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Green Investments and Sustainable Regional Diversification: Panel Data Evidence From Uzbekistan

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Abstract: The article provides a quantitative assessment of the impact of investments, including green investments, on the sustainable diversification of the regional economy of Uzbekistan. The empirical analysis is based on a fully balanced panel of 14 administrative-territorial units for 2019–2025 (98 observations) built on official data of the National Statistics Committee. Pooled OLS, fixed-effects and random-effects specifications with region-clustered standard errors were estimated, and the choice between estimators was made using the Hausman test. The elasticity of gross value added with respect to fixed-capital investment was found to be stable in the range of 0.83–0.91 and significant at the one percent level, while a higher share of foreign financing produced no additional independent effect. A confirmatory cross-sectional block demonstrated an almost functional correspondence between the Regional Green Investment Attractiveness Index (RGIAI) and the actual volumes of attracted green investments across regions (Spearman $\rho = 0.943$; $p = 0.005$ when the capital city is excluded). The results substantiate the need for institutional mechanisms that ensure not only the volume but also the green orientation of regional investment flows.

Keywords: *green investments; regional economy; sustainable diversification; panel data econometrics; investment attractiveness index.*

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1. Introduction

The transition to a green economy has become one of the central priorities of the state economic policy of Uzbekistan. The Strategy for the transition to a green economy for 2019–2030⁶ the comprehensive measures adopted in 2022 to increase the effectiveness of this transition and the introduction of the National green taxonomy in 2023 have formed an institutional framework within which green investments are turning from a marginal phenomenon into a significant driver of structural change [1]. According to the estimates obtained in the course of this research on the basis of taxonomy-classified projects and cross-checked against BloombergNEF Climatescope data, the volume of green investments in Uzbekistan increased from approximately 1.1 billion US dollars in 2021 to an expected 4.6 billion US dollars in 2026, while their share in total investments approached 9.5 percent against 4 percent at the beginning of the period [2]. The largest share of these flows (59.5 percent) is directed to renewable energy, followed by water-saving technologies (15.2 percent), green transport and urban infrastructure (9.5 percent) and green agriculture (6.8 percent) [3].

At the same time, the macroeconomic background of this process is characterized by pronounced regional heterogeneity. The real growth of the gross domestic product of

Uzbekistan accelerated from 6.5 percent in 2024 to 7.7 percent in 2025, with the nominal GDP reaching 1,849.7 trillion UZS (approximately 147 billion US dollars), and investments in fixed capital amounting to 591.1 trillion UZS with real growth of 10.5 percent (National Statistics Committee) [4]. However, the gap between the largest regional economy (Tashkent city) and the smallest one (Syrdarya region) exceeds ten times, and green investment flows are concentrated in a small group of regions rich in renewable energy resources. Under such conditions, any policy decision on the allocation of scarce investment resources across territories and sectors must rely on quantitatively measured relationships rather than on qualitative reasoning alone [5].

The central research question of this study is formulated as follows: do the volume and the structure of investments exert a statistically significant impact on the sustainable development of the regional economies of Uzbekistan, and is regional green investment attractiveness, measured by a composite index, associated with actual investment outcomes? Proceeding from this question, three research hypotheses were put forward [6]. Hypothesis H1 states that an increase in the volume of investments in fixed capital has a positive and statistically significant effect on the gross value added of a region. Hypothesis H2 states that a higher share of foreign investments and loans in the financing structure produces an additional positive effect on regional economic outcomes [7]. Hypothesis H3 states that regions with a higher value of the Regional Green Investment Attractiveness Index (RGIAI) also occupy higher positions in terms of the actual volume of attracted green investments. The purpose of the article is to test these hypotheses econometrically on the basis of official regional statistics and to derive evidence-based recommendations for the regional green investment policy of Uzbekistan [8].

2. Literature Review

The theoretical foundation of the study is formed by the literature on economic diversification and green finance. The conceptual model of the stages of diversification developed by Imbs and Wacziarg demonstrates that economies at low and middle income levels diversify their sectoral structure, whereas re-specialization is observed only at high income levels [9]. This model implies that for a middle-income economy such as Uzbekistan the expansion of the sectoral structure of regional economies, particularly at the expense of environmentally sound industries, constitutes a strategic task rather than a transitory phenomenon [10]. The structural shifts observed in Uzbekistan in 2019–2025, when the share of agriculture in gross value added declined from 28.0 to 20.8 percent while the share of services rose from 38.0 to 47.1 percent, are fully consistent with this theoretical prediction [11].

The empirical literature on the relationship between green finance and economic development provides direct methodological guidance for the present study. Ngo using data of the central banks of ASEAN countries for 2008–2019 and applying fixed-effects and generalized method of moments estimators, proved that green credit and green investment have a positive and statistically significant association with economic development [12]. Wang and Zhi showed that the effectiveness of green investment attraction increases substantially when direct economic, institutional-legal and market-administrative mechanisms are applied in combination. Campiglio substantiated that carbon pricing alone is insufficient and that the reorientation of capital towards the green sector through banking and monetary policy is of decisive importance [13]. Kurdyukov and Ovcharenko proposed an improved formula for assessing the net future value of green investment projects using differentiated rates of return for different outcomes of green investment.

A separate strand of literature concerns the measurement of investment attractiveness by means of composite indicators [14]. The joint handbook of the OECD and the Joint Research Centre of the European Commission provides the recognized eight-step

methodology for constructing composite indices (OECD & European Commission Joint Research Centre), while the analytic hierarchy process of Saaty (1980) remains the most widely used expert-based method for determining weights. In the authors' previous research, these instruments were combined in the Regional Green Investment Attractiveness Index (RGIAI), which aggregates five components – ecological potential (weight 0.25), institutional environment (0.20), infrastructure readiness (0.20), financial market development (0.20) and human capital (0.15) – into a single score in the range from zero to one [15]. Finally, the econometric strategy of the study relies on the classical results of panel data theory: Wooldridge demonstrates that combining the cross-sectional and time dimensions allows unobserved regional factors to be controlled for and the efficiency of estimates to be increased, Baltagi systematizes the properties of fixed-effects and random-effects estimators in short panels, and the specification test of Hausman provides the formal criterion for choosing between them. A review of the available literature shows that, despite the abundance of cross-country evidence, no quantitative assessment of the investment–growth relationship and of the predictive validity of green attractiveness indices has so far been performed at the regional level for Uzbekistan, which defines the research gap addressed by this article.

3. Research Methodology

The information base of the analysis is formed by five official indicators published on the open data platform of the National Statistics Committee of the Republic of Uzbekistan: quarterly series of gross regional product and gross value added of sectors, annual and quarterly data on the volume of investments in fixed capital, and the territorial structure of investment financing sources contained in the official press releases of the Committee (National Statistics Committee, 2026). The units of observation are the 14 administrative-territorial entities of the country: the Republic of Karakalpakstan, twelve regions and Tashkent city. The model was estimated on a fully balanced panel covering 2019–2025 ($N = 14$, $T = 7$, giving $N \times T = 98$ observations). The 2025 territorial values of investment volume were taken from the cumulative fourth-quarter indicators of the quarterly dataset, and the 2025 values of the share of foreign investments and loans were taken from the territorial table of the official press release of the National Statistics Committee dated January 24, 2026.

The dependent variable is the natural logarithm of gross value added (lnGVA), which serves as the generalizing outcome measure of regional economic development: sustainable diversification is ultimately materialized in the stable growth of value added, and official statistics publish the gross value added of sectors in the region-year dimension in aggregate form. All value indicators are expressed in current prices, and the common price dynamics is controlled in the model through year effects. The explanatory variables are the natural logarithm of investments in fixed capital (lnINV) and the share of foreign investments and loans in total investments (FDI). Investment intensity (the ratio of investments to gross regional product) and the RGIAI index are used in the descriptive and confirmatory blocks of the analysis. The variables are summarized in Table 1.

Table 1

Description of the variables used in the econometric analysis

Variable	Definition	Unit of measurement
lnGVA	Natural logarithm of the gross value added of the region	billion UZS
lnINV	Natural logarithm of the volume of investments in fixed capital	billion UZS
FDI	Share of foreign investments and loans in total investments in fixed capital	percent
INV/GRP	Investment intensity: the ratio of investments to the gross regional product	percent
RGIAI	Regional Green Investment Attractiveness Index	score in the range 0–1

Source: compiled by the author.

The baseline panel regression model has the following form:

$$\ln GVA_{it} = \beta_0 + \beta_1 \ln INV_{it} + \beta_2 FDI_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where i is the region index ($i = 1, \dots, 14$); t is the year index for 2019–2025; μ_i denotes unobserved region-specific constant effects (geographical location, resource base, inherited infrastructure, institutional environment); λ_t denotes year effects capturing the common macroeconomic environment, price dynamics and nationwide shocks such as the pandemic period; and ε_{it} is the random error term. Since the variables are introduced in logarithmic form, the coefficient β_1 is interpreted directly as an elasticity. The estimation followed a three-step sequence. First, pooled ordinary least squares was estimated as the baseline benchmark; second, the fixed-effects (FE) and random-effects (RE) models accounting for regional heterogeneity were estimated; third, the choice between FE and RE was resolved on the basis of the Hausman specification test. To account for within-region residual autocorrelation and heteroskedasticity, region-clustered standard errors were applied in all models. The robustness of the results over time was verified by an additional specification in which the regressors were introduced with a one-year lag. The analysis is organized in two mutually complementary blocks: the first block is the main econometric model on the panel of 14 regions, and the second block is a confirmatory cross-sectional comparison testing the correspondence between the RGIAI index and the actual volumes of attracted green investments by means of the Spearman rank correlation coefficient.

4. Analysis and Results

The descriptive statistics of the panel sample clearly reveal the scale of interregional differences (Table 2). In 2019–2025 the average annual gross value added across regions amounted to 67,029.1 billion UZS, while the indicator varied from 13,107.7 billion UZS (Syrdarya region, 2019) to 338,662.2 billion UZS, that is, the sample covers a more than 25-fold gap. The average annual volume of investments in fixed capital equalled 24,049.1 billion UZS, and the large standard deviation (19,285.2 billion UZS) indicates a strongly right-skewed distribution, which provides an additional statistical justification for the logarithmic transformation. Investment intensity averaged 35.5 percent and fluctuated between 18.8 and 75.5 percent across region-years. The average share of foreign investments and loans was 54.4 percent, and the role of external financing sources strengthened consistently over the period: for the republic as a whole this share rose from 43.6 percent in 2019 to 71.4 percent in 2025. In the territorial dimension the highest values were recorded in Bukhara and Namangan regions in 2024 and in Namangan, Navoi and Andijan regions in 2025, which is directly connected with the international financing of large energy and industrial projects. Figure 1 presents the GRP dynamics of the three leading regions by output volume – Tashkent city, Tashkent region and Navoi region – together with Bukhara region, the leader among the regions in the green investment attractiveness ranking.

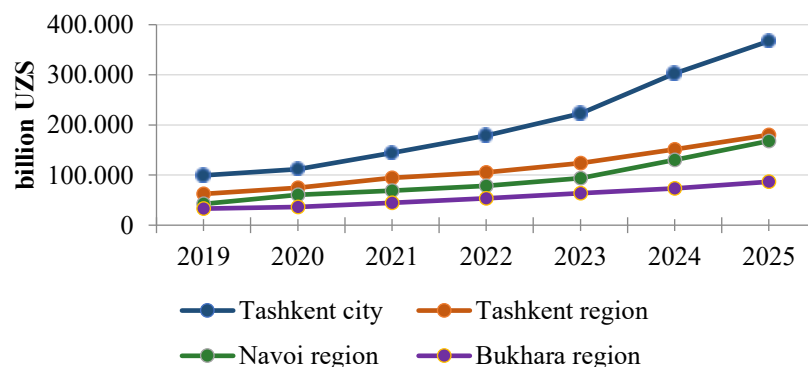


Figure 1. Leading regions of Uzbekistan by GRP dynamics in 2019–2025, billion UZS

Source: compiled by the author based on the National Statistics Committee (2026) data.

Table 2

Descriptive statistics of the panel sample

Indicator	GVA, bln UZS	Investment, bln UZS	FDI share, %	INV/GRP, %
Mean	67,029.1	24,049.1	54.4	35.5
Standard deviation	51,763.6	19,285.2	16.2	12.1
Minimum	13,107.7	5,032.0	26.0	18.8
Median	52,356.6	17,502.7	54.2	31.8
Maximum	338,662.2	105,708.3	82.3	75.5

Source: calculated by the author on the basis of official data of the National Statistics Committee (National Statistics Committee, 2026).

The territorial distribution of investments in fixed capital in 2025 demonstrates a high concentration of investment activity: Tashkent city (105.7 trillion UZS), Tashkent region (79.4 trillion UZS), Namangan region (61.1 trillion UZS – the leader among the regions), Navoi region (43.1 trillion UZS) and Bukhara region (42.9 trillion UZS) jointly accumulated the predominant part of total territorial investments (Figure 2). In Bukhara region investments grew from 10.4 trillion UZS in 2019 to 42.9 trillion UZS in 2025, that is, 4.1 times. The regional distribution of green investments is even more heterogeneous: Bukhara region attracted about 780 million US dollars of green investments in 2025 (the first position in the country), followed by Navoi (590 million), Samarkand (505 million) and the Republic of Karakalpakstan (430 million), which reflects the concentration of large wind and solar generation projects, including the Bash and Dzhankeldy wind farms with a total capacity of about 1,000 MW, in regions with high renewable energy potential.

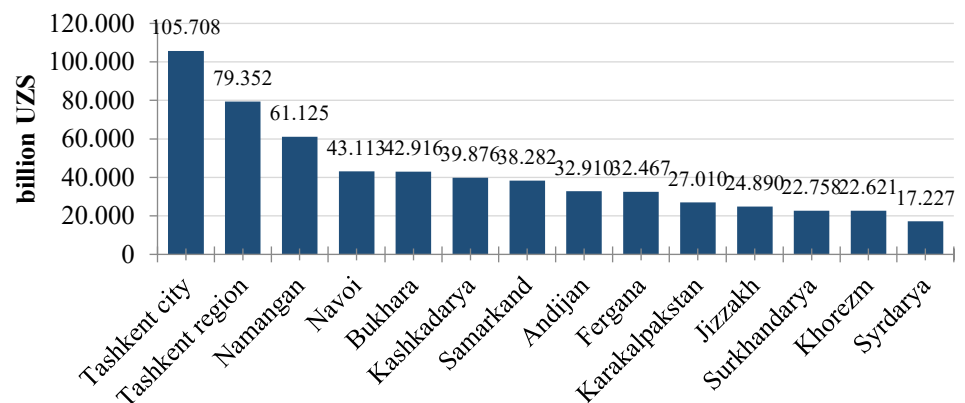


Figure 2. Territorial distribution of investments in fixed capital in 2025, billion UZS

The results of the panel regression estimation are presented in Table 3. In all three specifications the investment elasticity is positive, high and statistically significant at the one percent level, which confirms the reliability of hypothesis H1. The Hausman test result ($\chi^2 = 1.11$; $p = 0.573$) does not reject the null hypothesis of no correlation between the individual effects and the regressors; consequently, the random-effects estimator is consistent and efficient and was adopted as the main specification. According to the random-effects model, a one percent increase in investments in fixed capital is associated with an average increase of 0.88 percent in the gross value added of a region. Together with the fixed-effects and pooled OLS estimates (0.83 and 0.91 respectively), the reliable interval of the elasticity is 0.83–0.91. To verify the stability of the effect over time, a specification with a one-year lag of the regressors was also estimated: in the fixed-effects model with regional effects the coefficient of lagged investment remained significant at 0.898 ($t = 7.47$; $p < 0.01$; $N = 84$), which shows that the economic effect of investments manifests itself in full at least over a one-year horizon.

Table 3

Panel regression results (dependent variable: lnGVA)

Variable	Pooled OLS	Fixed effects (FE)	Random effects (RE)
lnINV	0.9147*** (t = 13.54)	0.8332*** (t = 6.84)	0.8781*** (t = 10.90)
FDI	-0.0080** (t = -2.48)	-0.0040 (t = -0.88)	-0.0056 (t = -1.66)
Constant	2.3309*** (t = 3.94)	–	2.5565*** (t = 3.75)
Regional effects	No	Yes	Yes (random)
R ²	0.820	0.804 (within)	0.806
Observations	98	98	98

Note: *** – $p < 0.01$; ** – $p < 0.05$; * – $p < 0.10$; t-statistics based on region-clustered standard errors are given in parentheses.

Source: author's calculations.

The result for hypothesis H₂ differed from expectations. The coefficient of the share of foreign investments and loans is negative and significant at the five percent level in the pooled OLS model (-0.0080 ; $p = 0.015$) but statistically insignificant in the random-effects and fixed-effects models ($p = 0.101$ and $p = 0.383$ respectively). Thus, the coefficient is neither positive nor significant in any specification: with the total volume of investments controlled for, a higher share of external sources in the financing structure produced no additional independent effect, and hypothesis H₂ was not confirmed. The probable economic explanation is that during the analyzed period foreign funds were concentrated mainly in large capital-intensive projects with long construction and absorption periods (energy, mining and metallurgy, transport infrastructure), whose effect on value added manifests itself with a considerable time lag, partly outside the analyzed period. In addition, the FDI share indicator measures only the composition of financing sources and not the green or technological quality of the funds, which once again substantiates the need for special indicators assessing the structural quality of investments, including the RGAII index. At the same time, given the short sample period ($T = 7$), a definitive conclusion on this coefficient would be premature.

The strong positive relationship between investment and gross value added (pairwise correlation coefficient $r = 0.89$) is clearly visible in the scatter plot presented in Figure 3, in which all 98 observations are densely clustered around the linear trend.

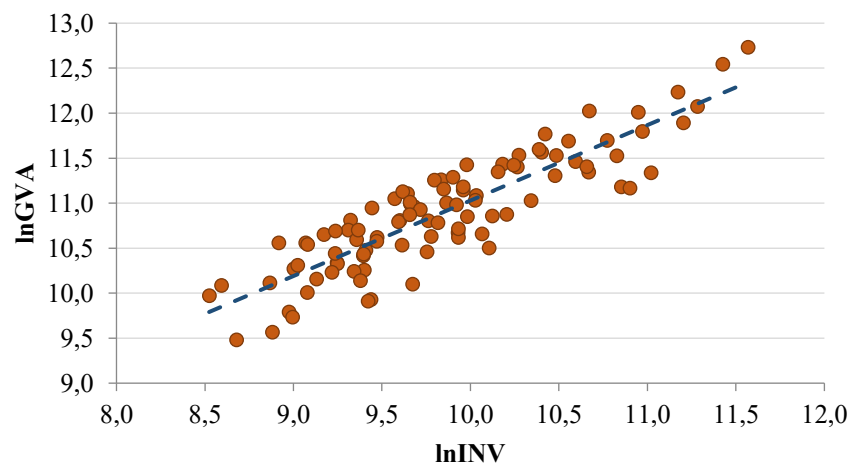


Figure 3. The relationship between investments and gross value added

Source: author's calculations.

The quality of the model was verified by a set of diagnostic tests (Table 4). The F-test of the joint significance of regional and year effects ($F = 122.8$; $p < 0.001$) confirms that territorial structural differences cannot be ignored. No multicollinearity problem was detected: the correlation between the regressors is low ($r = 0.39$) and the variance inflation

factor equals 1.18 for both regressors, far below the critical threshold. Since signs of first-order autocorrelation in the residuals were present ($\rho = 0.53$; $p < 0.001$) and the Jarque–Bera test rejected the normality hypothesis ($JB = 28.1$; $p < 0.01$), all statistical inference relied on region-clustered standard errors. As an additional robustness check, a strict specification with regional and year effects introduced jointly was estimated: in this specification the investment coefficient loses statistical significance, which is explained by the fact that in a short panel the year effects almost completely absorb the nominal growth trend common to all regions; this is an expected methodological outcome under current-price data. For this reason the main conclusions are based on the specifications with regional effects, while the replication of the estimates in real terms is defined as a prospective task to be carried out once the data base is extended.

Table 4
Results of model diagnostics

Test	Statistic	p-value	Conclusion
Joint significance of effects (F-test)	$F(19; 76) = 122.8$	< 0.001	Panel structure is required
Hausman test (FE vs RE)	$\chi^2(2) = 1.11$	0.573	RE is preferred
Multicollinearity (VIF)	max 1.18	–	No problem detected
Residual autocorrelation, AR(1)	$\rho = 0.53$	< 0.001	Clustered standard errors applied
Jarque–Bera (normality)	$JB = 28.1$	< 0.01	Clustered standard errors applied

Source: author's calculations.

The second, confirmatory block of the analysis was devoted to testing hypothesis H3, that is, the correspondence between the RGIAI integral index calculated in the authors' previous research and the actual investment outcomes of the regions. For this purpose the 2025 RGIAI values of the regions were compared with the actual volumes of attracted green investments (Table 5). To assess the correspondence of the rankings, the Spearman rank correlation coefficient was calculated. On the full sample of the seven regions for which green investment volumes are known, the coefficient turned out to be positive but statistically insignificant at conventional levels ($\rho = 0.571$; $p = 0.180$). A detailed analysis shows that the result is lowered by a single observation – Tashkent city: being the absolute leader in RGIAI (0.738) owing to its developed institutional environment, financial market and human capital, the capital occupies only the fifth position among the seven in terms of the actual volume of green investments, since its ecological potential is limited. When Tashkent city is excluded, the RGIAI and green investment rankings coincide almost completely: the Spearman coefficient reaches $\rho = 0.943$ ($p = 0.005$) (Figure 4), and for Bukhara, Navoi, Samarkand, Karakalpakstan, Khorezm and Kashkadarya the order of the index reproduces the order of actual flows without error. These two results jointly confirm hypothesis H3 for the regions and demonstrate the predictive value of the RGIAI index as a reliable reflection of the direction of regional green investment flows, while the deviation of the capital city indicates the prospect of adapting the index components for urbanized territories.

Table 5
2025 RGIAI index and the actual volumes of attracted green investments

Region	RGIAI value	RGIAI rank	Green investment, mln USD	Investment rank
Bukhara region	0.655	2	780	1
Navoi region	0.633	3	590	2
Samarkand region	0.610	4	505	3
Republic of Karakalpakstan	0.569	6	430	4
Tashkent city	0.738	1	395	5
Khorezm region	0.574	5	280	6
Kashkadarya region	0.549	7	235	7

Source: author's calculations on the basis of official statistical data and project-level information.

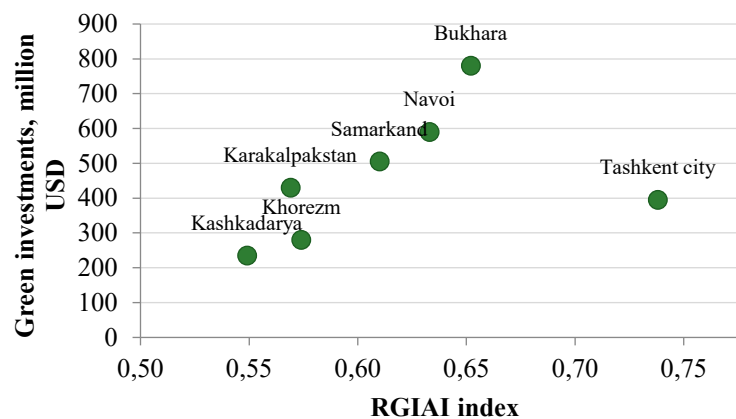


Figure 4. The RGIAI index and the actual volumes of attracted green investments across the leading regions in 2025

Source: author's calculations.

The outcomes of 2025, the final year of the panel, deserve special attention as an out-of-model consistency check. The gross regional product of the republic reached 1,849.7 trillion UZS in current prices; 591.1 trillion UZS of investments in fixed capital were absorbed from all financing sources with real growth of 10.5 percent; the share of foreign investments and loans in total investments reached 71.4 percent, of which direct foreign investments accounted for 47.5 percent. In the territorial dimension the highest nominal growth of gross regional product in 2025 was recorded in Navoi region (28.8 percent), Syrdarya region (24.9 percent), Jizzakh region (21.6 percent) and Tashkent city (21.2 percent), while the gross regional product of Bukhara region reached 86.6 trillion UZS with growth of 17.9 percent. These tendencies visibly confirm the continuation of the investment–growth relationship identified in the model. It should also be openly stated that the confirmatory cross-sectional block has limitations: owing to the small number of observations its results are of an indicative character and are interpreted as empirical evidence of ranking correspondence rather than as causal effects. Once green investment data for all 14 regions are collected, it is advisable to repeat the analysis on the full sample and to test each RGIAI component separately.

5. Conclusion and Recommendations

The econometric analysis performed on the fully balanced panel of 14 regions of Uzbekistan for 2019–2025 allows the following conclusions to be drawn. First, the elasticity of regional gross value added with respect to investments in fixed capital was estimated stably in the range of 0.83–0.91 at the one percent significance level, and according to the preferred random-effects specification each one percent increase in investments is associated with an average 0.88 percent growth of the regional economy; the effect remains significant with a one-year lag (0.898), which quantitatively proves the validity of hypothesis H1 and characterizes investment activity as the key channel of sustainable regional diversification.

Second, the share of foreign investments and loans in the financing structure produced no additional independent effect once the total volume of investments was controlled for, and hypothesis H2 was not confirmed. This result indicates that the composition of financing sources by itself does not guarantee higher economic returns: what matters is the structural quality of investments, including their green and technological orientation. Consequently, regional investment policy should focus not on

maximizing the share of external financing as such but on institutional mechanisms that channel capital of any origin into high value added and environmentally sound sectors.

Third, the confirmatory block demonstrated an almost functional correspondence between the RGIAI index and the actual volumes of attracted green investments across the regions (Spearman $\rho = 0.943$; $p = 0.005$ with the capital excluded), which confirms hypothesis H3 and the predictive validity of the index. The deviation of Tashkent city, whose high institutional and financial attractiveness is not converted into large green flows because of limited ecological potential, reveals an ecological potential paradox: natural resource endowment and institutional maturity are complementary rather than interchangeable conditions of green investment attraction. This substantiates a policy of differentiated incentives tied to the attractiveness level of each region: for regions with high ecological potential but weak institutional and financial components (Navoi, Karakalpakstan) the priority is the development of local financial instruments, including municipal green bonds; for the leader among the regions, Bukhara, whose weakest RGIAI component is the financial market (0.51), the formation of a green investment cluster and a pilot model of municipal green financing is recommended; for the capital, the adaptation of the index components to urbanized territories is envisaged. Finally, the introduction of separate statistical accounting of green investments in accordance with the National green taxonomy would remove the main data limitation of the present study and allow the analysis to be replicated on the full sample of regions in real prices, which is defined as the direction of further research.

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