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Impact of Bilateral Trade and Institutional Quality on Income Convergence in Central Asia

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ABSTRACT. This study determines the income convergence and the effect of bilateral trade and institutional quality on income convergence in Central Asia. This panel study covers the period from 2003 to 2023 and labor force and capital are treated as control variables. The income convergence is examined through beta and sigma convergence while panel techniques are applied to analyze the effect of bilateral trade and institutional quality on income convergence. The results of study confirms income convergence in Central Asia. Bilateral trade is found to have positive significant effect on income convergence while institutional quality negatively affect income convergence. Moreover, capital and labor force are positively and negatively affected income convergence, respectively. Policy implications are discussed on basis of this study findings.

1. Introduction

The per capita income of developed nations has shown a steady rise over the past two centuries. Industrial revolution paved way for economic expansion. So, to understand rapid economic expansion, economists developed theories of growth ([1], [2], [3]). Most growth theories are based on the principle of diminishing marginal returns. In a situation where population grows

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swiftly, occupying much of the available land, and the supply of land remains fixed, the marginal productivity of both land and labor tends to decline. The decline in marginal returns and rise in consumption will eventually lower the living standards of the population and this decline can be upset only by technological progress. The neoclassical growth model postulates that capital accumulation is a primary driver of economic growth. Technological progress further improves labor productivity, thereby increasing overall output through improved efficiency. On the other hand, the convergence hypothesis postulates that, under reduced trade barriers, the diffusion of advanced technologies enables developing countries to catch up with developed nations in terms of per capita income. However, this hypothesis based on several assumptions: perfect competition, continuous technological advancement, the exogenous nature of technology and the absence of externalities. Deviations from these assumptions provide evidence of persistent disparities in per capita income [4].

Real convergence takes place when lower-income regions or countries grow faster than richer ones, thereby lessening the income gaps over time. While real divergence occurs when disparities in real income between countries expand. The question of whether per capita incomes eventually converge across countries has attracted attention in economic research studies. As outlined in [5], the convergence hypothesis suggests that poorer countries, by sustaining higher growth rates, can gradually approach the average income levels of advanced countries. This process assumes that differences in per capita income diminish as developing countries manage population growth and enhance investment whereas sustained growth is therefore considered a critical driver of economic development, as it not only endorses economic expansion but also improves living standards [6].

The concept of conditional convergence advocates that income convergence occurs only when countries share similar structural characteristics, such as technological progress, saving behavior, and stable population growth. In contrast, absolute (unconditional) convergence posits that poorer countries inherently grow faster than richer ones in terms of per capita income due to lower diminishing returns. When the required conditions are satisfied, countries move toward the same steady-state equilibrium; otherwise, divergence persists. Furthermore, the notion of σ-convergence indicates that income disparities diminish over time as the dispersion of per capita income across nations decreases [7].

The case of Central Asia presents a compelling context for examining income convergence. The region's transition economies, resource dependence, shaped by historical legacies, and varying levels of institutional development make a good background to analyze income convergence and its determinants. Moreover, Central Asia faces distinct challenges in sustaining growth and narrowing income disparities. Bilateral trade has emerged as a potential driver of convergence through technology transfer, productivity spillovers and market

integration. On other hand, institutional quality plays a critical role in shaping how effectively these gains from integration translate into long-term development. This study therefore examines income convergence in Central Asia, along with emphasis on the effect of bilateral trade and institutional quality on income convergence. The aim is to assess whether these factors can foster sustained and inclusive economic growth across the central Asian region.

2. Literature review

The income convergence grab the attention of researchers since the pivotal work of Baumol's [8] study, which first provided empirical evidence on the convergence hypothesis. Since then, diverse methodologies are employed, covering cross-sectional, time series and panel data approaches, to analyze income convergence across countries, regions and economic blocs. Researchers have analyzed absolute and conditional convergence, as well as beta (β) and sigma (σ) convergence, in different contexts. Likewise, researchers also studied the determinants of income convergence. This growing body of literature reflects the complexity of convergence dynamics and highlights the importance of structural, institutional, and regional heterogeneity in shaping income trajectories.

Baumol [8] conducted the first empirical study on income convergence, which immediately gained popularity among researchers. Then the studies like ([5], [9]) followed the pioneer study [8], which began with cross-sectional investigations and came to similar conclusions. Later, economists questioned the findings of cross-sectional studies and focused on time series studies, for instance, Bernard and Durlauf [10] and Dawson and Strazicich [11]. The majority of time series research is conducted for industrialized countries, and the majority of these studies confirmed income convergence. In a study, Saglam and Onkan [4] investigate income convergence across different European regions Eastern, Western, Central Europe, and the Baltics focusing on regional rather than country-level trends. It explores how income inequality, influenced by historical, cultural, and economic factors affects wealth distribution. Using a stochastic convergence analysis with the panel stationarity tests, the study found that income levels tend to converge on average within regions, broader economic inequalities across Europe are likely to persist or even increase over time.

Sanli and Arslan [7] examined distinct kinds of β-convergence in GDP per capita among EU-28 and EU-19 countries between 1990 and 2019 using non-stationary heterogeneous panel-data methods. The research contributes uniquely by applying heterogeneous panel techniques to analyze convergence patterns individually for EU countries, unlike many prior studies relying on ordinary least squares approaches. The results confirmed both unconditional and conditional income convergence in the EU-28, while only conditional income convergence was found in the EU-19. The Group-specific conclusions indicate that 10-EU nations converge to the average of EU-19, while 11 converge to the EU-28 average, with convergence speeds ranging from 15% to 18%.

Robustness checks using alternative panel estimators support these findings. However, no evidence of stochastic or deterministic income convergence is found for either group. Additionally, newer EU members such as Bulgaria, Croatia, and others do not exhibit conditional convergence. Notably, the study suggests Brexit was economically rational for the UK.

Gul, Haq and Khan [12] looked at the Central Asian nations' income convergence. They used beta and sigma convergence to examine how incomes converged from 2003 to 2019. Both the sigma and beta convergence tests validated income convergence in Central Asian nations. Likewise, Gul et al. [6] evaluated income convergence using beta and sigma convergence for Central and South Asia countries. The coefficient of variation of average per capita income is employed to test for sigma convergence, while panel unit root tests were used to test for beta convergence. The results of the sigma and beta convergence demonstrated income convergence for Central and South Asia integration.

The literature on income convergence highlighted many factors that can effect income convergence. For instance, Menbere [13] highlighted the importance of human and physical capital for income convergence and concluded income convergence in EU-15 and transitional economies. Likewise, Christian and Seidel [14] emphasized on the role of trade and human capital for income convergence and determined the positive effect of trade and human capital on income convergence. Izelli and Teixeira [15] stressed on human capital and institutional quality whereas Baloyi [16] determined that capital and institutional quality ensure income convergence in Africa. Likewise, other researcher also emphasized on the importance of institutional quality for income convergence [17].

Jan, Boloch and Yousaf [18] explored the effect of institutional quality on inclusive growth in 91 developing countries between 2008 and 2021. Using the system generalized method of moments (GMM), researchers created an inclusive growth index based on a social opportunity function and assess institutional quality through six indicators. The findings revealed a positive and statistically significant relationship between stronger institutions and higher levels of inclusive growth. The study recommended that developing nations focus on improving institutional frameworks to promote inclusive growth, build public trust, and achieve lasting social and economic stability.

Ugwunna, Akamobi and Maduka [19] investigated how institutional quality affects economic growth in Sub-Saharan Africa, where many countries have faced persistently slow growth. The study applied stationarity tests and the system GMM method for analysis. The results showed that institutional quality has mixed impacts on growth in the region. A stable political environment tends to support economic growth while weak public and civil services hinder it. The study suggested that governments in Sub-Saharan Africa should focus on strengthening the quality of public administration and services to stimulate economic growth.

Lu and Staehr [20] examined economic growth and income convergence among 30 post-communist countries from 1995 to 2023. They documented that while all countries had reduced their income gaps with Western Europe however; the extent of convergence varies significantly. The study found an average annual beta convergence rate of about 1% across the region lower than typical rates for other emerging markets. However, Central and Eastern European countries showed much faster convergence, around 5% annually, forming a distinct, consistently progressing club. In contrast, most Balkan and former Soviet Union countries experience slower, uneven convergence. They concluded that conditional beta convergence analysis highlights institutional quality as the main factor explaining differences in convergence speed across countries, while other factors like reform intensity and political liberalization have little influence. Darku et al. [21] examined the influence of bilateral trade on income convergence between countries, focusing specifically on the roles of income levels and the nature of trade. Using data from 25 OECD and 30 Sub-Saharan African (SSA) countries between 1980–2018, the study applies a 2SLS estimation method to address potential endogeneity. The findings show that trade between high-income OECD and low-income SSA countries has the strongest positive effect on income convergence, mainly through one-way knowledge and technology transfer. Trade among OECD countries also fosters convergence, while trade within SSA countries has minimal impact. The study suggests that SSA countries should strengthen trade with high-income nations, pursue industrialization to diversify exports and invest in human capital and technology adoption to close the income gap.

Jamilu, Isah and Salihu [22] examine income convergence among 42 selected Sub-Saharan African countries from 2000 to 2020. Its main aim is to assess income trends, test for absolute and conditional income convergence, and explore the possible formation of income convergence clubs within the region. Using time-series data from the World Bank and applying descriptive analysis, regression techniques, and Nixon's α and ß-convergence models, the study finds evidence of income convergence among the countries. Additionally, the analysis reveals weak negative correlations between income and fertility, and weak positive correlations between income and school enrolment and is negatively associated with fertility and enrolment. The results suggest causality from fertility rates to enrolment levels. The study recommends that to reduce poverty and narrow income gaps, Sub-Saharan African countries should strengthen both inter-regional and intra-regional trade cooperation through bilateral, multilateral, and free trade agreements to support sustainable economic growth.

Lohani [23] examined the relationship between international trade and income convergence among nations of BRICS, particularly assessing how the formation of the BRICS economic alliance has influenced trade patterns and income convergence or divergence by using intra-group trade data through the panel unit root technique, and single difference technique.

The study evaluated convergence trends among BRICS nations. The findings indicated that while BRICS nations experienced overall income convergence during the study period. The study concluded by emphasizing the importance of BRICS countries strengthening trade and investment cooperation to support continued income convergence.

Ghatak [24] used the β-convergence and sigma convergence approaches in an empirical panel analysis to examine income convergence in Asian economies between 1990 and 2017. Additionally, this study attempts to investigate the factors that influence income convergence for Asian economies. The results of the study indicated that income disparities in the area are narrowing over time and show the presence of income convergence. Furthermore, openness to trade, infrastructure, and skilled labor all have a direct and substantial impact on the region's income convergence, which in turn reduces income disparities.

Zhang et al. [25] explore how the growth of the digital economy impacts the gap in income between rural and urban areas in China and how factors like education and human capital influence this relationship. Using data from 31 Chinese provinces between 2011 and 2022, the research finds that digital development helps to reduce urban-rural income inequality, though the impact varies by region. The effect is strongest in western, less developed provinces, but weaker or insignificant in central and eastern regions. Human capital plays a significant role in strengthening the positive effects of the digital economy, while surprisingly, higher education investment slightly undermines its inequality-reducing potential likely due to a mismatch between education systems and digital skill needs. The study recommends region-specific policies: improving digital infrastructure and human capital in underdeveloped areas, and focusing on advanced digital skills in wealthier regions.

Filauro, Parolin and Valetto [26] analyzed income disparity trends in the European Union by employing the data of EU-SILC between 2007 and 2019. Despite increasing income inequality within individual countries, overall EU-wide difference decreased by 9-20%, depending on the measurement used. Decomposition analysis shows that this reduction is entirely driven by between-country income convergence, while changes in transfer systems and taxes slightly increased inequality. Incomes at the 10th percentile rose six times more quickly than those at the 90th percentile, largely as a result of higher employment output in lower-income EU countries, rather than changes in the structure of the labor force. However, by 2019, within-country disparities remained the dominant contributor to EU-wide inequality, highlighting the growing importance of addressing domestic income gaps for future inequality reduction in the EU.

Ali [27] has conducted an empirical study of African nations for the period between 1996 and 2021 to test the impact of financial liberalization and institutional qualities on economic growth. The conclusion of the study indicates that the economic growth of the chosen nations is positively and significantly impacted by the political stability, accessibility of physical capital,

general labor force participation, and governmental efficacy. Economic growth, total labor force participation, and physical capital accumulation have causal connections in both directions. Financial openness has almost no effect on African nations' economic development. According to the findings, African countries should concurrently support high-quality institutions and raise the proportion of qualified workers and physical capital to promote economic development across the continent. Furthermore, African nations must control the negative impacts of financial liberalization to support this economic growth if they are to benefit from it.

Bhattarai and Qin [28] argue that labor productivity is convergent toward steady states in both β and σ convergence across Chinese provinces and industry sectors. Quintile, dynamic, and static panel data models serve as the foundation for their estimations. An uneven distribution of convergences across sectors is revealed by quantile panel regression models. The convergence tendency became more evident when controls for industrial concentration, FDI, inequality, and human capital were included for analytical robustness. Even while the advantages of FDI and human resources on output convergence are not uniform across provinces and sectors, there is divergence in simple or quantile panel estimations when there is more inequality or a higher incidence of industry concentration. These findings have clear ramifications. The convergence of productivity among workers across Chinese provinces and industries is better served by policies that promote fair distribution and competitiveness.

The literature discussed above revealed mixed findings on income convergence across regions and country groups. Several studies documented income convergence while some studies reported divergence. Researchers highlighted the role of important determinants in income convergence and pointed out that weaker institutions or limited trade integration may hinder income convergence within a region. The literature also emphasized on key determinants such as institutional quality, trade, human and physical capital, and technological adoption consistently emerge as central to narrowing income gaps. On the other hand, the diversity of results suggesting that sustained growth depends on country-specific structural reforms, regional cooperation, and the capacity to integrate into global trade and technology networks.

3. Research Methodology

This is a panel study that examines the impact of determinants of income convergence in Central Asian countries over a period from 2003 and 2023. The panel comprised of Kyrgyzstan, Kazakhstan, Uzbekistan, and Tajikistan. This panel did not include Turkmenistan as data was not available. Data on per capita income, capital and labor force is collected from World Bank [29]. Per capita is measured in US dollars while capital is measured in million US dollars. The labor force represents the sum of the employed, unemployed and those people who are actively searching for jobs and is measured in millions. Data on institutional quality is gathered from

World Governess Indicators World Bank [30]. Institutional quality has six sub-indices which are voice and accountability, government effectiveness, the rule of law, political stability and absence of violence, regulatory quality, and the control of corruption. The value for each index ranges from -2.5 which is regarded as poor to 2.5 and is regarded as good. Data from the United Nations online database and the International Monetary Fund are used to calculate "bilateral trade," which is the total of two trading partners' imports and exports and is expressed in millions of US dollars.

Following the literature, panel unit root tests, such as the ADF-Fisher Chi-square and PP-Fisher Chi-square tests developed by [31], the Levin-Lin-Chu (LLC) proposed by [32], and the Im-Pesaran-Shin (IPS) test suggested by [33], are employed to examine the income convergence. The alternative hypothesis (H1) in the Levin–Lin–Chu (LLC) test asserts that the all-time series are stationary, whereas the null hypothesis (H0) states that all-time series have unit roots. The null hypothesis in the IPS, Fisher-PP, and Fisher-ADF tests is that the series have unit roots, while the alternative hypothesis is that some series have no unit roots.

The equation may be expressed as under:

$$y_{i,t} = \beta y_{it-1} + \epsilon_{i,t} \quad (1)$$

Additional lags can be added to the above equation 1 to prevent the unit root issue, and may be expressed as under:

$$\Delta y_{i,t} = \rho y_{it-1} + \sum_{j=1}^{p} \delta_{ij} \Delta y_{i,t-j} + \epsilon_{i,t} \quad (2)$$

Where, Yi,t stands for the mean value of per capita income of the nations that were chosen for the study. When β is positive, it shows income divergence, and when it is negative, it shows convergence.

The sigma convergence looks at whether or not there has been a decline in the dispersion in per capita income of countries over time. The coefficient of variation (CV) is employed for testing the sigma convergence, and its equation is as follows:

$$C V = \frac{SD}{AM} * 100 \quad (3)$$

Where AM stands for the arithmetic mean of the per capita income of a group of nations and SD is the standard deviation. Sigma convergence is tested using the CV of the country's average per capita income. It shows how much has changed, either greater or lower, compared to the average value. Sigma convergence occurs when its value decreases over time, indicating that the differences in GDP per capita income between the nations have shrunk.

For testing the impact of determinants of income convergence the model is proposed:

$$lny_{i,t} = \alpha_{1\,i} + \beta_1 lnLF_{i,t} + \beta_2 lnK_{i,t} + \beta_3 Instq_{i,t} + \beta_4 lnBilTrd_{i,j,t} + \varepsilon_{i,t} \quad (4)$$

Where, lnLFi,t, lnBilTrdi, j, t , lnKit and Instqi, t, denote the natural logarithm of the labor force, bilateral trade, capital stock and institutional qualities respectively.

Panel data includes observations of several cross-sections (such as a country, firm, or individual) over a period. Managing unobserved heterogeneity, or traits that vary among entities but remain consistent over time and may have an impact on the dependent variable, is a crucial concern when examining panel data. The fixed effects (FE) and random effects (RE) models are two widely used methods for analyzing panel data. To prevent bias in the estimated coefficients of the regressors due to missing time-invariant characteristics, all of the time-invariant variations between the cross-sections are taken into consideration by the FE model. Fundamentally, the FE model allows each entity to have its own intercept term, which captures the effects of characteristics that remain constant over time within that entity. The model specification is as under:

$$y_{i,t} = \alpha_i + \beta X_{i,t} + \epsilon_{i,t} \quad (5)$$

Whereas $y_{i,t}$ is the dependent variable for cross-section i at time$t$, $X_{i,t}$ stands for the explanatory variable (s), α_i stands for unobserved time-invariant individual effect, and $\epsilon_{i,t}$ denotes idiosyncratic error term. This model is employed when it is suspected that individual-specific effects are correlated with the independent variables and when focusing on the effect of variables that vary over time within an entity. The advantages of the model are that it controls for all unobserved time-invariant heterogeneity and produces unbiased estimators if assumptions are hold. On other hand, RE accounts for individual heterogeneity but assumes that heterogeneity is random and uncorrelated with the independent variables. The model assumes no correlation between the explanatory variables and the individual-specific effects, which are treated as random variables drawn from a common distribution. The model specification is:

$$y_{it} = \alpha_i + \beta X_{it} + \mu_{it} + \epsilon_{it} \quad (6)$$

Where μi stands for random individual-specific effect and $\epsilon_{i,t}$denotes an idiosyncratic error. It assumes that μ_{it} is uncorrelated with the independent variables X_{it}, and both $\mu_{it}$and $\epsilon_{it}$are independently and identically distributed. It is used in situations when it is believed that the entity-specific effects are uncorrelated with the independent variables and aim is to evaluate the impacts of time-invariant variables.

A common statistical test used to decide between FE and RE is the Hausman test.

Null Hypothesis (H_0): RE is appropriate (no correlation between entity effects and regressors).

Alternative Hypothesis (H_1): FE is appropriate (correlation exists).

If the test is significant (p-value < 0.05), reject RE in favor of FE. Additionally, The Generalized Method of Moments (GMM) is a general-purpose estimation procedure. It is widely used in econometrics when the classical assumptions of OLS (like strict exogeneity) do not hold particularly when there is endogeneity (explanatory variables correlated with the error term) then dynamic models with lagged dependent variables are used or when there are heteroskedasticity

and autocorrelation. The GMM relies on using moment conditions derived from economic theory or model assumptions to estimate parameters and the model equation is as follows:

$$\Delta y_{i,t} = \alpha y_{it-1} + \beta X_{i,t} + \gamma_i + \epsilon_{it} \quad (7)$$

4. Results and Discussion

The findings in Table 1 confirm the β-convergence for Central Asia by employing the LLC, IPS, PP-Fisher Chi-square, and ADF-Fisher Chi-square tests. The results of all four applied panel unit root tests confirmed that sationarity i.e. income per capita of Central Asian countries is free from unit root problem at level. These results yielded a significant result and demonstrated the presence of β-convergence. Therefore, all four tests' results validated income convergence in Central Asia. The findings of σ-convergence in Figure 1 indicated that σ-convergence is for Central Asian countries because the coefficient of variation first rises to a maximum value of around 143 and since 2013 is on continuous decrease therefore confirmed σ-convergence.

Table 1. β-convergence Results

LLC test		IPS test		ADF Fisher Chi-square test		PP-Fisher Chi-square test	
Statistic	P-value	Statistic	P-value	Statistic	P-value	Statistic	P-value
-11.25	0.0000	-8.38	0.0000	107.67	0.0000	96.32	0.0000

Source: Author's calculation

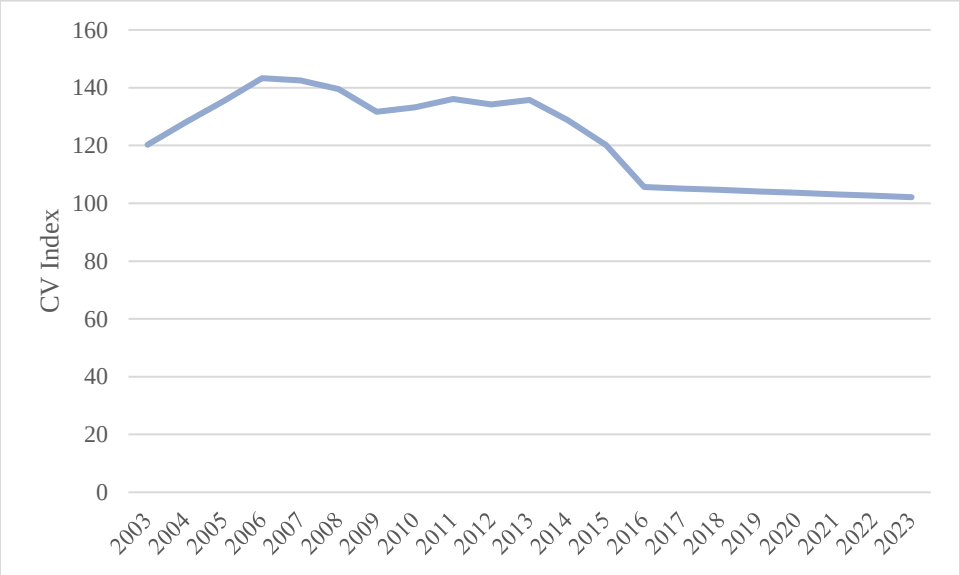

Figure 1. Depiction of σ-convergence based on CV Results

The Panel Unit Root (Levin, Lin, and Chu) test results are displayed in Table 2. These results indicated that all integrated at a level henceforth; there is no problem with unit roots. However, to apply RE or FE, this study applied Hausman test and The Hausman Test results are displayed in Table 3. It is employed to determine if the random effect model or the fixed effect model is more appropriate. The Hausman Test's null hypothesis states that the random effect model is

suitable. The test statistic came out significant which indicates that the null hypothesis is rejected and the alternative hypothesis that the fixed effect model is appropriate is accepted.

Table 2. The results of (Levin, Lin & Chu) test

Variable	At Level	At First Difference	Integration
lny	-11.25(0.0000)	-	I(0)
lnBilTrd	-2.30(0.0107)	-	I(0)
lnInstq	-11.07(0.0000)	-	I(0)
lnK	-10.79(0.0000)	-	I(0)
lnLF	-5.66(0.0000)	-	I(0)

Source: Author's calculation

Table 3. The Correlated Random Effects - Hausman Test

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f	Prob
Cross-section random	589.31	4	0.0000

Source: Author's calculation

The Results of FE and GMM are presented in Table 4. All explanatory variables are found to be significant factors of income convergence in Central Asia. The long-term estimates of FE indicate that bilateral trade and capital positively influence income convergence, while the labor force and institutional quality negatively affect income convergence. Specifically, the results showed that income convergence rises with higher levels of bilateral trade and capital accumulation. On the other hand, an increase in labor force reduces income convergence, implying potential inefficiencies or mismatches in labor market productivity across Central Asian region. Likewise, institutional quality negatively affecting income convergence, suggesting that variations in governance and institutional frameworks may hinder convergence across Central Asia. The model's R-squared value of 0.889 reflects a strong explanatory power, indicating that approximately 88.9% of variations in income convergence are explained by the included variables. On other hand, the results from the GMM estimation present a similar pattern but with varying magnitudes of effects. Like FE results, bilateral trade and capital positively affected income convergence, while the labor force and institutional quality hindered it. Nonetheless, the coefficients in the GMM model are usually smaller, suggesting that once endogeneity and dynamic relationships are accounted for, the overall impact of these factors becomes more moderate. The R-squared value of 0.744 indicates that the explanatory power of the GMM model is slightly lower than that of the FE model, which is expected given that GMM addresses potential biases arising from omitted variables and reverse causality. The comparative analysis of FE and GMM indicated that bilateral trade and capital played fostered income convergence in Central Asia, whereas labor force and institutional quality hindered income convergence.

Table 4. The long-run results of FE and GMM models

Variable	FE	GMM
lnBilTrd	0.064*** (3.405)	0.044*** (3.602)
lnLF	-0.883** (-2.421)	-0.671*** (-3.017)
lnK	0.702*** (19.155)	0.155*** (3.943)
lnInstq	-0.106* (-1.923)	-0.1306*** (0.0003)
Intercept	1.198*** (6.959)	0.731*** (6.451)
R-squared	0.889	0.744

Note: *** p<1%, ** p<5%, * p<10%, and t-statistics value in parenthesis.

5. Conclusion and Recommendations

Income convergence is a concept that poor nations grow more speedily than rich nations and approach to the mean value of per capita income of the group of countries owing to the earlier application of the law of decreasing marginal returns on capital in developed nations as compared to developing nations. Furthermore, the institutions, technologies, and manufacturing techniques employed by wealthy nations may be imitated and replicated by developing countries. The current study tries to test the impact of bilateral trade, capital, labor force, and institutional quality on income convergence in Central Asia over period from 2003 to 2023. The income convergence is determined by the sigma and beta convergence tests; the findings of these tests confirm the income convergence. The FE and GMM techniques are used to test the long-term impacts of these determinants on income convergence in the case of Central Asia. The results confirmed the positive impact of bilateral trade on income convergence in Central Asia and suggest that integration among Central Asian countries through trade networks promotes income convergence. It is concluded that Central Asia benefits from economic integration and recommended that these nations should continue to cooperate economically by lowering import taxes and trade restrictions. Promoting regional and bilateral trade links should be a top priority for governments. One way to capitalize on the growth-enhancing impacts of trade integration would be to improve logistical infrastructure, lower trade costs, and negotiate mutually beneficial trade agreements. The results confirm the negative impacts of the labor force on income convergence. This suggests that increases in the size of the labor force without corresponding improvements in productivity or job quality could put pressure on income convergence. To increase worker productivity, investments should be made in education, skill development, and vocational training. Measures to enhance labor market matching mechanisms and lessen under-employment are also crucial. The study's conclusions highlight the significance of consistent investment in physical capital formation by showing that capital continues to be a key driver of economic growth and has a favorable and very significant impact on income convergence. Prioritizing actions like enhancing financial accessibility, maintaining macroeconomic and

political stability, and updating infrastructure will encourage profitable investment. Capital accumulation has a significant beneficial impact on income convergence, which emphasizes how crucial it is to create a climate that is welcoming to both international and local investment. The study's conclusions support the notion that Central Asia's income convergence is significantly and negatively impacted by institutional quality. This unexpected outcome might point to transitory inefficiencies or difficulties putting institutional reforms into practice, which could short-term impair economic performance. The detrimental effect of institutional quality raises the possibility that the existing improvements are either unevenly executed or not specifically targeted enough. While addressing potential governance impediments and transitional frictions, policymakers should thoroughly assess ongoing institutional changes with an emphasis on enhancing the rule of law, regulatory quality, and public sector efficiency.

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References

[1] R.M. Solow, A Contribution to the Theory of Economic Growth, Q. J. Econ. 70 (1956), 65-94. https://doi.org/10.2307/1884513.

[2] T.W. Swan, Economic Growth and Capital Accumulation, Econ. Rec. 32 (1956), 334-361. https://doi.org/10.1111/j.1475-4932.1956.tb00434.x.

[3] P.M. Romer, Endogenous Technological Change, J. Polit. Econ. 98 (1990), S71-S102. https://doi.org/10.1086/261725.

[4] Y. Saglam, O. Onkan, Income Convergence and Divergence in European Regions: Insights and Policy Implications, Panoeconomicus (2025). https://doi.org/10.2298/PAN240925004S.

[5] X.X. Sala-i-Martin, Regional Cohesion: Evidence and Theories of Regional Growth and Convergence, Eur. Econ. Rev. 40 (1996), 1325-1352. https://doi.org/10.1016/0014-2921(95)00029-1.

[6] H. Gul, I. ul Haq, D. Khan, P. Allayarov, K. Abbas, Exploring Income Convergence for Central and South Asia, Comp. Econ. Res. Cent. East. Eur. 27 (2024), 89-108. https://www.ceeol.com/search/article-detail?id=1298606.

[7] D. Sanli, R. Arslan, Testing Convergence Hypothesis for EU Countries: A Heterogenous Panel Data Approach, J. Econ. Adm. Sci. 41 (2023), 635-657. https://doi.org/10.1108/jeas-08-2022-0202.

[8] W.J. Baumol, Productivity Growth, Convergence, and Welfare: What the Long-run Data Show, Am. Econ. Rev. 76 (1986), 1072-1085. https://www.jstor.org/stable/1816469.

[9] R.J. Barro, Economic Growth in a Cross Section of Countries, Q. J. Econ. 106 (1991), 407-443. https://doi.org/10.2307/2937943.

[10] A.B. Bernard, S.N. Durlauf, Convergence in International Output, J. Appl. Econ. 10 (1995), 97-108. https://doi.org/10.1002/jae.3950100202.

[11] J.W. Dawson, M.C. Strazicich, Time-Series Tests of Income Convergence with Two Structural Breaks: Evidence from 29 Countries, Appl. Econ. Lett. 17 (2010), 909-912. https://doi.org/10.1080/13504850802584807.

[12] H. Gul, I.U. Haq, D. Khan, Exploring Intra-Group Income Convergence for the Central Asian Countries, IRASD J. Econ. 4 (2022), 448-461. https://doi.org/10.52131/joe.2022.0403.0092.
[13] M.T. Workie, Determinants of Growth and Convergence in Transitive Economies in the 1990s: Empirical Evidence from a Panel Data, Prague Econ. Pap. 14 (2005), 239-251. https://doi.org/10.18267/j.pep.264.
[14] C. Lessmann, A. Seidel, Regional Inequality, Convergence, and Its Determinants – A View from Outer Space, Eur. Econ. Rev. 92 (2017), 110-132. https://doi.org/10.1016/j.euroecorev.2016.11.009.
[15] N.I. Doré, A.A.C. Teixeira, Do Human Capital and Institutional Quality Contribute to Brazil's Long Term Real Convergence/divergence Process? A Markov Regime-Switching Autoregressive Approach, J. Inst. Econ. 20 (2023), e9. https://doi.org/10.1017/s1744137423000358.
[16] E.N.C. Baloyi, Growth Convergence in Africa: The Role of Capital and Institutional Quality, in: 10th International conference on Applied Research in Management, Economics and Accounting, (2025).
[17] K. Harger, A.T. Young, J. Hall, Globalization, Institutions, and Income Convergence, J. Reg. Anal. Policy 47 (2017), 110-125. https://ssrn.com/abstract=2897973.
[18] M. Jan, A. Baloch, H. Yousaf, The Impact of Institutional Quality on Inclusive Growth in Developing Countries, J. Dev. Soc. Sci. 6 (2025), 170-180.
[19] O.T. Ugwunna, O.G. Akamobi, O.D. Maduka, Institutions and Economic Growth in Sub-Saharan Africa: A Panel Analysis, Int. J. Innov. Finance Econ. Res. 13 (2025), 1-11.
[20] M. Lu, K. Staehr, Revisiting Economic Growth and Real Convergence in the Post-Communist Countries, Eurasian Econ. Rev. 15 (2025), 89-123. https://doi.org/10.1007/s40822-024-00308-5.
[21] A.B. Darku, W. Baah-Boateng, I. Mohammed, W.A. Rahaman, Sorting Out the Bilateral Trade and Income Convergence Relationship: Does Income and the Nature of Bilateral Trade Matter?, J. Dev. Areas 57 (2023), 247-262. https://doi.org/10.1353/jda.2023.a907745.
[22] I.M. Jamilu, A. Isah, U. Salihu, Convergence Analysis of Per Capita Income (PCI) in the Sub-Saharan African (SSA), Int. J. Manag. Sci. Bus. Anal. Res. 3 (2024), 218-250.
[23] K.K. Lohani, Trade and Convergence: Empirical Evidence from BRICS Countries, Glob. Bus. Rev. 26 (2021), 500-519. https://doi.org/10.1177/0972150921993057.
[24] S. Ghatak, P. De, Income Convergence Across Asian Economies: An Empirical Exploration, J. Asia-Pacific Bus. 22 (2021), 182-200. https://doi.org/10.1080/10599231.2021.1943808.
[25] Y. Zhang, L. Hainan, F. Feng, X. Wu, Digital Economy, Education, Human Capital and Urban–Rural Income Disparity, Financ. Res. Lett. 71 (2025), 106464. https://doi.org/10.1016/j.frl.2024.106464.
[26] S. Filauro, Z. Parolin, P. Valetto, What Explains Recent Trends in Income Inequality in the European Union?, J. Econ. Inequal. 23 (2025), 483-505. https://doi.org/10.1007/s10888-024-09651-8.
[27] A. Ali, Financial Liberalization, Institutional Quality, and Economic Growth Nexus: Panel Analysis of African Countries, Bull. Bus. Econ. 11 (2022), 27-36. https://doi.org/10.5281/zenodo.7639577.
[28] K. Bhattarai, W. Qin, Convergence in Labor Productivity Across Provinces and Production Sectors in China, J. Econ. Asymmetries 25 (2022), e00247. https://doi.org/10.1016/j.jeca.2022.e00247.
[29] World Bank, World Development Indicators, (2025). https://databank.worldbank.org/source/world-development-indicators.
[30] World Bank, World Governance Indicators, (2025). https://www.worldbank.org/en/publication/worldwide-governance-indicators.

[31] I. Choi, Unit Root Tests for Panel Data, J. Int. Money Financ. 20 (2001), 249-272. https://doi.org/10.1016/s0261-5606(00)00048-6.

[32] A. Levin, C. Lin, C. James Chu, Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties, J. Econ. 108 (2002), 1-24. https://doi.org/10.1016/s0304-4076(01)00098-7.

[33] K.S. Im, M. Pesaran, Y. Shin, Testing for Unit Roots in Heterogeneous Panels, J. Econ. 115 (2003), 53-74. https://doi.org/10.1016/s0304-4076(03)00092-7.