production based on a comprehensive approach. The analysis of normative legal acts at the federal level revealed that, in the documents of strategic and programme-target planning of the interests of the industrial and trade policy, harmonisation was achieved at least at the level of goal setting. Thus, the approach proposed by us, based on the harmonisation of industrial and trade policy of the region, is essentially an adaptation of the federal experience for state target programmes at the regional level of management.

Our vision of industry development through the harmonisation of interests with trade agrees with the conclusions of Bogatyrev (2021). However, despite the similarity of approaches to choosing the tools of harmonisation, according to the author, the region's industrial and competition policy, rather than its industrial and trade policy, is subject to harmonisation. From our point of view, the option of stimulating the development of industry outlined in this paper allows for the use of regional potential, which contributes to a synergistic socio-economic effect.

The developed toolkit aimed to improve institutional support, that is, the quality of the developed and adopted trade and industrial policy of the region, which distinguishes the results from works on the harmonisation of industrial and trade policy (Bayanduryan and Kleimenova, 2019).

The tools proposed in this paper are not new on their own. Their difference from the tools proposed in the literature and used in practice lies in the coordination of measures for industrial and trade enterprises. The industrial potential of the region and the capacity of the consumer market are considered, which will increase the production output of the light industry, promote the product in the regional market, and improve the socio-economic indicators of the region.

6. Conclusion

The harmonisation of industrial and trade policies, in our opinion, is advisable through the combined application of administrative and economic methods. The tools of these methods proposed in this paper were developed for the light industry in St. Petersburg. However, they are applicable to other regions of the country that have competences and the potential to develop the light industry. In addition, the development of industries through coordination of their interests is applicable not only to industry and trade; for example, great potential lies in the harmonisation of professional education and state industrial policy.

The methods and tools of the harmonisation of industrial and trade policy are dynamic and ap-

plied situationally, depending on political, economic, epidemiological and other situations. Therefore, the actualisation of the methods and tools must meet the existing challenges and threats in a regime of instability and uncertainty.

The proposed tools are aimed at achieving a synergistic socio-economic effect, namely reducing the tax burden on business entities, increasing business loyalty to state authorities, reducing the production cost for the end consumer, promoting a regional product, increasing the investment attractiveness of the region, establishing inter-regional cooperation, supporting and developing small and medium businesses, and improving the business climate in the region.

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