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Scenario-Based Projections of Educational Capital in Russian Regions: A Comparison of Consolidated and Differentiated Investment Policies[1]

Abstract. In recent years, regional policy has prioritized developing human capital amid population decline and rising geoeconomic fragmentation. This paper projects the development of human capital in Russian regions up to 2035 under two scenarios: a consolidated policy scenario (CPS) promoting regional convergence and a differentiated policy scenario (DPS) maintaining existing heterogeneity. Using dynamic panel regression with Arellano–Bond estimators and Rosstat data for 84 regions, the study examines the impact of these scenarios on education and labour markets. Under the CPS, education spending relative to regional GRP is expected to decline, and higher education expansion slows, leading to a reallocation of human capital investments. The share of workers with tertiary education stabilizes at around 30 %, with each additional year of education contributing roughly 11 % to regional GRP. Under the DPS, education and research spending generally rise, the share of workers with higher education increases to 33–35 %, and interregional educational disparities narrow. However, the marginal contribution of each additional year of education to GRP falls to about 7 %, assuming similar economic growth. These findings illustrate the trade-offs between centralized coordination and differentiated development in human capital investment, offering guidance for regional policy. The projections are conditional and should be interpreted with caution due to assumptions of linear growth, stable demographics, and limited spatial interactions.

Keywords: human capital projections, scenario approach, education, economic policy, Arellano–Bond estimator, dynamic panel analysis

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

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Сценарные прогнозы развития образовательного капитала в российских регионах: сравнение консолидированной и дифференцированной инвестиционной политики

Аннотация. За последнее десятилетие воспроизводство человеческого капитала стало одним из центральных приоритетов региональной политики в условиях демографического спада и растущей геоэкономической фрагментации, сдерживающих технологический прогресс. Целью данной работы является формулирование прогнозов развития человеческого капитала в российских регионах до 2035 г. в рамках сценариев консолидированной и дифференцированной политики. Используется динамическая панельная регрессия с оценками Ареллано–Бонда и данные Росстата по 84 регионам. В исследовании моделируются сценарий консолидированной политики, способствующий региональной конвергенции, и сценарий дифференцированной политики, предусматривающий существующую гетерогенность траекторий развития. Результаты показывают, что в сценарии консолидированной политики доля расходов на образование в ВРП снижается, а экспансия высшего образования замедлится, что приведет к перераспределению инвестиций в человеческий капитал между регионами. В этом сценарии доля трудоспособного населения с высшим образованием стабилизируется на среднем уровне не более 30 %, при этом каждый дополнительный год обучения будет вносить около 11 % в ВРП в период с 2013 по 2035 г.. Напротив, в сценарии дифференцированной политики расходы на образование и исследования в целом возрастут, а доля работников с высшим образованием увеличится примерно до 33–35 %, что будет также сопровождаться ростом межрегионального образовательного неравенства. Однако средний вклад каждого дополнительного года обучения в ВРП снизится примерно до 7 % при условии схожих уровней экономического роста. Полученные результаты служат основой для разработки региональной политики, иллюстрируя компромиссы между централизованной координацией и дифференцированными путями осуществления инвестиций в человеческий капитал. Прогнозы должны интерпретироваться с осторожностью из-за предположений о линейном росте, демографической ситуации, заложенной в прогнозах Росстата, а также ограниченном пространственном взаимодействии.

Ключевые слова: прогнозы развития человеческого капитала, сценарный подход, образование, экономическая политика, оценка Ареллано-Бонда, динамический анализ панельных данных

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Introduction

Human capital (HC) is widely recognized as a driver of sustainable economic development, social cohesion, and innovation, thereby becoming central to policy considerations at regional, national, and global levels (Bucci et al., 2019). Human capital forecasting, therefore, involves examining expected developments in education, health, and demographic change in order to support strategic economic and social policy planning (Lutz et al., 2018). In a period of growing global fragmentation, with rising rivalry, geopolitical uncertainty, and rapid technological change (Aiyar et al., 2023) the ability of regions to maintain HC becomes particularly important. HC projections are essential for shaping policy measures that reflect regional diversity, strengthen economic productivity, and reinforce societal resilience. This is particularly important for countries with pronounced spatial heterogeneity, such as Russia, where the uneven distribution of HC creates obstacles to balanced economic development and social stability (Zubarevich, 2022). HC development trajectories shift as technologies, institutions, and economic policies evolve, either strengthening coordination among economic actors or introducing more flexible HC strategies, and these shifts often intensify regional differences.

The aim of this research is to formulate HC projections for Russian regions up to 2035 by developing scenarios and applying fixed and

mixed effects estimation, complemented with Arellano–Bond estimators to analyse panel data from 84 regions. The study introduces a novel scenario-based modelling approach for regional HC dynamics projections, enabling predictive insights through comparative analysis of policy-driven development trajectories.

By examining regional patterns from 2013 to 2023 and accounting for established regional structures, including the addition of new regions in 2014, we produce projections extending to 2035. These projections focus on key education indicators, such as enrolment and graduation rates, as well as the educational composition of the labour market. Two policy scenarios are considered: a consolidated policy scenario (CPS), which emphasizes convergence and harmonization in HC development across regions, and a differentiated policy scenario (DPS), which preserves existing regional disparities and supports heterogeneous development trajectories.

Theoretical Background

HC refers to the accumulation of labour market-relevant skills and individual capabilities that enhance personal productivity (Becker, 1993), though the skills may depreciate and transform with technological advancements, particularly those related to digitalization (Walter & Lee, 2022). Over the past three decades, the scope of HC research has broadened significantly beyond traditional frameworks of formal education, including health capital, creative competencies (Benea-Popuşoi, 2022), and non-cognitive attributes associated with personality traits (Gimpelson, 2019; Rozhkova, 2019).

Regional strategies for HC development are evolving under the influence of geopolitical risks, global climate change, and demographic changes (Fontagné et al., 2022; Varlamova & Sinyavskaya, 2021). Recent literature highlights a growing interest in phenomena related to the slowdown of globalization and rising economic fragmentation, affecting international trade flows, technological spillovers, and change local and labour market structures (Aiyar et al., 2023; Rodríguez, 2023). In Russia, geoeconomic fragmentation has disrupted the labour market, prompting adaptive responses from workers and employers amid emerging labour shortages. However, restoring technological capacity and restructuring the education system are expected to take time, resulting in substantial HC losses (Kapeliushnikov, 2023) and increasing long-term risks to educational attainment and health (Chernenko, 2024).

HC projections also highlight the impact of demographic decline, a natural outcome of technological transitions (Lutz et al., 2018). Aging populations in Asian countries, for example, impose demographic "taxes" on labour markets, slowing economic growth (Park & Shin, 2023). In Russian regional labour markets, aging triggers cohort replacement, where younger generations generally attain higher education levels than their predecessors, gradually increasing the aggregate stock of HC (Chernina & Gimpelson, 2023).

In evolutionary theory, regions are conceptualized as dynamically evolving systems that organize economic activity by using available information and resources through diffusion, replication, and selective adaptation (Dopfer, 2005). HC development is a continuous process that accumulates skills, knowledge, and learning over time, progressing through stages of coordination and liberalization shaped by public policy and social capital. Evolutionary systems are path-dependent, influenced by prior technological choices and environmental factors, and characterized by transformative episodes that build on previous configurations (Brenner & zu Jeddeloh, 2024). Paths shape regional specialization and employment structures, guided by technological resources, HC, institutional quality, and social networks that determine skill utilization (Benner, 2023). In Russian regions, path dependence plays a moderate role in technological innovation alongside the level of economic development (Domnich, 2024). To address uncertainty and explore alternative futures, scenario approaches are used to analyse potential development paths under varying economic growth assumptions.

One of the most influential projection methodologies is the MaGE model by Fouré et al. (2013), which forecasts the global economy to 2050. MaGE incorporates HC in a disaggregated, dynamic way, linking educational attainment to female labour force participation. Education affects total factor productivity (TFP), with secondary education facilitating technology diffusion and tertiary education fostering innovation (Fontagné et al., 2022). Scenario design is critical in projecting future education and life expectancy. The shared socioeconomic pathways (SSPs) provide an integrated long-term perspective with five narrative and quantitative scenarios (Koch & Leimbach, 2023). In SSP1, a sustainability pathway, strong investment in education and health drives high enrolment, greater educational attainment, and enhanced HC and productivity. In contrast, SSP3, representing

a geoeconomically fragmented world, assumes slower educational progress, regional rivalry, and lower HC accumulation.

Lutz and Goujon (2001) develop two principal long-term scenarios for HC. In the baseline scenario, the proportions of young cohorts progressing to higher levels of education remain unchanged over time. In contrast, the convergence scenario assumes gradual improvements in school enrolment across all regions, leading by 2025–2030 to near-universal primary education, substantially increased secondary enrolment, and a significant rise in tertiary participation. Later research aligns these projections with the SSPs, modelling both rapid educational expansion and a more fragmented world marked by growing inequality in HC (Lutz et al., 2018).

Cuaresma et al. (2018) construct two contrasting scenarios for long-term HC projections. In the benchmark scenario, tertiary education attainment evolves dynamically while other variables remain fixed, whereas in the second scenario, tertiary education levels are assumed to remain unchanged. Bouzahzah (2021) explores three distinct scenarios for reforming the Moroccan education system, projecting potential economic outcomes by enhancing student performance on PISA tests, revealing substantial long-term economic benefits, significantly outweighing the initial investment costs. Jiang et al. (2022) capture HC through mean years of schooling, which vary significantly across SSPs, reflecting each scenario's emphasis on education and HC development. For example, SSP1, with higher investments in education and HC, shows substantial gains in schooling, while SSP3, characterized by fragmentation and inequality, exhibits limited educational growth.

The literature indicates that HC projections primarily rely on educational attainment and life expectancy, both critical for productivity. Despite slowing global economic growth, studies consistently highlight higher education and employment in research and development as key drivers of the knowledge economy. Educational attainment structures are influenced by technological progress and social change, while socio-economic policies determine how effectively HC is utilized by supporting institutional mechanisms for resource allocation. Regulatory consolidation, coordination, and policy harmonization tend to promote convergence in development and reduce interregional disparities. Conversely, policy differentiation, fragmentation, and inconsistent efforts in education and health contribute to divergence and exacerbate inequality.

Based on these insights, we propose the following research hypothesis. Under a differentiated policy scenario (DPS), which supports regional heterogeneity and decentralized investment strategies, Russian regions will achieve higher average educational attainment and a larger share of the workforce with higher education compared to a consolidated policy scenario (CPS), which applies a uniform educational investment policy across all regions.

Methods and Data

Basic Assumptions, Sources of Expert Estimates and Data

Projections are conditional estimates that rely on explicit assumptions or scenarios, such as policy changes, economic shocks, or convergence trajectories, and are designed to explore alternative future outcomes. To construct the projections presented in this study, we adopted a multi-stage methodological approach.

The first stage involved compiling the necessary statistical data on HC, including the Rosstat database Regions of Russia[1], microdata from the Labour Force Survey (LFS)[2], and the Comprehensive Living Standards Survey (CLSS)[3]. To estimate the size and demographic structure of each region's population, we used Rosstat's medium and most probable population projections for 2046, which provide annual counts of men and women by age for each region. This demographic framework served as the input stage, capturing resource constraints linked to population dynamics. Rosstat data were chosen for their official status and national relevance. Our projections focus on formal and non-formal education indicators, including short-term programs of up to 12 months. The territorial structure of the projections is defined as of January 1, 2015, in line with the available Rosstat statistical data for the entire period.

This study employs a dynamic cohort-component projection approach with five-year cohort intervals, integrating demographic, educational, labour market, and economic indicators (Bucci et al., 2019). The indirect method employed in this study involves the calculation

[1] Rosstat. Regions of Russia. Socio-Economic Indicators. https://rosstat.gov.ru/folder/210/document/13204 (Date of access: 10.10.2024).

[2] Rosstat. Microdata from Sample Labor Force Surveys. https://rosstat.gov.ru/labour_force# (Date of access: 21.11.2024)

[3] Rosstat. Results of a Comprehensive Monitoring of Living Conditions of the Population. https://rosstat.gov.ru/free_doc/new_site/GKS_KOUZH_2022/index.html (Date of access: 17.10.2024).

and projection of enrolment, participation, and graduation rates across relevant educational levels and age cohorts, derived as simple ratios, for example, the proportion of individuals enrolled in or graduating from educational institutions in a given year relative to the total population within the corresponding age group. To increase accuracy, the empirical age range for participation at each education level was established using microdata from LFS.Projections Models and Scenarios

Projections Models and Scenarios

Projecting long-term economic growth is typically based on the Cobb-Douglas model, in which gross product (Y) depends on the TFP A, the capital stock K, and the labour input L:

$$Y_{rt} = A(t)K(t)^{\propto} L(t)^{1-\propto} \quad (1)$$

Variable A captures TPF, representing the portion of output not directly explained by the measurable inputs, capital, labour, and *HC*. Essentially, A reflects factors such as technological progress, institutional quality, and efficiency improvements that affect production. When introducing the factor of labour quality, which is reflected in *HC* in the form of accumulated person-years of formal and non-formal education, the model takes the following form:

$$Y_{rt} = A(t)K(t)^{\propto} HC(t)^{\beta} L(t)^{1-\alpha-\beta} \quad (2)$$

To estimate this model econometrically, we begin with the augmented Cobb-Douglas production function where *HC* acts as an effective labour multiplier. Applying natural logarithms transforms the function into a linear form. In a panel model with region-specific fixed effects, the TFP term ln*Art* is typically decomposed into a region-specific effect (δ_r) and, if applicable, a time-specific effect (λ_t), with ε_{rt} representing the error term:

$$\ln Y_{rt} = \delta_r + \lambda_r + \propto \ln K_{rt} + (1-\propto)\ln L_{rt} + \\ + (1-\propto)\ln HC_{rt} + \varepsilon_{rt} \quad (3)$$

In Equation 3, it is necessary to determine the basic components, such as the stock of capital, the availability of labour and HC, in order to determine the level of economic growth. In our case, we address a more focused problem, projecting only the level of HC based on a predetermined labour force and simple assumptions and expert estimates for two parameters: economic growth rate and population by age group. The first source of expert estimates is the data from the Ministry of Finance 1 on the average growth rate of GRP in the regions, which, as we assume, will remain at 2,5 % per year until the end of the forecast period in 2035. The second source is Rosstat's medium, most probable regional population forecast by age group, extending to 2046 2. According to this projection, the total population of Russia is expected to decline to 141,3 million by 2035, accounting for net migration gains. The working-age population is projected to reach 87,3 million, representing a modest increase of 0,5 million compared to 2023. Based on these assumptions, the size of the available labour force is expected to remain relatively stable over the period, while its educational composition and therefore its productivity will change significantly. In 2023, the labour market was operating near full capacity, with historically low unemployment levels (Kapeliushnikov, 2023). To form the projections, a database was compiled for 84 regions covering the period from 2013 to 2023.

The first stage includes projecting indicators of socio-economic development. Panel models with fixed effects and mixed models were used, allowing to combine data from many regions, which improves estimation precision by pooling information across regions. For the first scenario we assumed that the national government implements economic policies uniformly across all regions, creating a situation where the same set of measures drives growth or decline regardless of local conditions. In consolidated scenario or CPS, key variables such as the share of investment in research and development in GRP or entrepreneurial employment are projected using a time trend, represented by the variable τ, as a common vector of economic change. Centring τ on the average year of the 2013–2023 period allows it to represent each year's deviation from that average. The CPS emphasizes regional convergence and balanced territorial development, relying on common indicators for technology investment, business sector growth, and social subsidy distribution.

In a fixed-effects model, each region is allowed its own baseline level through region-

[1] Ministry of Finance. Forecast of Socio-Economic Development of the Russian Federation for 2025 and for the Planning Period of 2026 and 2027. https://www.economy.gov.ru/material/file/b028b88a60e6ddf67e9fe9c07c4951f0 /prognoz_socialno_ekonomicheskogo_razvitiya_rf_2025-2027.pdf (Date of access: 11.10.2024).

[2] Rosstat. Population Size and Composition up to 2046. Demographic Forecast. https://rosstat.gov.ru/folder/12781# (Date of access: 05.11.2024).

specific intercepts, while the slope associated with τ remains the same for all regions. Although regions begin at different levels, they are assumed to follow the same convergent growth trajectory over time. Consolidated policies are therefore considered strong enough to overcome local idiosyncrasies, producing uniform dynamic responses across regions. For the CPS the set of *k* dependent variables were socio-economic development indicators (*D*) for region *r* during year *t*. Independent variables included the lagged value of D_{t-1}, the time trend τ centred on 2018, GRP projected using expert assumption on average economic growth, and regional fixed effects γ_{rtk}:

$$D_{rtk} = \beta_0 + \beta_1 \cdot D_{r(t-1)k} + \beta_2 \cdot \tau_{rt} + f_1 \cdot \beta_3 \cdot \tau^2_{rt} + \\ + f_2 \cdot \beta_4 \cdot lnGRP_{rt} + \gamma_{rtk} + \varepsilon_{rtk} \quad (4)$$

Additionally, we introduced model selection coefficients $f_{1,2}$ into the equation. These coefficients are set to zero if the model fits the data better and predicts subsequent periods even when a variable is excluded. The coefficient equals one if the variable is retained in the equation for projections.

The development indicators *D* include the knowledge intensity of the region (share of investment in research in *GRP* and number of scientific personnel), regional specialization (share of natural resources, share of employment in the entrepreneurial sector, and service sector), total education expenditure as a share of *GRP*, income structure (shares of social subsidies and property incomes in total household income), and the level of informal sector employment. These indicators capture local labour market configurations, which directly shape human capital accumulation and individual educational strategies.

The second scenario is an alternative situation in which local factors, institutional differences, or tailored policies lead to varied regional outcomes even under a national framework. In the case of differentiated policies or DPS, the effect of time is not uniform. Instead, each region may experience its own unique rate of change, reflecting differentiated policies or responses that are specific to local economic conditions. DPS imply increased divergence and regional inequality, in which some regions will retain their resource specialization, while other regions will invest in technological development.

The heterogeneous dynamic is captured by allowing the slope on *t* to vary by region. In a mixed-effects model, random slopes *b* for *t* allow each region's trend to deviate from the overall national trend captured in the fixed part of the model. The random slope for *t* represents the unique influence of local factors or differentiated policies on regional trajectories, producing distinct development paths over time:

$$D_{rtk} = (\beta_0 + b_{0,rt}) + \beta_1 \cdot D_{rk(t-1)} + (\beta_2 + b_{1,rt}) \cdot \tau_{rt} + \\ + f_1 \cdot \beta_3 \cdot lnGRP_{rt} + \varepsilon \quad (5)$$

In the second stage, we projected educational indicators through participation in formal and non-formal education, as well as structural labour market indicators for each region, in order to estimate the total stock of accumulated years of education, reflecting the level of individual investment in HC in the region. Educational structure indicators (*ESI*), including enrolment and graduation rates, and shares of educational groups in employed populations were calculated for the baseline period 2013–2023 and then estimations were used for projections. *ESI* were calculated for major levels e of the Russian education system, including higher education programs, mid-level specialist training, skilled workers, and secondary general education. Independent variables included a lagged *ESI* variable and a vector of k socio-economic development indicators D, which were used to control for the two proposed scenarios:

$$ESI_{rte} = \eta_{0e} + \rho_e \cdot ESI_{r(t-1)e} + \delta_{ke} \sum_{k=1}^{K} D_{rtk} + \gamma_{rte} + \varepsilon_{rte} \quad (6)$$

Our approach uses the Arellano–Bond estimator (Arellano & Bond, 1991) because the model includes a lagged dependent variable, which means that previous values strongly influence current outcomes. The estimator is designed to capture dynamic behaviour while addressing potential biases arising in panel data when fixed effects are present (Kaneva & Untura, 2021). Rather than simply demeaning the data, which removes unobserved fixed effects but introduces bias when a lagged dependent variable is included, the method first differences the data to eliminate time-invariant characteristics. The Arellano–Bond estimator then uses lagged levels of the dependent variable as instruments, assuming that earlier levels are uncorrelated with the differenced error. After estimating the equation for the baseline period, the educational structure indicators are predicted and projected for each subsequent year:

$$\widehat{ESI_{rte}} = \eta_{0e} + \rho_e \cdot \widehat{ESI_{r(t-1)}} + \delta_{ke} \sum_{k=1}^{K} D^{proj}_{rtk} + \varepsilon_{ert} \quad (7)$$

On the third stage, using the enrolment and graduation rates from educational programs, the actual population size N_{rte}^{group} in each educational group e in region r was calculated by multiplying the number of people P_{rte} at expected ages according to the Rosstat forecast until 2046 by the projected ESI rates. For example, for higher education, Pe for each region r and year t is equal to the corresponding number of men and women aged 18 to 24:

$$N_{rte}^{enroll/graduate} = P_{rte} \times \widehat{ESI}_{rte} \quad (8)$$

Then, the balance method was used to determine the total number of students N_{rte}^{group} in year t considering errors and other internal movements π by adding the number of enrolled N_{rte}^{enroll} and subtracting the number of graduated individuals $N_{rte}^{graduate}$ in region *r* at each level of education e in order. Movements in π are mostly associated with expulsions and graduations across different enrolment years and, according to estimates for 2013–2023, they typically account for only 1–2 % of the total number of students:

$$N_{rte}^{group} = N_{r(t-1)e}^{group} + N_{rte}^{enroll} - N_{rte}^{graduate} + \pi \quad (9)$$

The total size of the employed population in the labour market was estimated by using another group of ESI coefficients, indicating educational structure for the employed population. The expected number of the population of working age P_{rtW} according to Rosstat data (16–54 years for women and 16–59 years for men) was multiplied by the employed to population ratio $\widehat{EPR}_{rt}$, and by the projected share of population in the educational structure $\widehat{ESI}_{rte}$:

$$HC_{rt}^{total} = \sum_{e=1}^{E} P_{rtW} \times \widehat{EPR}_{rt} \times \widehat{ESI}_{rte} \quad (10)$$

In addition to formal training, the total number of people participating in non-formal training was calculated in a similar manner using a dynamic panel regression model, based on the microdata of the CLSS for 2014–2022 to estimate the baseline equations.

In the final fourth stage, the parameters of the augmented Cobb–Douglas production function were estimated to assess the return on investment in HC at the regional level under different policy scenarios. The independent variable in the model is the average number of accumulated person-years of education per region, calculated from the projected data obtained in previous stages. The model estimates inform policy-relevant conclusions on the contrasts between the development scenarios considered.

The methods have three main limitations arising from model assumptions. First, regional spillover effects are not explicitly captured. Second, demographic dynamics are held constant according to Rosstat's medium forecast, ignoring potential shocks or policy changes in fertility, migration, or aging. Third, the model assumes linear economic growth, which may overlook cyclical or structural shifts. These simplifications are necessary for feasibility, given current data constraints and limited growth prospects under ongoing sanctions.

Results and Discussion

Socio-Economic Development Indicators for Two Scenarios

Using the results from the first-stage fixed – and mixed-effects models, we obtained estimates of socio-economic development indicators for the period 2013–2023. These estimates were then used to project participation in educational groups within the education system and the labour market up to 2035. The models' explanatory power is largely driven by the lagged dependent variable, although GDP also shows statistically significant effects in most model variants. Because the estimates of socio-economic indicators are highly sensitive to nonlinear factors and can become distorted in the projection period, the squared trend variable was excluded from several of the models (i. e. $f_2 = 0$). Moreover, fixed-effects coefficients were estimated for each model to capture the initial level of development for each region over the baseline period. Mixed-effects models indicate that the linear time trend is statistically significant for most socio-economic indicators, with the exception of the share of research personnel and the share of the natural resource extraction sector in GRP. The lagged dependent variable, reflecting the influence of baseline conditions, demonstrates the strongest explanatory power across all model specifications. As in previous regional research (Domnich, 2024), this highlights the path-dependent nature of regional development.

The two scenarios show notable differences in both the rate and direction of indicator changes over time (Table 1). Across all scenarios, the share of investment in R&D is projected to decline on average. However, under the DPS, where regional heterogeneity is preserved, investment is expected to grow moderately, reaching 1,2 % of GRP by

Table 1

Baseline and Projected Socio-Economic Development Indicators for Russian Regions, 2013–2035
Базовые и прогнозные показатели социально-экономического развития регионов России на 2013–2035 годы

Scenario	Development indicator (DI)	Baseline period			Projections		
		2013	2018	2023	2025	2030	2035
CPS	RND	1,01	0,64	0,61	0,63	0,76	1,05
	NRD	2,65	2,50	2,41	2,44	2,75	3,41
	ENE	23,46	23,80	22,56	22,91	23,21	23,46
	NAT	10,24	9,97	9,89	9,83	9,67	9,52
	SOC	22,51	22,72	22,38	23,56	24,82	25,69
	SER	44,03	46,49	46,47	46,54	46,66	46,75
	EDU	4,50	3,73	3,44	3,35	3,11	2,86
	PRO	2,64	2,93	4,07	4,32	5,07	5,84
	INF	14,42	13,23	12,26	11,51	9,86	8,24
DPS	RND	1,01	0,64	0,61	0,65	0,88	1,24
	NRD	2,65	2,50	2,41	2,36	2,23	2,10
	ENE	23,46	23,80	22,56	22,37	21,86	21,31
	NAT	10,24	9,97	9,89	9,83	9,71	9,62
	SOC	22,51	22,72	22,38	21,64	18,94	15,23
	SER	44,03	46,49	46,47	46,21	44,53	41,38
	EDU	4,50	3,73	3,44	3,45	3,78	4,49
	PRO	2,64	2,93	4,07	4,52	5,89	7,59
	INF	14,42	13,23	12,26	11,46	9,14	6,49

Source: Authors' elaboration based on own calculations

2035. DPS also anticipates a rise in research productivity, as automation leads to a slight reduction in the number of workers employed in knowledge-intensive sectors.

Note: RND — share of investment in R&D in GRP; NRD — number R&D personnel per 1000 population; ENE — share of employment in SMEs; NAT — share of natural resources in GRP; SOC — share of social subsidies in total households income; SER — share of the service sector in GRP; EDU — share of education expenditure in GRP; PRO — share of private property income in household income; INF — share of informal employment in total employment.

The CPS, which establishes a unified vector of change across all regions, is primarily oriented toward convergence, that is, reducing regional disparities in economic growth by moderating growth in the most developed regions and accelerating it in less developed and lagging territories. Within the framework, reproduction of HC is guided by a focus on aggregate education expenditures, the structure of which facilitates regional redistribution. CPS emphasizes the optimization and reduction of public and household expenditures on formal education. Specifically, it is projected that the share of education spending will decline to an average of 2,9 % of GRP by 2035. In contrast, under the DPS, where regions continue along their current development trajectories, education spending is expected to increase to an average of 4,5 % of GRP in constant prices by 2035. As illustrated in Figure 1, under the CPS, education expenditures in the Central and Northern Federal Districts, which currently allocate the highest levels of investment in HC, are projected to decrease by 14–27 % on average. However, other regions will be required to increase education budgets by approximately 5–10 %, with the regions in the south and in the Far East expected to experience the most significant growth in education investment by 2035.

Projections of Enrolment, Coverage and Graduation

Based on the estimated and projected values of key socio-economic development indicators, second-stage models were constructed to assess enrolment and graduation rates, as well as the dynamics of structural labour market indicators. All models were estimated using the Arellano–Bond estimator, with diagnostic tests confirming the robustness of the dynamic panel specifications. Specifically, the p-values for the Arellano–Bond test for AR(1) were below 5 %, AR(2) showed *p*-values above 5 %.

A comparison of key educational indicators across the two scenarios reveals significant differences in HC investment strategies (Table 2). In both scenarios, the coverage of the population

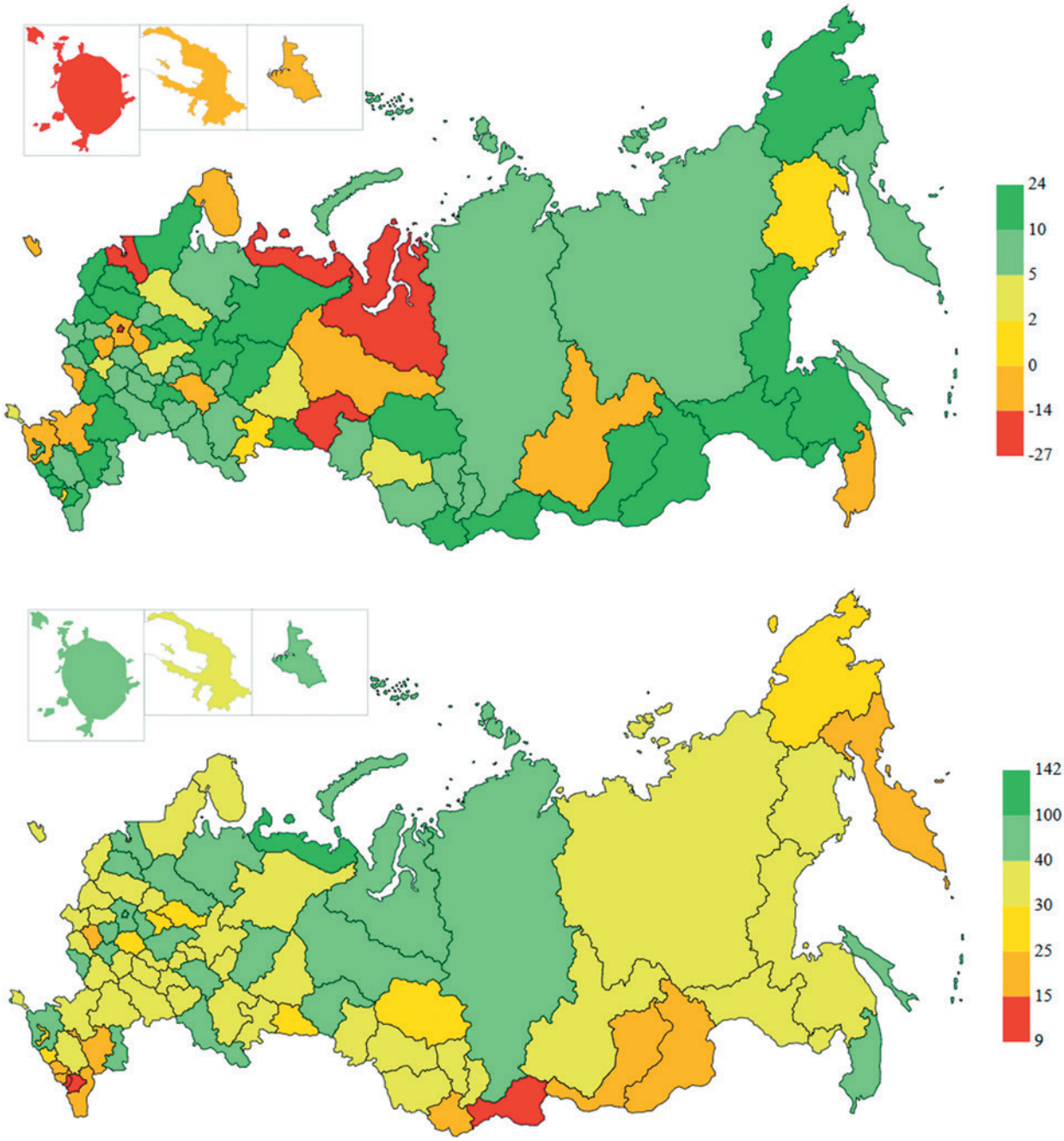

Fig. 1. *Projected Change in Gross Education Expenditure in Russian Regions by 2035 compared to 2023 (%, constant prices). Top: CPS; bottom: DPS. The maps are defined as of January 1, 2015*

Рис. 1. *Прогнозируемое изменение валовых расходов на образование в регионах России к 2035 году по сравнению с 2023 годом (%, в постоянных ценах). Вверху: сценарий консолидированной политики; внизу: сценарий дифференцированной политики. Карты определены по состоянию на 01.01.2015*

Source: Authors' elaboration based on own calculations

by secondary vocational education programs for mid-level specialists, remains substantial. In Russia, secondary vocational education reinforces general schooling, supports sustainable careers, and provides pathways to higher education. Under the CPS, the share of skilled worker training is projected to remain largely unchanged. In contrast, the DPS anticipates a modest increase in secondary education coverage, reflecting varied regional strategies and priorities. Despite the projected decline in relative education investment in the more developed Central and Northwestern Federal Districts under the CPS, higher education will continue to expand, though more slowly than under the DPS, where regional heterogeneity is preserved. Overall investment in human capital is

Table 2

Educational Structure Indicators (Enrollment, Graduation Rates and Coverage) for the Relevant Age Groups (2013–2035)

Таблица 2

Индикаторы образования (прием, выпуск и охват) для соответствующих возрастных групп (2013–2035 гг.)

Scenario	ESI	Baseline period			Projections		
		2013	2018	2023	2025	2030	2035
CPS	ESI_1	44,89	49,87	47,53	47,46	45,62	42,33
	ESI_2.1	3,42	1,82	1,89	1,78	1,51	1,18
	ESI_2.2	5,31	4,67	5,17	5,01	5,11	5,07
	ESI_2.3	3,23	1,45	1,50	1,29	0,96	0,71
	ESI_3.1	3,84	6,34	8,14	8,70	9,73	10,25
	ESI_3.2	11,85	20,61	25,46	24,45	24,91	23,87
	ESI_3.3	2,63	4,25	5,32	5,63	6,32	6,91
	ESI_4.1	3,94	4,26	5,34	5,02	5,25	5,39
	ESI_4.2	17,92	15,90	18,49	19,62	22,51	24,08
	ESI_4.3	4,06	3,40	3,38	3,11	3,03	3,09
DPS	ESI_1	44,89	49,87	47,53	47,76	47,64	47,34
	ESI_2.1	3,42	1,82	1,89	1,95	2,72	4,18
	ESI_2.2	5,31	4,67	5,17	4,97	5,30	5,86
	ESI_2.3	3,23	1,45	1,50	1,52	2,33	3,88
	ESI_3.1	3,84	6,34	8,14	8,80	10,52	12,40
	ESI_3.2	11,85	20,61	25,46	25,04	27,61	29,24
	ESI_3.3	2,63	4,25	5,32	5,61	6,03	5,90
	ESI_4.1	3,94	4,26	5,34	5,65	6,48	7,22
	ESI_4.2	17,92	15,90	18,49	19,95	24,17	28,58
	ESI_4.3	4,06	3,40	3,38	3,20	3,36	3,74

Source: Authors' elaboration based on own calculations

higher under the DPS, driven by continued growth in both secondary and tertiary education.

Note: ESI_1 — graduation, secondary education; ESI_2.1 — enrolment, skilled workers; ESI_2.2 — coverage, skilled workers; ESI_2.3 — graduation, skilled workers; ESI_3.1 — enrolment, mid-level specialists; ESI_3.2 — coverage, mid-level specialists; ESI_3.3 — graduation of mid-level specialists; ESI_4.1 — enrolment, higher education; ESI_4.2 — coverage, higher education; ESI_4.3 — graduation, higher education.

Figure 2 illustrates the projected differences in university enrolment rates across Russian regions in 2035, calculated as the difference between the DPS and the CPS. The results clearly show that reduced education spending under the CPS will primarily affect the more developed central regions, where enrolment rates are projected to be up to 7 percentage points lower compared to the DPS. A number of regions, particularly those with smaller or declining populations, are expected to increase university enrolment rates under the CPS in order to meet convergence targets. Adjustments are needed to align access to education with projected regional populations for 2035, according to Rosstat forecasts. The largest increases are expected in Sevastopol, Tomsk and Magadan regions, and several southern republics, reflecting targeted policies to reduce regional disparities in higher education. access.

In addition, projections were developed for population participation in lifelong learning, specifically in the form of non-formal education (Figure 3). The overall participation rate in such programs across Russian regions remains relatively low and stable, historically not exceeding 3,5 %. Given the limited observed dynamics in this indicator, participation is projected to remain within the 2–3 % range under both scenarios. However, under the DPS, a gradual increase in retraining participation is anticipated, with the share of the population involved in non-formal education expected to reach approximately 3 % by 2035.

Projections of Labor Market Educational Structure

Human capital acquired through the education system operates as a labour market resource. Accordingly, we projected the educational structure of employment in Russian regions through 2035. To estimate the employed

Fig. 2. *Projected Difference in University Enrollment Rates in 2035 (Percentage Points): CPS vs. DPS. The maps are defined as of January 1, 2015*
Рис. 2. *Прогнозируемая разница в показателях зачисления в университеты в 2035 году (процентные пункты): консолидированный минус дифференцированный сценарий. Карты определены по состоянию на 01.01.2015*
Source: Authors' elaboration based on own calculations

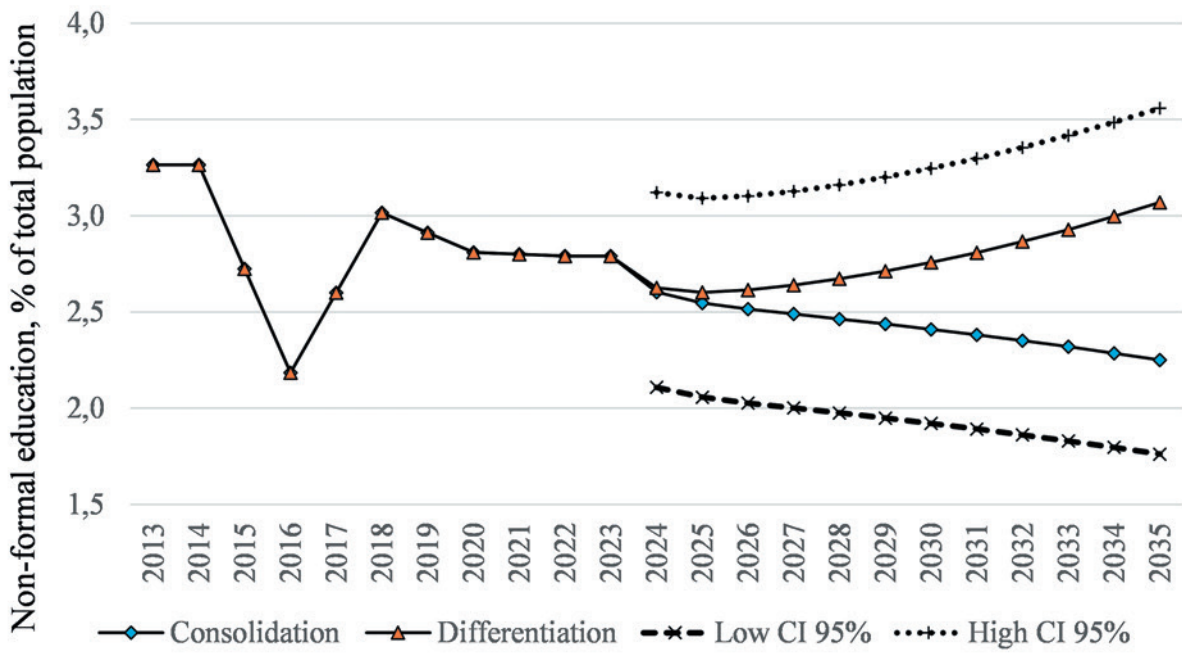

Fig. 3. *Projected Participation in Non-Formal Education under CPS and DPS, of Total Population*
Рис. 3. *Прогнозируемое участие в неформальном образовании в сценариях консолидированной и дифференцированной политики, % от общей численности населения*
Source: Authors' elaboration based on own calculations

population, we used the employment-to-population ratio (EPR), which measures the share of employed individuals in the total working-age population. Unlike the employment rate, EPR is not age-specific. Assuming the EPR remains stable at 75 % in the Southern republics and at 95 % in Moscow and St Petersburg, total employment is projected to peak in 2026 at around 74.2 million

people, closely matching the Ministry of Finance forecast. Thereafter, employment is expected to decline gradually, reflecting demographic trends and workforce ageing.

We focused on the main educational groups in the employed population, specifically, those with higher and secondary vocational education. Projecting structural changes in smaller groups, such as individuals with less than secondary education, which comprise only 10–15 % of total employment, is statistically less robust. As shown in Figure 4, the most substantial structural changes are expected among workers with higher education. Under the DPS, their share is projected to increase steadily, reaching approximately one-third of all employed individuals by 2035. Accounting for the 95 % confidence interval, the figure could approach 35 %. In contrast, under the CPS, where education investment as a share of GRP is reduced, the share of higher-educated workers is not expected to exceed 30 % by 2035. The expansion of higher and secondary vocational education will lead to a marked decline in the share of workers with only secondary general education, who constitute the least-qualified segment of the labour force. In the CPS, their share is projected to fall to 12 % by 2035, down from just over 20 % in 2013. The transformation is primarily driven by the retirement of older cohorts, who generally possess lower levels of formal education.

The results of the projection assessment are summarized in Table 3. The most significant differences between the two scenarios emerge in the category of workers with higher education. By 2035, under the CPS, which assumes convergence in HC development strategies, the number of employed individuals with higher education is projected to reach approximately 21 million. In contrast, the DPS scenario projects a higher total of about 24 million, driven by more active participation in university education and an increased average share of education investment within the GRP structure. Structural differences in educational attainment are also reflected in the average number of accumulated years of education per employed person. Under the CPS, this figure is expected to reach approximately 12,5 years, whereas under the DPS, assuming continued investment in higher and vocational

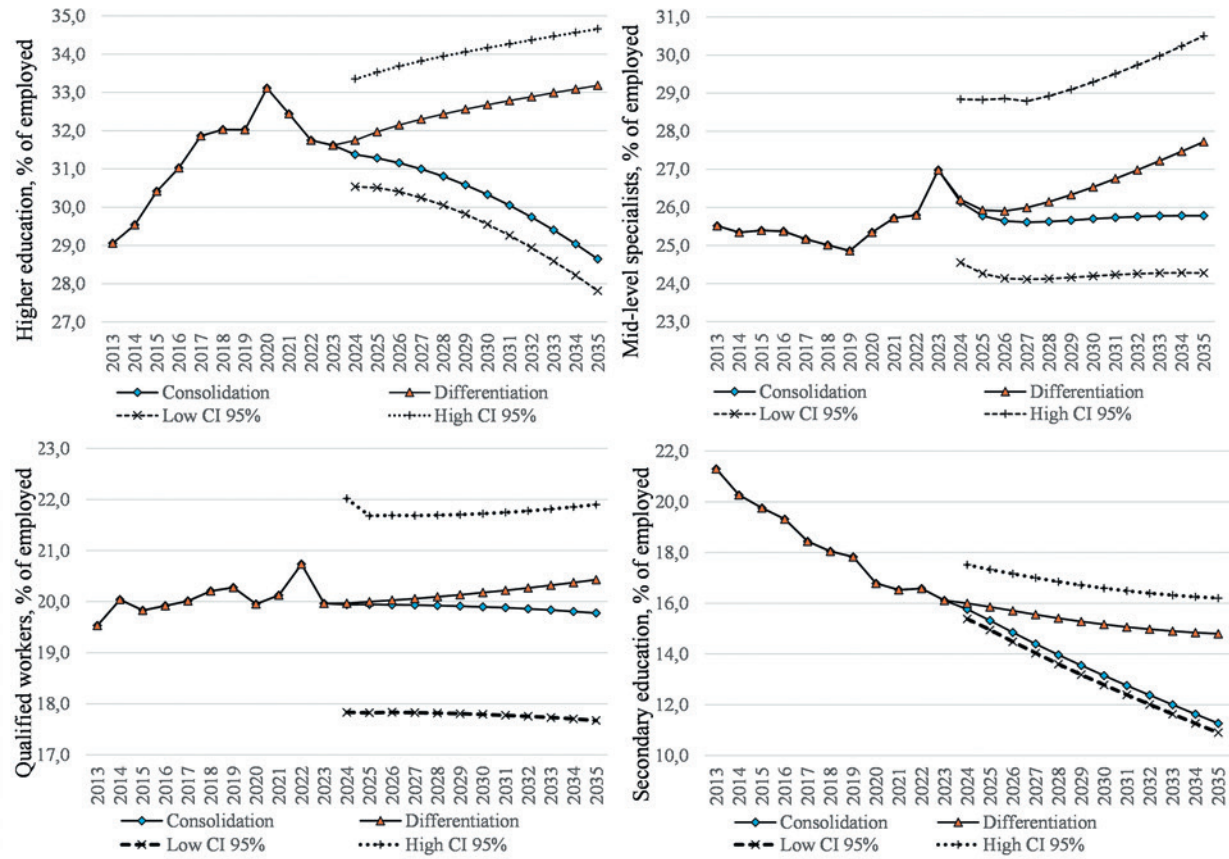

Fig. 4. *Projected Educational Structure of the Labor Market by Main Education Groups with 95 % Confidence Intervals (CI)*
Рис. 4. *Прогнозируемая образовательная структура рынка труда по основным образовательным группам с 95 % доверительными интервалами (ДИ)*
Source: Authors' elaboration based on own calculations

Table 3

Total Number of Employed Persons by Education Level Under Policy Scenarios (2013–2035)

Таблица 3

Общее количество занятых по уровню образования в рамках двух сценариев (2013–2035 гг.)

Scenario	Development indicator	Baseline period			Projections		
		2013	2018	2023	2025	2030	2035
CPS	Higher	20 869	23 039	23 187	23 153	22 492	21 039
	Mid-level specialists	18 326	17 989	19 787	19 079	19 058	18 936
	Skilled workers	14 030	14 536	14 641	14 761	14 756	14 526
	Secondary education and lower levels	18 599	16 365	15 724	17 019	17 851	18 950
	Education, average years per employed	12,64	12,85	12,89	12,82	12,75	12,63
DPS	Higher	20 869	23 039	23 187	23 662	24 230	24 370
	Mid-level specialists	18 326	17 989	19 787	19 192	19 678	20 362
	Skilled workers	14 030	14 536	14 641	14 801	14 963	15 005
	Secondary education and lower levels	18 599	16 365	15 724	16 358	15 287	13 713
	Education, average years per employed	12,64	12,85	12,89	12,88	12,95	13,04
Total employed population		71824	71 929	73 341	74 012	74 158	73 450

Source: Authors' elaboration based on own calculations

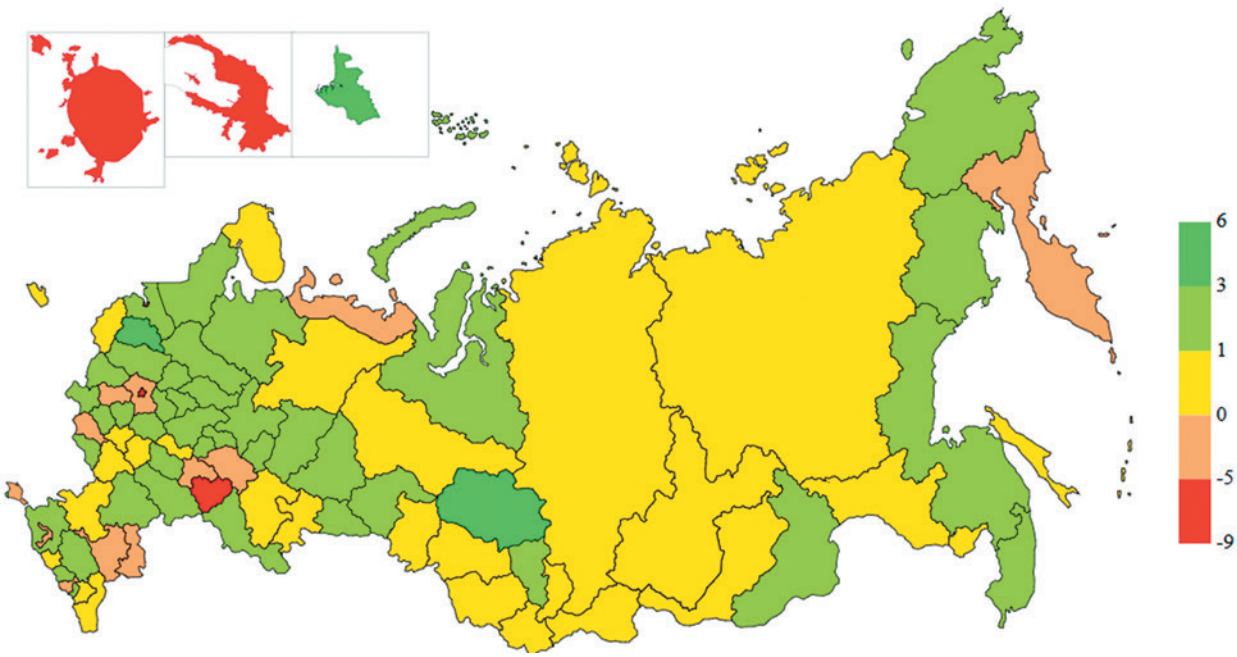

Fig. 5. *Projected Difference in the Share of Employed Persons with Higher Education in 2035 (percentage points): CPS vs. DPS. The maps are defined as of January 1, 2015*

Рис. 5. *Прогнозируемая разница в доле занятых с высшим образованием в 2035 году (процентные пункты): консолидированный минус дифференцированный сценарии. Карты определены по состоянию на 01.01.2015*

Source: Authors' elaboration based on own calculations

education, the average could exceed 13 years per person by 2035.

Regional differentiation becomes particularly evident when comparing the scenario outcomes for 2035 in terms of the employed population with higher education. Under the CPS, which assumes convergence and equalization of HC investments across regions, more developed regions, particularly in Central Russia, are projected to experience a decline in the share of highly educated workers. At the same time, modest gains are expected in Western and Far Eastern regions, while much of the North-East, including large territories such as Krasnoyarsk Krai and the Sakha Republic, is projected to see no significant change. Convergence may result in a productivity decline in knowledge-intensive

Table 6

Panel Regression Estimates with Log GRP Per Capita as the Dependent Variable

Таблица 6

Оценки панельной регрессии с логарифмом ВРП на душу населения в качестве зависимой переменной

Independent variables	Basic (2013-2023)	CPS (2013-2035)	DPS (2013-2035)
Logarithm of capital	0,186*** (0,007)	0,204*** (0,006)	0,221*** (0,006)
Labour force participation rate	0,007*** (0,001)	0,005*** (0,001)	0,005*** (0,001)
Share of natural resources in GRP	0,007*** (0,001)	0,009*** (0,001)	0,002*** (0,000)
Investments in research	-0,115*** (0,012)	-0,034*** (0,009)	0,013*** (0,004)
HC (average years of education)	0,095*** (0,018)	0,111*** (0,010)	0,073*** (0,011)
HC (life expectancy)	0,023*** (0,003)	0,045*** (0,002)	0,043*** (0,001)
Constant	4,189*** (0,283)	2,084*** (0,126)	2,237*** (0,145)
Observations	924	1932	1932
Regions	84	84	84
R-squared adjusted	0,720	0,882	0,875
F-statistics	410,3***	2 410,2***	2 275,3***

industries concentrated in Central Russia, which are currently national leaders in innovation. However, reallocation of investment could simultaneously stimulate diversification strategies and promote the development of HC in other regions, particularly in manufacturing and industrial sectors, that have historically lagged behind in educational attainment and workforce qualifications.

At the final stage we estimated the parameters of the Cobb–Douglas production function econometric approximation, where the dependent variable is the logarithm of GRP per capita (Table 6). The model was estimated using panel regression techniques, applied both to the historical baseline period and to the two projected scenarios across Russian regions. The results indicate that the GRP per capita increases by approximately 9,5 % for each additional year of accumulated education in a region. Under the CPS, where the expansion of higher education slows and investment in the education system is optimized or reduced, the return on each year of education is projected to rise to 11 %. In contrast, the DPS, which maintains regional heterogeneity and allows for continued variation in education investment, is associated with a lower return of approximately 7,3 % per year of education. The estimates are based on a linear assumption for GRP growth, using an average projected growth rate of 2,4 % per year. However, under the DPS, non-linear effects may arise through interactions between innovation, workforce skills, and regional specialization, potentially accelerating GRP growth. In this setting, the marginal return on each additional year of education may remain stable or even increase despite ongoing regional disparities.

Conclusion

In an environment defined by uncertainty, regional diversity, and increasing technological complexity, the demand for reliable regional socio-economic projections continues to grow. This study examines human capital by focusing on its accumulation and use in formal and non-formal education systems and in the educational structure of the labour market. To support evidence-informed policymaking, the study introduces a multi-stage scenario-driven modelling approach that links socio-economic development indicators with education-related projections. The comparison of CPS and DPS outcomes confirms the central hypothesis: under a DPS, which maintains regional autonomy and decentralized educational investment, regions reach higher average levels of educational attainment and a larger share of workers with tertiary education by 2035.

The policy implications follow from the contrasting trajectories of the two scenarios. Under the CPS, which is more likely in conditions of geopolitical fragmentation and sanctions, education spending declines while research investment remains stable. This scenario results in lower enrolment, a projected 28 % share of workers with higher education by 2035, and

regional convergence driven by slower growth in Central regions and gradual improvement elsewhere. Under the DPS, educational expansion continues, supported by regional autonomy. This leads to higher enrolment and graduation rates and a projected 33 % share of workers with tertiary education. Although non-formal education remains difficult to project due to historically low participation, the differentiated trajectories under the DPS appear better aligned with ongoing digital transformation and the persistence of technological lag, given their institutional flexibility and reduced coordination requirements.

The findings can support academic projections of other human capital components and inform policy documents at national, macro-regional, and regional levels focused on developing educational capital. Future research should extend the framework to incorporate non-linear growth, energy intensity, and physical capital investment, drawing on more detailed data on the educational structure of the labour force by age and gender.

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