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Human Capital, Investment, and Economic Growth in Central Asia: A System GMM Analysis

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Abstract

Introduction/Main Objectives: This study examines the effect of the Human Development Index (HDI) and its inequality-adjusted counterpart (IHDI) on economic growth in five Central Asian countries - Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, and Turkmenistan - over the period 2004–2023. **Background Problems:** Despite sustained macroeconomic reforms across Central Asian transition economies, the mechanisms through which human capital investment translates into economic growth remain insufficiently understood at the regional level. **Novelty:** The empirical evidence demonstrates that HDI and IHDI as major positive drivers on Growth. Research Methods: A dynamic panel framework is estimated using Pooled OLS, Fixed Effects, and the two-step System Generalized Method of Moments (System GMM) estimator with Windmeijer-corrected standard errors, controlling for growth persistence, endogeneity, and unobserved country-specific heterogeneity. **Finding/Results:** The results show that physical investment is a robust and statistically significant driver of growth in the pooled specifications, while trade openness is significant in the within-country (Fixed Effects) dimension. The coefficients on HDI and IHDI are not statistically significant in any specification. This finding is attributable to three identifiable factors: the non-stationary, I(1) character of the human development indices relative to the stationary I(0) growth series; the very small within-country variation in a slowly moving composite index over a twenty-year horizon; and the conditional-convergence pattern whereby the highest-HDI economy (Kazakhstan) records the lowest average growth. Diagnostic tests (AR(2) and Hansen J) confirm the validity of the System GMM instrument set. **Conclusion:** The study concludes that in a small-N regional panel the growth contribution of human development operates primarily through physical-capital and trade channels that are statistically recoverable, whereas the direct HDI–growth elasticity cannot be precisely identified without a larger cross-country panel — an important methodological caution for regional policy evaluation

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1. INTRODUCTION

The relationship between human capital and economic growth is one of the most debated questions in development economics. While classical growth theory attributed economic expansion primarily to physical capital accumulation, the endogenous growth models of Lucas (1988) and Romer (1990) reoriented this understanding by positioning human capital — encompassing health, education, and skills — as a central engine of sustained long-run growth (Mankiw, Romer, & Weil, 1992; Barro, 2001). The Human Development Index (HDI), developed by the United Nations Development Programme, operationalizes this concept by capturing three dimensions of human well-being: life expectancy, educational attainment, and gross national income per capita (UNDP, 2025). Unlike income-based measures alone, the HDI provides a more comprehensive assessment of a country's development trajectory (Sen, 1999; Todaro & Smith, 2020).

Central Asian economies present a compelling yet understudied context for examining this relationship. Since gaining independence in the early 1990s, Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, and Turkmenistan have undergone profound structural transitions from centrally planned to market-based systems, while undertaking significant investments in education and public health. Despite these transformations, the region continues to exhibit marked heterogeneity in both development outcomes and growth trajectories (Izvorski et al., 2024; Tleppayev et al., 2025), raising the question of whether improvements in human development have translated into commensurate economic gains.

The existing literature has not sufficiently addressed two gaps. First, most prior studies focus on individual countries — particularly Kazakhstan or Uzbekistan in isolation — or on broader cross-country samples (Sultana et al., 2022; Puttitanun & Lerskullawat, 2025), rather than the full five-country regional panel. Second, the evidence rarely accounts for the distributional dimension of human development. A country may record a high average HDI while significant portions of the population remain excluded from the gains, a distortion the standard HDI fails to capture. The Inequality-adjusted Human Development Index (IHDI) discounts average development for inequality across its dimensions, yet it has been largely absent from empirical growth studies focused on this region.

This study pursues two objectives. First, it empirically assesses the effect of both HDI and IHDI on economic growth across all five Central Asian countries over 2004–2023, using a dynamic panel framework that includes Pooled OLS, Fixed Effects, and System GMM. Second, it examines whether the empirical evidence supports a statistically identifiable HDI–growth link in a small-N regional panel, or whether the growth contribution of human development operates chiefly through complementary channels such as physical investment and trade. In doing so, the study contributes both substantive regional evidence and a methodological caution regarding the identification of slowly moving composite indices in short panels.

Endogenous growth theory, formalized by Lucas (1988) and Romer (1990), treats human capital as the central engine of sustained growth: investments in education and health raise labor productivity, generate knowledge spillovers, and drive technological innovation. Mankiw, Romer, and Weil (1992) empirically confirmed that cross-country income differences are largely explained by human capital variation, while Sen (1999) broadened this framework by arguing that development should be measured by the expansion of human capabilities rather than income alone — directly motivating the use of the HDI as this study's key variable.

Empirical studies frequently report a positive HDI–growth relationship. Barro (2001) finds robust effects of education and life expectancy on long-run growth across more than one hundred countries, and Sultana, Dey, and Tareque (2022) confirm this for 141 countries after controlling for institutions and physical capital. In the ASEAN context, Selvia and Idris (2021) and Elistia and Syahzuni (2018) report HDI as a consistent predictor of GDP expansion, and comparable evidence spans development contexts — Metzger and Shenai (2022) for OECD economies, Han and Lee (2020) for Korea, Dankyi et al. (2022) for ECOWAS, and Oyinlola et al. (2021) for inclusive growth in sub-Saharan Africa. Importantly, however, several of these studies show that the strength and even the sign of the effect vary across income levels and estimators: Puttitanun and Lerskullawat (2025) find a significant positive

HDI effect in middle- and high-income countries but an insignificant effect in low-income countries, and note that the result is sensitive to the choice between static and dynamic estimators.

Key debates concern causality (wealthier countries invest more in education, creating reverse causality), institutional context (Todaro & Smith, 2020), and the distributional limitation of the standard HDI, which masks inequality. Methodologically, the HDI is a slowly moving composite index, so its within-country variation over a short panel is small; estimators that rely only on that variation, such as Fixed Effects, tend to have low power to identify its coefficient. In addition, when a stationary growth series is regressed on a trending, non-stationary HDI, levels estimators can produce distorted coefficients. These considerations are directly relevant to a small-N regional panel such as Central Asia.

Recent regional studies confirm the policy relevance of this question: Tleppayev et al. (2025) find that education and capital investment drive long-run growth in Central Asia and the Caucasus, while the World Bank identifies education quality as the key constraint on the region's convergence (Izvorski et al., 2024). Yet neither employs the composite HDI/IHDI measures within a dynamic panel framework. No existing study has simultaneously examined HDI and IHDI effects on economic growth for all five Central Asian countries using a dynamic panel that controls for endogeneity and growth persistence. This study addresses that gap by applying Pooled OLS, Fixed Effects, and System GMM to a 2004–2023 panel, and by reporting transparently the identification limits that arise in a small-N regional setting.

2. METHODS

This study employs a quantitative panel data design covering five Central Asian countries (Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan) over the period 2004–2023, yielding 100 country-year observations ($N = 5$, $T = 20$); the inclusion of a one-period lag of the dependent variable reduces the effective estimation sample to 95 observations. The unit of analysis is the country-year, and the five countries constitute the complete regional population rather than a sample, so the analysis is not subject to sampling bias.

The dataset is compiled from internationally recognized sources. Human development data (HDI and IHDI) are obtained from the United Nations Development Programme (UNDP Human Development Report 2025). Macroeconomic indicators — annual GDP growth, gross fixed capital formation, and trade openness — are sourced from the World Bank World Development Indicators (2024). Where early-year values were missing (notably for Turkmenistan), linear interpolation was applied to preserve a balanced panel, a standard procedure in macroeconomic analysis of transition economies.

The dependent variable is economic growth, operationalized as the annual percentage growth rate of real GDP. The key independent variable is the HDI, a composite index of life expectancy, education, and gross national income per capita. In a second set of specifications, the HDI is replaced by the IHDI, which discounts average human development for inequality across its three dimensions, thereby capturing the effective level of development available to the broader population. Two control variables, grounded in the augmented Solow framework, are included: gross fixed capital formation as a share of GDP (a proxy for physical capital accumulation) and trade openness, measured as the sum of exports and imports as a share of GDP. The baseline dynamic specification is:

$$Growth_{i,t} = \alpha + \beta_1 Growth_{i,t-1} + \beta_2 HDI_{i,t} + \beta_3 inv_{i,t} + \beta_4 trade_{i,t} + \mu_i + \varepsilon_{i,t}$$

where i denotes the country ($i = 1, \ldots, 5$) and t the year ($t = 2004, \ldots, 2023$). Growth is the GDP growth rate; its one-period lag captures growth persistence and the conditional-convergence dynamic; μ_i captures unobserved country-specific fixed effects; and ε_{it} is the idiosyncratic error term. In the second specification HDI is replaced by IHDI to test the distributional hypothesis.

Three estimators are applied. Pooled OLS with robust standard errors provides a baseline that exploits the full cross-country variation. Fixed Effects (with country-clustered standard errors) exploits only within-country variation but suffers from Nickell (1981) bias in short panels with a lagged dependent variable. The two-step System GMM estimator of Arellano and Bover (1995) and Blundell and Bond (1998) addresses this bias by instrumenting endogenous regressors with their own lagged levels and differences, thereby also accommodating the reverse causality between human development and growth and the non-stationarity of the HDI. Because the panel has only five cross-sections, instrument proliferation is a binding concern (Roodman, 2009): lag depth is restricted to lags 2–4 and the instrument matrix is collapsed, and Windmeijer (2005) finite-sample corrected standard errors are used. Instrument validity is assessed with the Hansen J-test of over-identifying restrictions and the Arellano–Bond AR(2) test for second-order serial correlation. All estimation was carried out in Stata 17 using the xtabond2 routine.

3. RESULTS AND DISCUSSION

Result

Table 1 reports descriptive statistics for the full panel. Mean GDP growth is 6.60 percent per annum with a standard deviation of 3.16 percentage points, reflecting substantial variation across countries and time; the minimum of −8.6 percent corresponds to a pandemic-year contraction and the maximum of 14.7 percent to Turkmenistan's gas-driven expansion. Mean HDI is 0.691, ranging from 0.556 (Tajikistan, 2004) to 0.811 (Kazakhstan, 2023), while mean IHDI is 0.582, implying an average inequality loss of approximately 15.8 percent relative to the HDI.

Table 1. Descriptive Statistics (N = 100, 2004–2023)

Variable	Mean	Std. Dev.	Min	Max
GDP growth (%)	6.60	3.16	−8.60	14.70
HDI	0.691	0.064	0.556	0.811
IHDI	0.582	0.071	0.445	0.716
Investment (% GDP)	27.02	5.01	16.20	39.40
Trade openness (% GDP)	92.21	20.38	52.80	130.20

Source: UNDP Human Development Report 2025; World Bank WDI 2024. Author's computations.

Fisher-type panel unit root tests (Maddala & Wu, 1999) indicate that GDP growth and trade openness are stationary in levels, I(0), whereas HDI, IHDI, and investment are non-stationary in levels but stationary after first differencing, I(1). This mixed order of integration — an I(1) regressor (HDI) alongside an I(0) dependent variable — implies that levels regressions risk distorted coefficients unless the non-stationarity is instrumented, which provides a further rationale for the System GMM estimator that uses lagged differences and levels of HDI as instruments.

Table 2 reports the estimation results across six specifications: Pooled OLS and Fixed Effects and System GMM, each with HDI and, alternatively, with IHDI. All standard errors are robust (country-clustered for the Fixed Effects models; Windmeijer-corrected for System GMM). The dependent variable throughout is annual GDP growth.

Table 2. Regression Results — Dependent Variable: GDP Growth (%)

Variable	(1) OLS-HDI	(2) OLS-IHDI	(3) FE-HDI	(4) FE-IHDI	(5) GMM-HDI	(6) GMM-IHDI
L.GDP growth	0.378***	0.388***	0.024	0.022	0.278	0.276
	(0.093)	(0.093)	(0.112)	(0.111)	(0.413)	(0.411)
HDI	−4.733	—	3.286	—	92.255	—
	(4.123)		(24.759)		(87.180)	
IHDI	—	−2.633	—	1.352	—	110.329
		(3.738)		(29.370)		(101.930)
Investment	0.129**	0.121**	0.141	0.156	−0.881	−0.888
	(0.053)	(0.052)	(0.198)	(0.198)	(1.108)	(1.091)
Trade openness	0.010	0.011	0.124**	0.122**	0.345	0.346
	(0.012)	(0.013)	(0.043)	(0.043)	(0.216)	(0.222)
Constant	2.799	1.028	−11.319	−10.029	−68.104	−68.210

Variable	(1) OLS-HDI	(2) OLS-IHDI	(3) FE-HDI	(4) FE-IHDI	(5) GMM-HDI	(6) GMM-IHDI
	(3.466)	(3.135)	(15.291)	(15.313)	(56.454)	(56.614)
Observations	95	95	95	95	95	95
Country FE	No	No	Yes	Yes	—	—

*Note: Robust standard errors in parentheses (country-clustered for FE; Windmeijer-corrected two-step for GMM). * p<0.10, ** p<0.05, *** p<0.01. GMM: instruments collapsed, lags 2–4; number of instruments = 14 < groups×T. Diagnostics reported in Table 3.*

Three findings stand out. First, growth persistence is present: the lagged growth coefficient is positive and highly significant in the Pooled OLS specifications ($\beta_1 = 0.378$, $p < 0.01$), consistent with the AR(1) dynamics embedded in the Solow–Mankiw–Romer–Weil framework. In the Fixed Effects models the persistence coefficient collapses toward zero (0.024, insignificant), the classic signature of Nickell (1981) bias in a short panel, which motivates the use of System GMM.\

Second, physical investment is a robust growth driver in the pooled dimension ($\beta_3 = 0.129$, $p < 0.05$ for the HDI model; 0.121, $p < 0.05$ for the IHDI model): a one-percentage-point increase in the investment-to-GDP ratio is associated with roughly 0.13 percentage points of additional annual growth, consistent with the augmented Solow model. Trade openness is insignificant in Pooled OLS but becomes significant in the Fixed Effects models ($\beta_4 = 0.124$, $p < 0.05$), indicating that within-country increases in trade intensity are associated with modest growth gains, in line with the trade–technology-diffusion channel.

Third, and most importantly for the research question, the coefficients on HDI and IHDI are not statistically significant in any of the six specifications. In Pooled OLS the HDI coefficient is even negative (−4.733) though insignificant; in Fixed Effects it turns positive (3.286) but remains insignificant with a very large standard error (24.759); and in System GMM the point estimate is large and positive (92.255) but statistically indistinguishable from zero (standard error 87.180). The IHDI results mirror this pattern across all three estimators. The instability of the HDI point estimate across estimators — combined with uniformly large standard errors — is itself diagnostic of a weak-identification problem rather than of a genuine null effect.

Table 3 reports the System GMM diagnostics. The Arellano–Bond AR(1) tests are significant, as expected for first-differenced residuals, while the AR(2) tests are insignificant in both models, confirming the absence of second-order serial correlation and the validity of instruments lagged at t−2 and beyond. The Hansen J-tests do not reject the null of instrument exogeneity. With only five cross-sections, however, the Hansen test has very low power (the number of instruments is close to the number of groups), so a non-rejection should be read as a necessary but not sufficient condition for instrument validity rather than as strong confirmation.

Table 3. System GMM Diagnostic Tests

Test	HDI model	IHDI model	Interpretation
AR(1) (p-value)	< 0.05	< 0.05	Significant (expected)
AR(2) (p-value)	> 0.10	> 0.10	No AR(2): valid
Hansen J (p-value)	> 0.10	> 0.10	Fail to reject: exogenous
Instruments / Groups	14 / 5	14 / 5	Collapsed, lags 2–4

Note: AR tests refer to residuals of the first-differenced equation. Hansen null: all instruments exogenous. Instrument count restricted via collapse and limited lag depth to respect the small-N constraint (Roodman, 2009).

Discussion

The results yield a coherent and defensible interpretation. The statistically insignificant HDI and IHDI coefficients should not be read as evidence that human development is irrelevant to growth in Central Asia; rather, they reflect the limits of what a small-N regional panel can identify about a slowly moving composite index. Three complementary explanations account for the finding.

First, the panel unit root tests show that HDI is I(1) while GDP growth is I(0). In a levels regression pairing a stationary dependent variable with a non-stationary regressor, OLS and Fixed Effects estimates can be distorted; System GMM mitigates this by instrumenting HDI with its own lagged differences, but at the cost of larger standard errors in a five-country panel. Second, HDI is a slowly moving index that improves by roughly 0.005 points per year within any country, so the within-country variation exploited by Fixed Effects carries little identifying information — reflected in the very large standard errors in columns (3) and (4). Third, the cross-country pattern is dominated by conditional convergence: Kazakhstan, with the highest HDI (0.811 in 2023), records the lowest average growth (about 5.5 percent), while lower-HDI Tajikistan and Turkmenistan grow faster. This convergence dynamic pushes the pooled HDI coefficient toward zero or even negative territory and does not imply that human development impedes growth (Barro, 1991; Mankiw et al., 1992).

What the data do identify robustly is the role of the complementary inputs. Physical investment is a significant growth driver in the pooled dimension, and trade openness matters within countries — both consistent with the augmented Solow model and with recent regional evidence (Tleppayev et al., 2025). Human capital, in this reading, operates in Central Asia primarily as a complementary and enabling factor whose direct elasticity is difficult to isolate statistically when N is small and the index moves slowly, rather than as an independently estimable growth lever. This interpretation is consistent with Puttitanun and Lerskullawat (2025), who recover significant HDI effects only in a large 73-country panel with substantial cross-sectional variation, and who report insignificant effects in smaller or lower-income subsamples.

The descriptive evidence nonetheless documents an unambiguous co-movement: over 2004–2023 all five countries experienced simultaneous gains in human development (ΔHDI from +0.098 in Turkmenistan to +0.129 in Tajikistan) and positive average growth, providing prima facie support for a complementary human-development–growth relationship at the macro level even where the regression coefficient is imprecisely estimated. The transmission mechanism also differs across the panel — fiscal (resource-revenue-financed) in Kazakhstan and Turkmenistan, remittance-financed household investment in Tajikistan and Kyrgyzstan — and pooling these heterogeneous channels into a single coefficient further attenuates the estimated effect.

4. CONCLUSION

This study examined the effect of the HDI and IHDI on economic growth in five Central Asian countries over 2004–2023 using Pooled OLS, Fixed Effects, and System GMM estimators. The analysis finds that physical investment is a robust growth driver and that trade openness matters in the within-country dimension, whereas the direct effect of human development — whether measured by HDI or by the inequality-adjusted IHDI — cannot be identified with statistical precision in this small-N panel. The System GMM diagnostics confirm a valid instrument set, but the estimator's low power with only five cross-sections, combined with the I(1) character and slow evolution of the human development indices and the conditional-convergence pattern in the data, jointly explain the insignificant coefficients.

The policy reading is therefore nuanced rather than dismissive. Because the descriptive evidence shows human development and growth rising together, and because investment and trade — the channels through which human capital is put to productive use — are robustly growth-enhancing, governments should sustain investment in education and health while simultaneously strengthening the physical-investment and trade environment that allows human capital to translate into output. Reducing the inequality loss embedded in the IHDI (from about 10.5 percent in Kazakhstan to roughly 20 percent in Tajikistan) through targeted health and education access for rural and disadvantaged populations remains a defensible priority, since it raises the effective human-capital stock available to the economy even where the aggregate elasticity is hard to estimate.

Several limitations follow directly from the findings. The panel covers only five countries over twenty years, which limits the power of dynamic panel estimation; the human development indices are composite and slowly moving, masking heterogeneous sub-component effects; and the small N makes the Hansen test weak. Future research should embed Central Asia within a larger panel of transition economies — including the South Caucasus and Eastern Europe — to increase cross-sectional variation, exploit disaggregated human-capital measures such as quality-adjusted schooling, and extend the analysis to post-2023 data as ongoing reforms in Uzbekistan and Kazakhstan mature. Such extensions would allow the growth contribution of human development to be estimated with the precision that a five-country panel cannot deliver.

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