HUMAN CAPITAL AND REGIONAL ECONOMIC GROWTH: A PANEL ANALYSIS OF THE LUCAS-UZAWA MODEL FOR THE REGIONS OF UZBEKISTAN

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Abstract. *The paper estimates the effect of human capital on regional growth in Uzbekistan, and its external effect, during the rapid expansion of higher education after 2017. A Lucas–Uzawa production function is estimated on a panel of 14 regions for 2010–2024 with region and year fixed effects and Driscoll–Kraay standard errors. A 10 % rise in the stock of university graduates per worker raises real gross regional product (GRP) per worker by 3.9 % (elasticity 0.391, p = 0.003). With a Mincer-consistent measure, the social return to a one-percentage-point increase in the graduate share (4.2–5.0 %) is several times the private return (0.55 %), indicating sizeable externalities. Yet regions diverge: the σ-dispersion rose from 0.371 in 2016 to 0.419 in 2024, and weak convergence appears only conditional on the level of human capital. In Surkhandarya region, human capital accounts for 40.8 % of the growth of real GRP per worker in 2013–2024; raising its graduate stock to the regional average could increase GRP per worker by about 31 %.*

Keywords: *human capital, Lucas–Uzawa model, externalities, regional growth, higher education, panel data, Surkhandarya region.*

Annotatsiya. *Maqolada 2017-yildan keyin oliy ta’lim qamrovi keskin kengaygan sharoitda O‘zbekiston hududlarida inson kapitalining iqtisodiy o‘sishga ta’siri va tashqi samarasi baholangan. Lukas–Uzava ishlab chiqarish funksiyasi 14 hudud bo‘yicha 2010–2024-yillar panel ma’lumotlarida hudud va yil qat’iy samaralari hamda Driskoll–Kraay standart xatolari bilan baholandi. Bir ishchiga oliy ta’lim bitiruvchilari zaxirasining 10 % ga oshishi bir ishchiga real yalpi hududiy mahsulotni (YaHM) 3,9 % ga oshiradi (elastiklik 0,391; p = 0,003). Minser tenglamasiga mos o‘lchovda bitiruvchilar ulushining 1 foiz punktga oshishining ijtimoiy samarasi (4,2–5,0 %) xususiy samaradan (0,55 %) bir necha barobar yuqori, ya’ni tashqi samara mavjud. Biroq hududlar yaqinlashmayapti: σ-ko‘rsatkich 2016-yildagi 0,371 dan 2024-yilda 0,419 ga oshgan, zaif yaqinlashish faqat inson kapitali darajasi hisobga olinganda kuzatiladi. Surxondaryoda 2013–2024-yillarda bir ishchiga real YaHM o‘sishining 40,8 % i inson kapitali hisobiga to‘g‘ri kelgan; bitiruvchilar zaxirasini hududlar o‘rtachasiga yetkazish bir ishchiga YaHMni taxminan 31 % ga oshirishi mumkin.*

Kalit so‘zlar: *inson kapitali, Lukas–Uzava modeli, tashqi samara, hududiy o‘sish, oliy ta’lim, panel ma’lumotlar, Surxondaryo viloyati.*

Аннотация. *В статье оценивается влияние человеческого капитала на экономический рост регионов Узбекистана и его внешний эффект в условиях резкого расширения охвата высшим образованием после 2017 года. Производственная функция Лукаса–Удзавы оценена на панельных данных 14 регионов за 2010–2024 годы с фиксированными эффектами регионов и лет и стандартными ошибками Дрисколла–Краая. Рост запаса выпускников вузов на одного занятого на 10 % увеличивает реальный валовой региональный продукт (ВРП) на одного занятого на 3,9 % (эластичность 0,391; p = 0,003). При показателе, согласованном с*

уравнением Минцера, общественная отдача от увеличения доли выпускников на 1 процентный пункт (4,2–5,0 %) в несколько раз превышает частную (0,55 %), что указывает на наличие внешнего эффекта. Однако регионы не сближаются: σ-показатель вырос с 0,371 в 2016 году до 0,419 в 2024 году, а слабая конвергенция наблюдается лишь с учётом уровня человеческого капитала. В Сурхандарьинской области 40,8 % прироста реального ВРП на одного занятого в 2013–2024 годах обеспечено человеческим капиталом; доведение запаса выпускников до среднего по регионам уровня может увеличить ВРП на одного занятого примерно на 31 %.

Ключевые слова: *человеческий капитал, модель Лукаса–Удзавы, внешний эффект, региональный рост, высшее образование, панельные данные, Сурхандарьинская область.*

1. Introduction

Human capital is a central concept of modern endogenous growth theory [1]. In a study of 1,569 subnational regions in 110 countries, education explains about 25 % of regional income differences within countries [2]. Uzbekistan is currently undergoing one of the fastest expansions of higher education anywhere: gross enrolment of 18–23-year-olds rose from 7.2 % in 2016 to 47.7 % in the 2024/2025 academic year [3]. The “Uzbekistan – 2030” strategy targets enrolment of at least 50 % and per capita income of 4,000 US dollars [4].

Yet the expansion of education has not narrowed regional disparities. The ratio of per capita GRP (at current prices) between Tashkent city and Surkhandarya region rose from 2.93 in 2010 to 5.07 in 2024, and Surkhandarya’s ratio to the national average fell from 0.58 to 0.47 [5]. By our calculations, although the number of students in the region increased 10.9-fold in 2010-2024, the region has ranked last among the 14 regions in real per capita GRP since 2019.

The topic is relevant for three reasons. *First*, the expansion of higher education requires large public and household spending, but its effect on regional output has not been assessed with a structural model. *Second*, if the social return to education exceeds the private return (i.e., if there is an externality), state grants and regional admission quotas are economically justified. *Third*, in the Lucas [1] model the externality raises the return to education where human capital is already high, so lagging regions cannot catch up on their own unless the education gap is closed; no econometric study of this kind exists for Surkhandarya region.

The aim of the study is to estimate the effect of human capital on economic growth and its external effect in the regions of Uzbekistan on the basis of the Lucas–Uzawa model, and to substantiate directions for raising the potential of Surkhandarya region. The following hypotheses are tested: **H1** – human capital has a positive and statistically significant effect on real GRP per worker; **H2** – human capital generates an externality ($\gamma > 0$); **H3** – the externality exceeds the elasticity of physical capital ($\gamma > \beta$), i.e., the total return to human capital exceeds that to physical capital; **H4** – the regions are converging in real per capita GRP (σ- and β-convergence).

2. Literature review

International studies. In the model of R. Lucas [1], a worker devotes a share u of time to production and 1 – u to education, while average human capital generates an externality of the form h_a^{γ}. With an externality, the model predicts that income levels do not converge and that skilled labour migrates to regions rich in human capital; Lucas himself estimated γ at about 0.4 for the United States. N. Gennaioli et al. [2], controlling for country fixed effects across 1,569 regions in 110 countries, estimate the coefficient of average years of schooling on regional income at 0.28. E. Moretti [6] finds

that a one-percentage-point rise in the share of college graduates in US cities raises the wages of other workers by 0.4–1.9 %. A. Valero and J. Van Reenen [7] show, using data for 78 countries, that a 10 % increase in the number of universities raises per capita GDP by 0.4 %. The strengths of this literature are large samples and careful identification, but Central Asian regions are almost absent and the parameters γ and u have not been tested at the regional level.

Studies from CIS countries. S. P. Zemtsov and Y. A. Smelov [8] find that the effect of human capital in Russian regions was strongest in 2005–2008 and became insignificant in 2009–2014. B. I. Alekhin [9], using an ARDL model for 82 regions, shows that the long-run effect of human capital exceeds that of physical capital. A. Oshchepkov et al. [10] report that Russian regions converge at about 2 % a year, while human capital becomes insignificant under system GMM. Y. M. Turganbayev [11] finds that in Kazakh regions human capital acts through total factor productivity. These studies take the transition context into account but mostly rely on Solow-type models, do not estimate u and γ, and their results are highly sensitive to the estimation method.

Studies from Uzbekistan. O. Kasimov [12] finds in a VAR model that education spending explains 70.2 % of the forecast-error variance of per capita GDP; M. Djumanova [13] shows that the age structure of the population significantly affects regional growth; and O. K. Turayev [14] finds that a one-standard-deviation improvement in institutional quality raises per capita GRP by 12.4 %. However, no study has estimated the human capital externality with a structural model on a regional panel, and there is no econometric study of human capital in Surkhandarya region.

The advantages of this study are as follows: (1) the Lucas–Uzawa model is estimated in structural form at the regional level and γ is tested directly; (2) human capital is measured in three ways (graduate stock, student inflow and a Mincer-consistent measure); (3) Driscoll–Kraay standard errors robust to cross-sectional dependence are used; (4) the results are translated into quantitative scenarios for Surkhandarya region.

3. Methodology

In the Lucas [1] model, output of region i in year t is:

$$Y_{it} = A_{it}K_{it}^{\beta}(u_{it}h_{it}L_{it})^{1-\beta}h_{a,it}^{\gamma} \quad (1)$$

where Y is real GRP; K is physical capital; L is employment; h is human capital per worker; u is the share of time spent in production; h_a is average human capital (the source of the externality). Setting $h_a = h$ within a region, the per-worker equation in logarithms is estimated:

$$\ln y_{it} = \alpha_i + \lambda_t + b_1 \ln k_{it} + b_2 \ln h_{it} + b_3 \ln u_{it} + \varepsilon_{it} \quad (2)$$

where y = Y/L, k = K/L; α_i is a region fixed effect; λ_t is a year effect (common shocks, reforms). According to the model, $b_1 = \beta$, $b_2 = 1 - \beta + \gamma$ and $b_3 = 1 - \beta$, hence:

$$\gamma = b_1 + b_2 - 1, \ \gamma - \beta = b_2 - 1 \quad (3)$$

H2 is tested with the linear restriction $b_1 + b_2 > 1$ and H3 with $b_2 > 1$.

The data come from the SIAT open database of the Statistics Agency under the President of the Republic of Uzbekistan: 14 regions × 2010–2024, 210 observations. Nominal GRP and investment were converted to 2010 prices with chain volume indices. Physical capital (K) and the stock of higher-education graduates (H^C) were constructed by the perpetual inventory method:

$$K_{it} = (1-\delta)K_{i,t-1} + I_{it}, \ \ {H_{it}}^{C} = (1-\delta_H){H_{i,t-1}}^{C} + G_{it} \quad (4)$$

where I is real investment, G is the number of graduates, $\delta = 0.05$ and $\delta_H = 0.03$. Initial stocks are $K_{i0} = I_{i0}/(g_i + \delta)$ and $H^C_{i0} = G_{i0}/(0.03 + \delta_H)$, where g_i is the average annual growth rate of real GRP in 2010–2015. The main human capital measure is the graduate stock per worker, $h^C = H^C/L$; the

alternative is the number of students per 10,000 population, h^B. To identify the structural parameters, a Mincer-consistent measure and the share of time outside education were constructed:

$$h_{it}^{M} = 1 + h_{it}^{C}(e^{\varphi \Delta S} - 1), \;\; u_{it} = 1 - \frac{S_{it}}{P_{it}^{14-30}} \quad (5)$$

where φ = 0.1 is the private return to a year of schooling and ΔS = 5 is the difference in years between higher and secondary education; S is the number of university students and $P^{14–30}$ is the population aged 14–30 (available from 2013). As a robustness check, S also includes students of colleges, lyceums, technical and vocational schools; the structural break caused by the 2017 education reform is absorbed by the year effects. Descriptive statistics are reported in Table 1.

Table 1

Descriptive statistics[1]

Variable	N	Mean	Std. dev.	Min.	Max.
y – real GRP per worker, mln soums	210	9.646	4.429	4.484	30.693
k – physical capital per worker, mln soums	210	21.273	15.734	4.953	83.496
h^C – graduate stock per worker	210	0.112	0.103	0.038	0.507
h^B – students per 10,000 population	210	161.7	216.8	26.1	1,773.8
u – share of time outside education	168	0.934	0.098	0.251	0.992

Equation (2) was estimated with region and year fixed effects (two-way fixed effects model). In regional panels, common macroeconomic shocks make residuals correlated across regions. This was tested with the Pesaran [15] CD test:

$$CD = \left(\frac{2}{N(N-1)}\right)^{1/2} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}^{1/2} \hat{\rho}_{ij} \quad (6)$$

where $\hat{\rho}_{ij}$ is the correlation between the residuals of regions i and j and N is the number of regions. In all models CD = 6.1–12.9 ($p < 0.001$). Standard errors were therefore computed with the Driscoll–Kraay method, which is robust to cross-sectional and serial dependence [16]. Regional convergence was assessed through σ-convergence (the cross-regional standard deviation of log real per capita GRP) and a β-convergence regression, and the sources of growth in Surkhandarya were computed from the estimated elasticities:

$$g_i = a + \beta_c \ln y_{i,2010} + e_i, \;\; \Delta \ln y = b_1 \Delta \ln k + b_2 \Delta \ln h + b_3 \Delta \ln u + \Delta R \quad (7)$$

where g_i is the average annual growth rate in 2010–2024 ($\beta_c < 0$ indicates convergence) and ΔR is the residual (total factor productivity and year effects). All calculations were carried out in Python (pandas, NumPy, statsmodels).

4. Results and analysis

Table 2 compares the main indicators of Surkhandarya region with the average of the 14 regions.

[1] Source: author's calculations based on SIAT data.

Table 2

Main indicators of Surkhandarya region and the regional average[2]

Indicator	Surkhandarya region			Average of 14 regions		
	2010	2016	2024	2010	2016	2024
Real GRP per worker, mln soums	4.85	6.52	9.17	6.42	9.07	13.41
Real GRP per capita, mln soums	1.83	2.60	3.26	2.74	3.89	5.34
Physical capital per worker, mln soums	5.90	8.41	25.30	11.81	16.91	37.83
Graduate stock per worker (h^C)	0.042	0.039	0.066	0.105	0.107	0.132
Students per 10,000 population (h^B)	34.0	30.8	266.5	98.0	86.7	390.0
Share of time outside education (u)	–	0.991	0.902	–	0.971	0.847

In 2010–2024, real GRP per worker in Surkhandarya rose from 4.85 to 9.17 million soums but fell from 75.5 % to 68.4 % of the regional average; physical capital per worker is 67 % of the average. The population grew by 2.36 % a year (average 1.93 %), which depresses per capita indicators. The number of students per 10,000 population rose from 30.8 in 2016 to 266.5 in 2024, reaching the regional median (Figure 1), but this inflow has not yet become a stock: in graduate stock per worker (0.066) the region ranks last, at half of the average level (0.132).

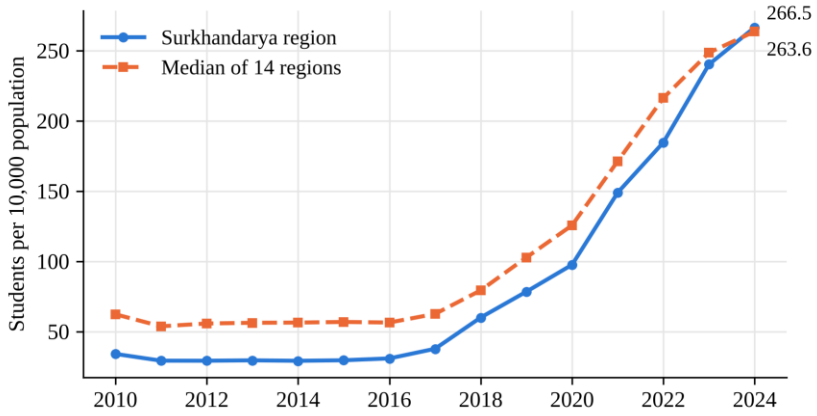

Figure 1. Higher-education students per 10,000 population, 2010–2024
Source: author's calculations based on SIAT data.

Table 3 reports the estimates of equation (2). When time spent in education is not controlled for (column 1), the graduate stock coefficient is positive but insignificant. With u controlled for (column 2, baseline model), the elasticity of human capital is 0.391 and significant at the 1 % level: a 10 % increase in the graduate stock raises real GRP per worker by 3.9 % (H1 confirmed). The result holds in the sample without Tashkent city (0.311), with a one-year lag (0.514) and with a measure of u covering all types of education (0.394); the correlation between the two u measures net of region and year effects is 0.994. In economic terms, a one-percentage-point increase in the graduate share raises GRP per worker by 3.5 % at the average level and by 5.9 % at Surkhandarya's low 2024 level – the return to an additional graduate is higher where the stock is small. The number of students

[2] Source: author's calculations based on SIAT data; real values at 2010 prices.

(column 3) has no significant effect: the effect stems from the stock of graduates who have entered the labour market. Without year effects (column 4), the elasticity of physical capital rises to 0.366, because common capital accumulation and technological change are now attributed to k.

Table 3

Estimates of the Lucas-Uzawa production function (dependent variable – ln y)[3]

	(1) no u	(2) base-line	(3) stu-dents	(4) no year FE	(5) excl. Tashkent city	(6) lagged h	(7) u – all edu-cation
ln k	0.086	0.043*	0.053	0.366***	0.055	0.069***	0.047**
	(0.056)	(0.023)	(0.034)	(0.032)	(0.034)	(0.023)	(0.022)
ln h^C	0.269	0.391***	–	0.222***	0.311***	0.514***	0.394***
	(0.206)	(0.131)		(0.062)	(0.114)	(0.123)	(0.130)
ln h^B	–	–	0.032	–	–	–	–
			(0.022)				
ln u	–	−0.257***	−0.169**	−0.247***	−0.748***	−0.254***	−0.252***
		(0.071)	(0.068)	(0.049)	(0.277)	(0.058)	(0.073)
Year effects	Yes	Yes	Yes	No	Yes	Yes	Yes
N	210	168	168	168	156	168	168
R^2 (within)	0.09	0.29	0.16	0.90	0.21	0.35	0.29

The coefficient on u is negative in all models (−0.257 in the baseline), so the model restriction $b_3 = 1 - \beta$ is rejected: output grew faster in regions where higher-education enrolment expanded faster. This reflects the demand channel of universities and reverse causality. Because h enters Table 3 as a share, b_2 is not directly equal to the structural parameter $1 - \beta + \gamma$; the structural parameters were therefore estimated with the Mincer measure (5) (Table 4).

The elasticity of physical capital is $\beta = 0.090–0.121$, while b_2 is significantly greater than 1 ($t = 3.25–5.77$); hence $\gamma > 0$ (H2) and $\gamma > \beta$ (H3) are not rejected. A one-percentage-point increase in the graduate share raises GRP per worker by 4.2–5.0 %, whereas the private return alone would imply no more than 0.55 %; the difference is the externality arising from knowledge spillovers and technology adoption. At the same time, the size of γ (6–7) is several times Lucas's [1] estimate (≈ 0.4): unobserved factors and reverse causality inflate the estimate in a 14-region panel. The sign and significance of the externality are therefore reliable, while its magnitude should be read as an upper bound.

[3] Note: Driscoll–Kraay standard errors in parentheses; all models include region fixed effects; *, **, *** – significant at the 10, 5 and 1 % levels. In column (6) ln h^C is lagged one year. Source: author's calculations.

Table 4

Structural parameters based on the Mincer measure[4]

Parameter	(8) baseline	(9) excl. Tashkent city	(10) lagged h	(11) no u, 2010–2024
$\beta = b_1$	0.090*** (0.024)	0.093*** (0.029)	0.097*** (0.028)	0.121*** (0.047)
b_2 (ln h^M)	7.810*** (1.617)	6.876*** (1.807)	7.886*** (1.193)	8.238*** (1.533)
$\gamma = b_1 + b_2 - 1$	6.900*** (1.627)	5.969*** (1.800)	6.982*** (1.206)	7.359*** (1.566)
H3: t ($b_2 = 1$)	4.21	3.25	5.77	4.72
Social return (+1 p.p.), %	4.71	4.21	4.75	4.97
Private return (+1 p.p.), %	0.55	0.56	0.54	0.53
N	168	156	168	210

Interregional disparities narrowed in 2010–2015 (σ: 0.381 → 0.368) but widened steadily after 2016, reaching 0.419 in 2024 (Figure 2a). The unconditional β-convergence coefficient is positive and insignificant (β_c = 0.274; p = 0.722), also when the growth of the graduate stock is controlled for (0.273; p = 0.711). H4 is therefore not confirmed: real per capita GRP grew by 7.1 % a year in Tashkent city and 4.1 % in Surkhandarya (average 4.6 %), and the region's ratio to the average fell from 66.9 % to 61.1 % (Figure 2b). However, when the initial (2010) level of the graduate stock is controlled for, β_c becomes negative (−1.022; p = 0.093), while the coefficient on initial human capital is positive and highly significant (1.656; p = 0.001). This points to weak conditional convergence: regions are moving towards different steady states determined by their level of human capital, and regions with more human capital grow faster [17].

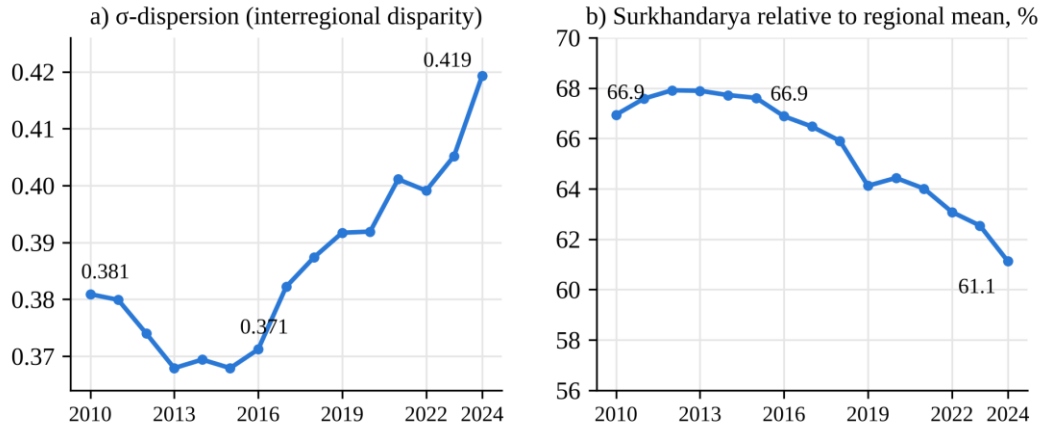

Figure 2. Regional convergence: a) σ-convergence; b) relative level of Surkhandarya region

Using the elasticities of the baseline model, the 59.3 % growth of real GRP per worker in Surkhandarya in 2013–2024 was decomposed into its sources (Figure 3): 40.8 % is due to human capital, 11.7 % to physical capital, 5.2 % to the change in u and 42.3 % to total factor productivity

[4] Note: Driscoll–Kraay standard errors in parentheses; all models include region and year fixed effects. Social return = $b_2 \cdot \Delta \ln h^M$, private return = $(1 - \beta) \cdot \Delta \ln h^M$, where $\Delta \ln h^M$ is the change corresponding to a 0.01 increase in h^C at the average level. Source: author's calculations.

and year effects. The main source of the human capital contribution is the increase in the number of graduates from 3,962 in 2022 to 14,294 in 2024.

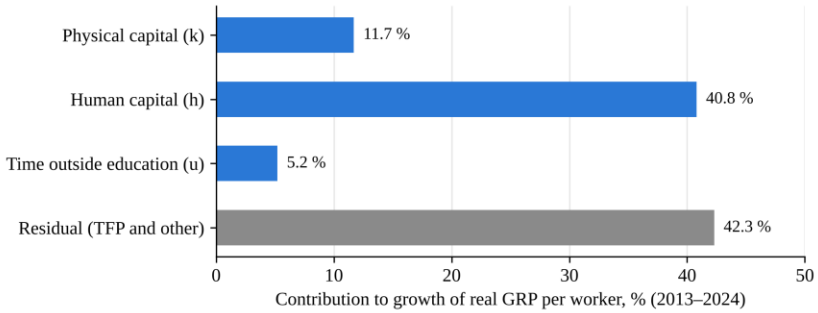

Figure 3. Sources of growth of real GRP per worker in Surkhandarya, 2013–2024

Table 5 shows the increase in real GRP per worker (other things equal) if the region's graduate stock reached various target levels.

Table 5

Human capital scenarios for Surkhandarya region[5]

Scenario	h^C, per worker	$\Delta \ln h^C$	Increase in GRP per worker, %
Current level (2024)	0.066	–	–
S1: increase the stock 1.5 times	0.099	0.405	17.2
S2: reach the regional average	0.132	0.691	31.0
S3: average of the three leading regions excluding Tashkent city	0.155	0.850	39.4

If the region raised its graduate stock to the regional average, real GRP per worker could increase by about 31 %. Since the region has already reached the median in student numbers, this target is attainable in the medium term provided that graduates stay in the region.

5. Discussion

The results add to the literature in three respects. *First*, the finding that the effect of human capital exceeds that of physical capital is consistent with evidence for Russian regions [9]. Unlike Kazakhstan [11], human capital is directly significant in Uzbekistan, which may be explained by the high pace of higher-education expansion and by the use of the graduate stock. The insignificance of the effect when time in education is not controlled for is in line with findings on the sensitivity of such estimates to the specification [8, 10].

Second, the externality estimate (4.2–5.0 %) exceeds the wage effect in US cities (0.4–1.9 % [6]). This is because GRP also includes capital income and agglomeration effects, and because returns to knowledge spillovers are high in an economy short of skilled workers; the negative coefficient on u is consistent with the demand channel of universities [7]. Given the externality, tuition-based education alone cannot provide the socially optimal number of graduates, which justifies state grants and targeted admission quotas for lagging regions.

Third, in contrast to the 2 % annual convergence of Russian regions [10], the regions of Uzbekistan have been diverging since 2016. The graduate stock per worker in Tashkent city is 0.489,

[5] Note: increase = $\exp(0.391 \cdot \Delta \ln h^C) - 1$; S3 – average of Karakalpakstan, Navoi and Bukhara. Source: author's calculations.

3–7 times higher than in other regions. This is fully consistent with the prediction of the Lucas [1] model: with a strong externality, the return to education is higher in regions rich in human capital, so an uneven distribution of the stock does not narrow disparities on its own but widens them. For lagging regions to catch up, graduates must not only be trained but also retained.

Policy recommendations. For Surkhandarya region we propose: (1) retaining graduates in the region through housing incentives for young specialists and targeted training contracts with enterprises; (2) complementing human capital with physical capital – since capital per worker is only 67 % of the average, attracting investment into agro-processing, logistics, tourism and digital services; (3) improving the quality of education in engineering, information technology and agronomy; (4) adopting the "graduate stock per worker" as a target indicator in regional programmes and raising it to the regional average (0.132) in the medium term.

Limitations. The panel consists of 14 regions and T is small, so Driscoll–Kraay standard errors may be somewhat understated; human capital is measured by graduate numbers and does not reflect education quality or migration; the Mincer measure relies on calibrated φ and ΔS; without instrumental variables, reverse causality is not fully eliminated; 2024 data are preliminary. Future research should use district-level data, spatial models and instrumental-variable approaches.

6. Conclusion

Estimating the Lucas–Uzawa production function for the 14 regions of Uzbekistan over 2010–2024 leads to the following conclusions.

1. The stock of higher-education graduates is an important determinant of regional output: a 10 % increase raises real GRP per worker by 3.9 % (robust within 0.311–0.514), whereas the number of students has no significant effect.

2. Human capital generates an externality: the social return to a one-percentage-point increase in the graduate share (4.2–5.0 %) is 7.6–9.4 times the private return (0.55 %); the estimate is interpreted as an upper bound. This provides an economic rationale for public support of higher education.

3. The model restriction on time spent in education is rejected: output grew faster in regions where higher-education enrolment expanded faster.

4. The regions are not converging: the σ-dispersion rose from 0.371 in 2016 to 0.419 in 2024; weak convergence is observed only conditional on the level of human capital.

5. In Surkhandarya, human capital accounted for 40.8 % of the growth of real GRP per worker in 2013–2024, yet the region ranks last in graduate stock; raising it to the regional average could increase real GRP per worker by about 31 %.

Thus, the expansion of higher education leads to the convergence of lagging regions only when it is complemented by retaining graduates in the region and by investment that creates jobs for them.

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