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Article

Analysis of labor force, capital and production outputs of border territories of Kazakhstan and Uzbekistan on economic growth

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Abstract: Border areas can play a crucial role in market integration and infrastructure development between Central Asian countries, thus creating favorable economic growth and regional cooperation conditions. This study aims to assess the economic impact of border areas between Kazakhstan and Uzbekistan, focusing on their role in enhancing market integration and infrastructure development to foster regional growth and cooperation. Focusing on labor and capital as essential production drivers, this study employs a sophisticated panel data regression model to explore the Cobb-Douglas production function's application in these border territories. The research findings indicate that regions' elasticity towards capital and labor inputs vary, necessitating differentiated economic strategies. For capital-intensive areas, we recommend prioritizing investments in infrastructure and technology to boost production outputs. Conversely, in regions where labor significantly influences production, the emphasis should be on human capital development through education, training, and improved labor market conditions. The study's insights into the evolving trade relations between the two countries underscore the need for flexible economic policies to enhance regional integration and cooperation. This research not only fills a crucial knowledge gap but also offers a blueprint for leveraging the diverse economic landscapes of Central Asia's border areas in future policy-making and regional economic strategy.

Keywords: labor force; investment; trade; regional production outputs; border; border region; Kazakhstan; Uzbekistan; Central Asia; cooperation

1. Introduction

Kazakhstan and Uzbekistan, two prominent nations in Central Asia, have shared a historically intertwined relationship that has evolved across cultural, economic, and political dimensions. As former Soviet Republics, both countries embarked on their journey of independence simultaneously in 1991. This shared history, combined with geographical proximity, has resulted in intricate socio-political and economic interdependencies that are worth exploring. Historically, Kazakhstan and Uzbekistan have shared cultural solid and trade ties rooted in the ancient Silk Road that crossed their territories. The rich tapestry of intercultural exchanges over the centuries has led to the synthesis of unique traditions and practices in both nations. Their mutual linguistic similarities, with Kazakh and Uzbek languages belonging to the Turkic language group, further underscore this intertwined cultural relationship.

Economically, the relationship between the two nations has been multifaceted. While both economies have been heavily influenced by their Soviet past, post-independence, they embarked on distinct developmental trajectories. Kazakhstan, with

its abundant oil reserves, adopted a resource-driven growth model. At the same time, Uzbekistan, being the most populous country in Central Asia, focused on a mixed economy with an emphasis on agriculture and manufacturing. However, despite these divergent economic paths, bilateral trade and investment ties between Kazakhstan and Uzbekistan have seen steady growth, particularly in the last decade. Establishing free trade zones, joint ventures in agriculture, energy, and textile sectors, and enhanced transportation connectivity has further deepened their economic cooperation.

On the political front, both nations have collaborated closely in regional forums like the Shanghai Cooperation Organization and have worked together to address shared challenges such as water resource management, border security, and regional stability. Their mutual commitment to fostering regional peace and development has been pivotal in shaping Central Asian geopolitics. In this study, against the backdrop of this prosperous bilateral relationship, we delve into the economic dynamics of the border territories of Kazakhstan and Uzbekistan. By examining the role of labor and capital inputs in influencing regional production outputs, we aim to provide insights that can guide policy-making in both countries.

In this study, the works of Becker (1993), Barro (1991), Jumayev (2021), Mankiw et al. (1992) and Pomfret (2020) are particularly pivotal, providing a comprehensive theoretical and empirical foundation to explore the economic interdependencies and developmental trajectories of Kazakhstan and Uzbekistan. These authors offer essential perspectives on economic growth models, human capital, geopolitical influences, and the role of international institutions, all of which are crucial for understanding the complex dynamics at play in the border regions of these Central Asian nations.

Kazakhstan and Uzbekistan are situated in a region that serves as a bridge between Europe and Asia, making their economic strategies, infrastructure developments, and political alliances critical to understanding Eurasian geopolitics. The border areas between these countries, in particular, are crucial for regional stability and security. In 2023, the bilateral trade between Kazakhstan and Uzbekistan reached approximately more than $4.1 billion, underscoring their increasing economic interdependence. Such ties are of paramount importance in a region where geopolitical stability and economic integration are deeply linked with global security and market dynamics. The paper contributes to the literature by offering a comprehensive analysis of the economic dynamics in the border territories of Kazakhstan and Uzbekistan, a topic that has received limited attention in previous studies. By employing a sophisticated panel data regression model based on the Cobb-Douglas production function, this research provides novel insights into the role of labor and capital inputs in influencing regional production outputs. Furthermore, the study's recommendations for differentiated economic strategies based on regional characteristics offer practical implications for policymakers and stakeholders aiming to foster economic growth and cooperation in Central Asia's border regions.

Building upon the introduction, this study explores the economic dynamics of Kazakhstan and Uzbekistan more profoundly, with a specific emphasis on the border territories between these nations. The research encompasses a thorough analysis of how labor and capital inputs impact regional production outputs. Investigating these dynamics is essential for understanding the economic interactions and dependencies

in these strategic regions, which act as critical channels for trade and cultural exchange between the two countries. The paper is organized into several pivotal sections, each designed to fulfill a distinct role in investigating the economic dynamics between Kazakhstan and Uzbekistan. Following the introduction, a detailed literature review is presented, synthesizing existing research and theories pertinent to our study's focus. This section is followed by a methodology segment detailing the analytical frameworks and data sources utilized in our investigation. The subsequent sections include results and analysis, where the findings from our empirical research are discussed, and a conclusion, summarizing the key insights and policy implications derived from our study. This study structure ensures a coherent and thorough investigation of the economic interplay between these two Central Asian nations, mainly focusing on their border regions.

2. Literature review

The intricate dynamics of border territories play a pivotal role in shaping regional economic landscapes, offering a fertile ground for examining the interplay between labor mobility, capital investment, and production capacities. These regions, characterized by their geographical liminality, are focal points of economic interaction and integration between neighbouring nations. The dynamics within these regions encapsulate the challenges of balancing economic development with social equity, environmental sustainability, and cultural preservation.

The labor force in border territories often exhibits unique characteristics due to cross-border mobility, migration patterns, and the diversity of employment opportunities. Nicolae-Balan (2009) highlights the role of labor mobility in enhancing economic resilience and adaptability in border regions. Moreover, the labor markets in these areas are significantly influenced by bilateral agreements and labor laws, which can either facilitate or restrict the flow of labor across borders (Blank, 2011; Martínez-Zarzoso et al., 2016). The disparities in wage levels, employment standards, and working conditions between neighbouring countries can also lead to labor market segmentation and create challenges for economic integration (Beramendi and Cusack, 2009; Ramos et al., 2016; Vacas-Soriano et al., 2019). It becomes evident that the dynamics of labor force mobility in border territories necessitate a multifaceted analysis to understand their impact on local and regional economies fully.

Vokhidova and Abdullaeva (2024) provide crucial insights into the evolving trade dynamics between Uzbekistan and its Central Asian neighbors. Analyzing trade turnover data from 2000 to 2021 through regression correlation methods, they identify promising prospects for enhancing trade relations with Kazakhstan, Kyrgyzstan, and Turkmenistan. The study underscores that the primary challenge in boosting Uzbekistan's foreign trade turnover is not its non-membership in the World Trade Organization (WTO), but the pressing need for modernizing production, particularly in the chemical industry, and attracting foreign investments. Isiksal's (2023) study provides crucial insights for our research on economic dynamics in Central Asia, particularly between Kazakhstan and Uzbekistan. Analyzing data from 1996 to 2020, she discovers an initially beneficial but eventually detrimental effect of natural resource wealth on financial growth, a phenomenon termed as transitioning from a

"resource blessing" to a "resource curse". This finding, along with evidence of the positive roles of institutional quality and human development in financial expansion, underscores the importance of economic diversification and strategic investments in human capital for sustainable development. This aligns with our focus on modernization and diversification in border regions to harness economic potential effectively.

In the context of Central Asia's economic policies and debt sustainability, the work of Nikonov et al. (2023) emerges as a seminal contribution. Their analysis meticulously delineates the variegated landscape of national debt across Kazakhstan, Kyrgyzstan, Uzbekistan, and Tajikistan. By identifying the divergent risk factors such as budget deficits in Kazakhstan and currency devaluation in other states, this study underscores the complexity of fiscal management within the region. Some study explores disaster risk management (DRM) cooperation in Central Asia's border regions, including Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan (Mavlyanova et al., 2023). Highlighting a shift towards proactive risk and hazard anticipation, their work emphasizes the growing role of regional associations in coordinating efforts to mitigate natural disasters. It provides valuable insights into the potential for enhanced environmental security through collaborative regional strategies, contributing significantly to our understanding of resilience and cooperation in Central Asian borderlands.

Energy consumption, both renewable and non-renewable, plays a pivotal role in shaping the economic growth trajectories of countries. Rasoulinezhad and Saboori (2018) delve into this causality, highlighting a linkage between economic growth and renewable energy use. Such findings can guide energy policies that align with sustainable economic development. Jumayev (2021) explores the controversial nature of Central Asia's economic development, characterized by rapid GDP growth yet ineffectiveness in resource distribution and wealth generation. The study delves into the roles of development banks and institutions like the BRI and EAEU in shaping the region's economic landscape, revealing the complex interplay of interests from China, Russia, and other significant players. Li et al. (2019) address the strategy of low-carbon economic development in Central Asia. Their research employs the LMDI decomposition method to analyze CO_2 emissions and their relationship with economic growth, highlighting the challenges and policy recommendations for achieving sustainable development in the region (Li et al., 2019).

Productivity remains a cornerstone for economic growth. Yormirzoev (2022) offers insights into the total factor productivity growth rates in Central Asia, revealing modest rates for Kazakhstan (1.7%) and Uzbekistan (1.4%). Such insights are crucial for understanding their economic patterns and development strategies. Toktomushev (2019) discusses China's increasing economic and developmental influence in Central Asia, urging Central Asian leaders to adopt evidence-based policymaking to capitalize on opportunities presented by China's Belt and Road Initiative. This approach could lead to greater regional integration and mutual benefits (Toktomushev, 2019). Pomfret (2020) argues that Central Asian economies must diversify to move from primary product exports and remittances towards more outward-oriented economies. He suggests that the reintegration into a Eurasian economy, facilitated by rail services between Europe and China, could be a key catalyst for this transition (Pomfret, 2020).

Demographics also play a significant role in economic dynamics. The implications of high population increase rates, especially since the 1970s, on the Soviet economy and its successor states, including Kazakhstan and Uzbekistan. Such growth poses challenges and opportunities for economic development in the region (Moscow State University, 1991). Gaur (2021) examines the competitive economic initiatives in Central Asia, discussing the influence of Russia within the EAEU economic space and China's promotion of the Silk Road initiative since 2013. The study emphasizes the need for domestic experts to consider long-term integration and the resolution of internal conflicts for effective economic development in Central Asia (Gaur, 2021).

Lastly, the interplay between environmental degradation and ethnic conflicts in Central Asia is explored by De Cordier (1996). The division of the Ferghana Valley between Uzbekistan and other countries, coupled with industrial development in Northern Kazakhstan, offers a lens to understand the socio-economic and environmental challenges these nations face. The economic development and growth in Kazakhstan and Uzbekistan are influenced by many factors, from biothreats and energy consumption to productivity, demographics, and environmental challenges. A comprehensive understanding of these dynamics requires a multifaceted approach, as provided by the reviewed articles. Further granular research is essential for a more in-depth exploration of these challenges and opportunities. Plottka et al. (2019) provide forecasts for Central Asia in 2030, suggesting continued positive political, societal, and economic development trends, albeit at different paces. The study also underscores the EU's continued significance in Central Asia despite growing influences from China and Russia.

Economic growth and development across regions have long been subjects of academic inquiry. Even within the same country, different regions often showcase disparate economic performance driven by various factors, including labor force, capital investments, and more. The importance of the labor force in driving economic outcomes is well-documented. According to Becker (1993), human capital, representing the labor force's knowledge, skills, and experience, significantly impacts economic growth. This theory has been further echoed by Mankiw et al. (1992), who found a substantial positive correlation between human capital and per capita income growth across countries.

Gross Regional Product (GRP) per capita provides a lens to assess the overall economic health of a region. Barro (1991) emphasized the significance of initial levels of GRP in determining subsequent growth rates, suggesting a convergence theory where poorer economies grow faster than richer ones until equilibrium is reached. In Kazakhstan and Uzbekistan, regional economic disparities and growth drivers have been the focus of several studies. While the specific dynamics of each region can vary, the broader themes around labor force, investments, and GRP per capita remain consistent with global research trends.

Capital allocation in border territories is pivotal for spurring economic growth and development. The research conducted by Brülhart and Koenig (2006) sheds light on how border regions can magnetize investment through the strategic use of geographical proximity, trade facilitation measures, and the bolstering of infrastructure. Various studies have underscored the imperative for focused

investments in infrastructure, technology, and human capital to ramp up productivity and competitive edges in border areas (Ghebrezgabher and Sereke, 2021; Sysoeva and Rudneva, 2021). Mukhtarova et al. (2021) delve into the state and future possibilities of economic cooperation among Central Asian countries, highlighting a regional trend toward economic diversification. In parallel, Tsoi (2022) explores the dynamics of cooperation between Russia and Central Asian countries in the realm of investment, pinpointing the most efficacious economic partners for fostering regional integration processes. This study provides a critical perspective on Central Asia's geopolitical and economic chessboard, revealing the intricate interplay of regional powers vying for influence and partnership in this strategically significant area. By strategically directing capital towards these critical areas, border territories can unlock their economic potential, contributing to regional growth, economic diversification, and sustainable development.

Despite the body of literature on the economic dynamics of Kazakhstan and Uzbekistan, a discernible gap persists in comprehensively understanding how regional leadership's nuanced roles, combined with strategic resource management and allocation, drive economic development specifically in border areas. There's a lack of analysis of factors that contribute to economic development in these key regions, which, in turn, can have an important impact on strengthening market integration and cooperation between Central Asian countries. The scientific novelty of this research arises from its targeted exploration into the roles and impacts of border areas between Kazakhstan and Uzbekistan thus offering a valuable framework for policy formulation and regional economic strategy. Thus, this study aims to bridge this gap by delivering a granular exploration of the interplay between these factors, thus shedding light on the economic trajectories and policy frameworks in the border areas of Kazakhstan and Uzbekistan.

3. Research methodology

This research aims to explore the economic dynamics within the border areas of Kazakhstan and Uzbekistan, focusing on the interplay between labor and capital inputs and their impact on production output. The study is driven by the objective to quantify the contributions of these inputs towards regional economic growth and to identify strategies that could promote economic cooperation and development between these two nations. We employ the Cobb-Douglas Economic Theory as our primary analytical framework to investigate the economic dynamics within the border areas of Kazakhstan and Uzbekistan (Caselli, 2005). This decision is anchored in the theory's robustness and its proven applicability in examining the interplay between key inputs—labor and capital—and their impact on production output. The Cobb-Douglas model is selected for its versatility and adaptability, which are essential for analyzing the diverse economic conditions present across the border regions we study. Its flexibility allows us to model how variations in labor and capital inputs differentially influence production outputs in these territories, accommodating the unique economic contexts of each.

The Cobb-Douglas function provides the analytical depth needed to quantify the elasticity of production relative to changes in labor and capital, offering precise

measurements of their impact on economic output. This level of detail is invaluable for understanding the economic underpinnings of the regions in question and for identifying the specific contributions of labor and capital to regional growth. The comparative nature of the Cobb-Douglas model further enhances our research by facilitating a side-by-side evaluation of the economic performance across different border territories. This comparative analysis is crucial for identifying disparities and similarities in economic activities, enabling us to draw nuanced conclusions about the economic strategies and policies most likely to promote growth and cooperation between Kazakhstan and Uzbekistan. Given the structure of our dataset, which features cross-sectional units across different periods, a panel data regression is the most suitable analysis method (Cameron and Trivedi, 2005). The generic form of the Cobb-Douglas function is given as $Q = A \times L^{\alpha} \times K^{\beta}$. We take the natural logarithms on both sides to ease the estimation process with linear regression techniques. Thus, the equation becomes:

$$\ln(Q_{it}) = \ln(A) + \alpha \ln(L_{it}) + \beta \ln(K_{it}) + u_{it} \quad (1)$$

where, i represents the cross-sectional unit, namely regions in our context, and t represents the time component (Johnston and DiNardo, 1997). The error term u_{it} encapsulates all other unobserved effects.

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

Considering the potential presence of unobserved heterogeneity across regions, we will implement Fixed Effects (FE) and Random Effects (RE) techniques for robustness. The FE method will allow us to control for any time-invariant discrepancies across regions (Arellano, 2003), while the RE method offers more efficient estimates, assuming that the unobserved effects are uncorrelated with the regressors (Greene, 2003). The Fixed Effects model seeks to control for unobservable time-invariant characteristics of each cross-sectional unit that can affect the dependent variable. This is done by taking deviations from means or introducing dummy variables for each cross-sectional unit. The primary objective of the FE model is to eliminate the λ_i by demeaning the data or using dummy variables (Wooldridge, 2002). The formula for the Fixed Effects model is:

$$\ln(Q_{it}) = \alpha + \lambda_i + \beta_1 \ln(L_{it}) + \beta_2 \ln(K_{it}) + u_{it} \quad (2)$$

where: λ_i is the unobserved time-invariant individual effect for each cross-sectional unit i. This captures the specific effect for each region; α is the constant term. β_1 and β_2 are the coefficients for the logarithm of labor and capital, respectively; u_{it} is the error term.

The Random Effects model assumes individual-specific effects are uncorrelated with the independent variables. These effects are random and can be captured by a random variable. The formula for the Random Effects model is:

$$\ln(Q_{it}) = \alpha + \lambda_i + \beta_1 \ln(L_{it}) + \beta_2 \ln(K_{it}) + u_{it} + \epsilon_{it} \quad (3)$$

where:

λ_i is the region-specific random effect.

ϵ_{it} is the idiosyncratic error term.

Other terms remain the same as in the FE model.

The RE model combines the time-invariant region-specific effect $\lambda_i\lambda_i$ and the usual error term to form a composite error. It provides more efficient estimates if the assumption of no correlation between the region-specific effects and the regressors holds (Baltagi, 2005).

The choice between FE and RE models often rests on the nature of the data and the research question at hand. If one believes that the unobserved effects are correlated with the independent variables, then the FE model is more appropriate. On the other hand, if these unobserved effects are random and uncorrelated with the independent variables, the RE model is suitable. Formal tests, such as the Hausman specification test, can be employed to help decide between the two models (Hausman, 1978). The final regression outcomes will provide coefficient estimates for $\ln(L)$ and $\ln(K)$, which in turn yield the values for α and β respectively, enabling a deeper insight into the production dynamics of the regions under study.

The stages of the data analysis method are carried out based on **Figure 1** as follows:

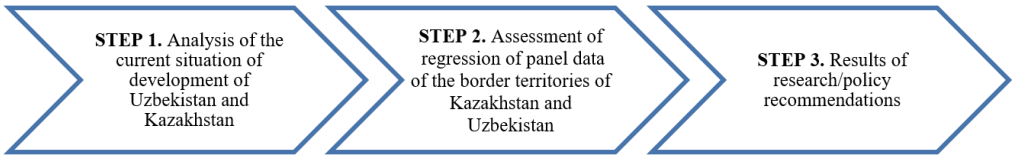

Figure 1. Step-by-step actions in scientific research.

Figure 1 shows the steps of the study, starting with an analysis of the current situation of the dynamics of trade indicators and then analyzing the differences in the elasticity of production concerning labor and capital. Recommendations are based on the data received.

4. Results and analysis

4.1. Current dynamics of development of Uzbekistan and Kazakhstan

Currently, Uzbekistan and Kazakhstan, two leading countries in Central Asia, are attracting significant international attention due to their rapidly developing economies, strategic geopolitical position, and rich natural resources. These countries play a crucial role in regional economic integration and geopolitical interactions. In this context, the study of the level of development of their territories becomes especially relevant for understanding current trends and forecasting future development directions. Aware of this, the current study aims to provide a comprehensive analysis and understanding of these countries' unique challenges and opportunities. This includes an analysis of key economic indicators such as GDP, employment, investment attractiveness, and trade balance.

As two of the largest economies in the region, their trade dynamics offer a window into the broader economic developments of Central Asia. In the early 2000s, following the dissolution of the Soviet Union, both countries were navigating their new-found economic sovereignty. Initial years were marked by emphasizing building domestic industries and stabilizing their economies. Mutual trade during this period was moderate, characterized by traditional exchanges in primary commodities and

goods, reflecting their shared Soviet-era economic structures.

The dynamics of changes in mutual trade relations from 2000 to 2022 are shown in **Figure 2**.

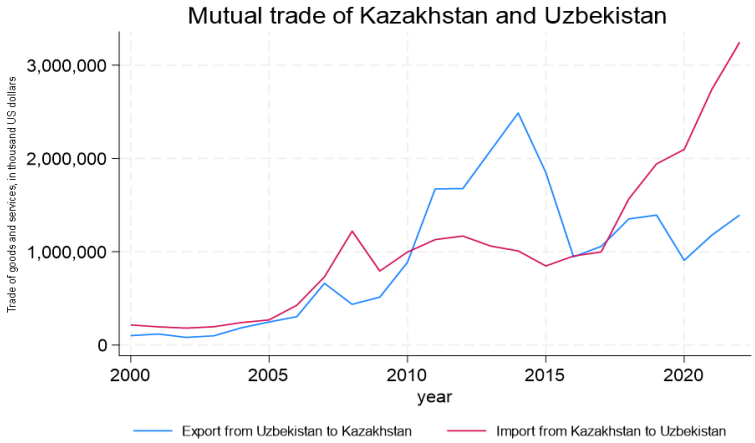

Figure 2. Mutual trade of Kazakhstan and Uzbekistan from 2000 to 2022.

However, by the mid-2010s, a noticeable shift was observed. With global economic changes, diversification strategies, and regional integration efforts, the trade volume between Kazakhstan and Uzbekistan rose significantly. Kazakhstan's oil and mineral exports found a market in Uzbekistan, while Uzbekistan's agricultural and textile products gained traction in Kazakhstan. Establishing transportation corridors, free trade agreements, and reducing trade barriers further facilitated this growth. By 2022, their mutual trade relationship had evolved into a multifaceted partnership encompassing various sectors, from energy and manufacturing to technology and services. Joint ventures, investments in infrastructural projects, and collaborations in industries like renewable energy and the digital economy marked this new phase of economic cooperation.

The relationship between inputs, such as labor and capital, and outputs in the production process has been a central topic of discussion in economics since its inception. Initially introduced by Cobb and Douglas (1928), the Cobb-Douglas production function has become a cornerstone in empirical economic research, offering a flexible form to capture the production relationships. Its popularity lies in its multiplicative structure, which allows it to accommodate different degrees of substitutability between inputs (Solow, 1957). In the context of understanding regional production dynamics, the Cobb-Douglas function provides a framework to dissect the contributions of labor and capital in generating output. With the increasing availability of panel data, capturing both cross-sectional and temporal variations, researchers can dive deeper into understanding these relationships, controlling for both observable and unobservable factors (Wooldridge, 2002).

Regions within countries, like the ones in Kazakhstan and Uzbekistan, present unique economic characteristics and developmental trajectories. Investigating how labor and capital interact to produce output in these regions can offer invaluable insights for policymakers aiming at balanced regional development. However, employing the correct econometric techniques to ensure accurate, unbiased, and consistent estimations is essential. Panel data methods, especially Fixed Effects (FE)

and Random Effects (RE) have become increasingly popular due to their ability to address concerns related to omitted variable bias and unobserved heterogeneity (Baltagi, 2005). This study aims to employ the Cobb-Douglas production function to analyze the relationship between labor, capital, and output in select regions of Kazakhstan and Uzbekistan. Through panel data analysis, we seek to provide a robust estimation of this relationship, offering insights that could guide regional economic policies. The research question of the study is the following:

"How do labor and capital inputs influence regional production outputs, and what are the implications of their interplay for economic policy in Kazakhstan and Uzbekistan?"

This research question encapsulates the core objective of examining the relationship between labor, capital, and output using the Cobb-Douglas production function while emphasizing the regional focus on Kazakhstan and Uzbekistan. It sets the stage for an in-depth analysis and discussion of the implications of these relationships for economic policy in the two countries.

This research paper is systematically organized to understand Kazakhstan and Uzbekistan's economic dynamics comprehensively. It begins with an introduction that delves into the historical trade relationships and current economic ties between the two nations. This is followed by a literature review synthesizing existing studies and establishing our analysis's theoretical foundation. The subsequent methodology section elucidates the panel data regression approach employed, explaining the rationale behind the chosen econometric techniques. The results section presents the outcomes of our analysis, visually supported by graphs. It is succeeded by a detailed discussion contextualizing these findings within broader economic theories and previous research. Finally, the paper concludes by answering the research question, drawing implications for economic policy in both nations, and suggesting avenues for future study. Throughout the paper, accurate references are employed to ensure the validity and robustness of our arguments.

4.2. Panel data regressions

To analyze the economic dynamics of regions in Kazakhstan and Uzbekistan, we collated data on three primary variables: labor force, investment in fixed assets, and gross regional product (GRP) per capita. This data is sourced from regional statistics for selected regions from both countries, as shown in **Table 1**.

In Kazakhstan, regions like Aktobe, Kyzylorda, and Mangystau, among others, have been considered. For instance, Aktobe demonstrates a labor force averaging at 404.47 (with a standard error of ±4.52), investments typically around 1.11×10^9 ($\pm 1.08 \times 10^8$), and a GRP per capita of 5696.87 (±566.89). Turkistan, another region in Kazakhstan, showcases a significant labor force mean of 851.05 (±24.15) and a GRP per capita of 1935.06 (±209.69).

Moving to Uzbekistan, our focus spans regions from Syrdarya to Tashkent city. Syrdarya region, for instance, has a labor force mean of 336.79 (±4.08) and a GRP per capita of 671.74 (±130.04). Tashkent, the capital, and its urban hub, Tashkent city, are also significant contributors, with the latter showing an impressive investment average of 1.61×10^9 ($\pm 4.59 \times 10^8$) and a GRP per capita of 1538.71 (±334.01).

Table 1. Descriptive statistics.

Country	Region	Labor Force (Mean)	Labor Force (Std. Err.)	Investment to Fixed Asset (Mean)	Investment (Std. Err.)	GRP per Capita (Mean)	GRP (Std. Err.)
Kazakhstan	Aktobe	404.4667	4.516812	1.11×10^9	1.08×10^8	5696.873	566.8878
	Kyzylorda	318.9933	4.443577	6.12×10^8	4.33×10^7	3999.027	283.9588
	Mangystau	266.32	12.12665	1.06×10^9	7.04×10^7	8871.844	616.0541
	Shymkent	343.3308	17.98946	3.06×10^8	1.27×10^7	1749.499	664.3803
	Turkistan	851.0467	24.15144	9.42×10^8	9.35×10^7	1935.059	209.694
	Syrdarya	336.7933	4.075881	2.43×10^8	7.87×10^7	671.7438	130.043
Uzbekistan	Tashkent	1214.54	15.10354	8.08×10^8	2.39×10^8	929.7421	205.1809
	Tashkent city	1189.773	17.62787	1.61×10^9	4.59×10^8	1538.709	334.0112
	Navoi	412.3133	2.173649	5.25×10^8	1.47×10^8	1734.929	441.3767
	Karakalpakstan	639.3933	14.357	3.54×10^8	7.07×10^7	472.4063	103.1551
	Jizzakh	451.3533	17.16736	2.91×10^8	9.05×10^7	585.7905	119.862

This data provides a foundational understanding of the economic landscape in the regions, enabling further econometric analysis to discern patterns and infer potential causal relationships. Future analyses might consider fixed effects or random effects panel data regressions to understand better the impact of labor and investment on regional economic outcomes.

Table 2. FE results.

Variable	Coefficient	Std.err.	*t*	*P* > *t*	[95% conf.	interval]
ln*L*	0.4107956	0.2333158	1.76	0.080	−0.0504256	0.8720168
ln*K*	0.7340806	0.022256	32.98	0.000	0.6900847	0.7780764
_cons	−9.952405	1.31686	−7.56	0.000	−12.55559	−7.349222
sigma_u	0.93247431	-				
sigma_e	0.22835123	(Fraction of variance due to u_i)				
rho	0.94342306	-				
R-squared (Within)	0.9108	-				
R-squared (Between)	0.3492	-				
R-squared (Overall)	0.5149	-				
Number of Observations	155	-				
Number of Groups	11	-				
F-statistic	725.12	-				
Prob > *F*	<0.0001	-				

In the conducted analysis, we applied the Cobb-Douglas production function to examine the relationship between output and its determinants, notably labor and capital, in various regions across two countries. Our regression results suggest a significant and positive association between the natural logarithm of capital (ln*K*) and the Gross Regional Product (GRP) per capita. Specifically, a 1% increase in capital investment is associated with a 0.7341% increase in GRP per capita, holding all other factors constant. This outcome corroborates earlier findings in the literature,

suggesting capital's pivotal role in driving economic productivity (Romer, 1986), as shown in **Table 2**.

On the contrary, although positive, the association between the natural logarithm of labor (ln*L*) and GRP per capita is less conclusive. The coefficient of 0.4108 suggests that a 1% increase in the labor force might lead to a 0.4108% increase in GRP per capita, but this relationship is only marginally significant at the 10% level ($p = 0.080$). This is in line with the postulations of some scholars who argue that mere labor increase does not necessarily translate to direct proportional gains in output, especially in contexts where labor productivity remains stagnant (Lucas, 1988).

The constant term (_cons) of −9.9524 suggests the expected value of GRP per capita when both labor and capital inputs are zero. While this might seem counterintuitive in a real-world scenario, it is a mathematical artifact of the logarithmic transformation and regression analysis (Mankiw et al., 1992).

The model's goodness-of-fit, as evidenced by the within *R*-squared value of 0.9108, indicates that approximately 91.08% of the variation in GRP per capita within the regions is explained by variations in labor and capital inputs. However, the between *R*-squared value of 0.3492 suggests that only about 34.92% of the variation between the average GRP per capita of the regions is explained by the average labor and capital inputs. These findings suggest the existence of other region-specific factors influencing the GRP per capita, which might not have been captured in our model (Hsiao, 2003).

The F-statistic value of 725.12, significant at the 0.0001 level, further attests to the joint significance of the labor and capital variables in explaining the variation in the dependent variable (Wooldridge, 2002). Lastly, the sigma_u and sigma_e values reflect the variances of the region-specific and idiosyncratic errors, respectively. The rho value of 0.9434 suggests that a substantial portion (94.34%) of the total variance in GRP per capita is due to differences across regions.

Table 3. RE results.

Variable	**Coefficient**	**Std. Err.**	***t***	***P* > *t***	**[95% conf. interval]**	
ln*L*	−0.8028	0.1348	−5.95	0.000	−1.0670	−0.5386
ln*K*	0.7340806	0.022256	32.98	0.000	0.7631	0.8551
_cons	−3.8208	0.8528	−4.48	0.000	−5.4923	−2.1493
sigma_u	0.2091	-				
sigma_e	0.2284	(Fraction of variance due to u_i)				
rho	0.4562	-				
R-squared (Within)	0.8946	-				
R-squared (Between)	0.9713	-				
R-squared (Overall)	0.9021	-				
Number of Observations	155	-				
Number of Groups	11	-				
Wald chi2	1198.10	-				
Prob > chi2	<0.0001	-				

Using a random-effects generalized least squares regression, the study assessed

the determinants of regional output, captured by the Gross Regional Product (GRP) per capita, based on the inputs of labor and capital. The data encompassed 155 observations spanning across 11 distinct groups, as shown in **Table 3**.

The results from the regression delineate that the natural logarithm of capital (ln*K*) is positively and significantly associated with the GRP per capita. A 1% increase in capital investment leads to an approximately 0.8091% rise in GRP per capita, an outcome that echoes previous findings emphasizing the importance of capital in fostering regional economic growth (Barro and Sala-i-Martin, 2004).

Conversely, the relationship between the natural logarithm of labor (ln*L*) and GRP per capita is negative. This implies that a 1% augmentation in the labor force is tied to a 0.8028% decrease in the GRP per capita. Such a counterintuitive relationship might stem from diminishing returns to labor or instances where rapid labor force growth is not matched with commensurate capital and technology improvements, leading to reduced productivity (Acemoglu and Zilibotti, 2001).

The model's *R*-squared values indicate a robust explanatory power. With an *R*-squared of 0.8946, the model accounts for nearly 89.46% of the variation in GRP per capita within the regions due to variations in labor and capital inputs. The *R*-squared value of 0.9713 suggests that the average labor and capital inputs explain about 97.13% of the difference between average GRP per capita values across regions. Collectively, the overall *R*-squared of 0.9021 emphasizes that the model explains over 90% of the total variation in the GRP per capita (Baltagi, 2008).

The values of sigma_u and sigma_e reveal the variances of the region-specific and idiosyncratic errors, respectively. The rho statistic, 0.4562, suggests that approximately 45.62% of the total variation in the GRP per capita is attributed to differences across the regions. In conclusion, the findings reiterate the essential role of capital in economic productivity and suggest a nuanced interpretation of labor's contribution, demanding further exploration into the contexts and conditions under which labor operates (Krugman, 1994).

A pivotal step in panel data analysis is discerning between fixed effects (FE) and random effects (RE) models, as the choice can substantially affect the interpretation of the regression results. Our study employed the Hausman specification test to aid this decision-making process. The Hausman test's essence, as put forth by Hausman (1978), is to determine if the coefficients obtained under the random effects estimation are consistent and, consequently, more efficient than those from the fixed effects estimation, as shown in **Table 4**.

Table 4. Hausman test results.

Variable	Fixed Effects (FE) Coefficient (b)	Random Effects (RE) Coefficient (B)	Difference (b-B)	Standard error of difference
ln*L*	0.4107956	−0.8027787	1.213574	0.1904268
ln*K*	0.7340806	0.809107	−0.0750264	NA

There is a noticeable discrepancy between the FE and RE coefficients. While the FE model reveals a positive coefficient of 0.4108, suggesting that a 1% increase in labor leads to a 0.4108% rise in GRP per capita, the RE model offers a contrasting perspective. The RE coefficient is −0.8028, indicating that a 1% surge in labor

correlates with a 0.8028% decrease in GRP per capita. Such stark coefficient differences underscore the necessity to decide on the most appropriate model (Baltagi, 2005).

FE and RE models portray a positive relationship between capital and GRP per capita, with coefficients of 0.7341 and 0.8091, respectively. Though both models suggest that capital is a significant determinant of GRP per capita, the slight difference in magnitudes might influence the exact interpretation of capital's contribution (Barro and Sala-i-Martin, 2004).

The chi-square value from the Hausman test stands at 36.31, with a *p*-value less than 0.0001. This significant result rejects the null hypothesis that the coefficient difference between the FE and RE models is not systematic. Thus, this affirms the consistency of the FE model over the RE model for this particular dataset (Wooldridge, 2002). In light of the above, the study opts for the fixed effects model for subsequent analyses and interpretations. The choice is further grounded on the premise that unobserved heterogeneities, which might be correlated with the regressors, are aptly controlled for in the FE model (Greene, 2003).

5. Discussion

This comparison is pivotal in understanding how the effects vary when considering time-invariant characteristics of the cross-sectional units (regions, in this case). **Figure 3** visually represents the FE and RE estimations derived from the Cobb-Douglas production function.

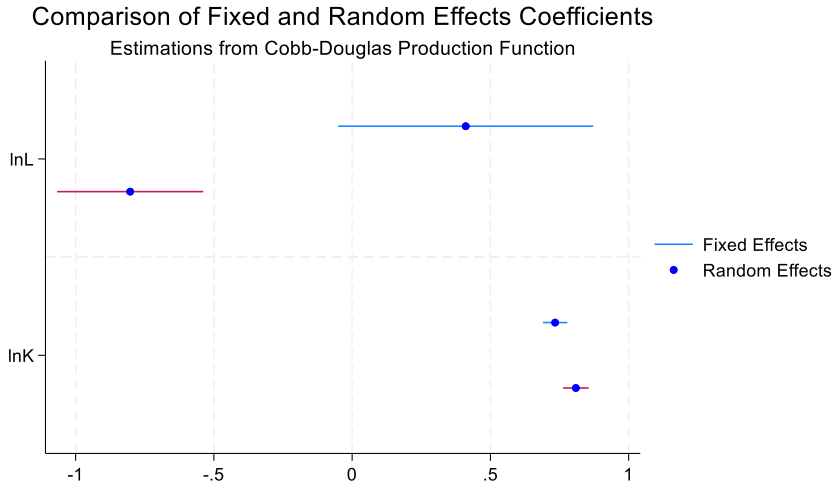

Figure 3. Comparison of fixed and random effects coefficients.

However, by the mid-2010s, a noticeable shift was observed. With global economic changes, diversification strategies, and regional integration efforts, the trade volume between Kazakhstan and Uzbekistan rose significantly. Kazakhstan's oil and mineral The FE estimation for the labor coefficient is positive, suggesting a direct relationship between labor and the production output. This means that as labor input increases, the output increases, ceteris paribus. On the other hand, the RE estimation indicates a negative relationship, implying that there might be unobserved factors, which when accounted for, lead to a decrease in output with an increase in labor. The

difference in these coefficients emphasizes the importance of considering both within and between variations in the data, as highlighted by Greene (2003).

FE and RE estimations for the capital coefficient are positive but differ slightly in magnitude. This underscores the consistent positive impact of capital on production output. The minor divergence in values can be attributed to the differential treatments of the unobserved heterogeneity by the FE and RE models (Cameron and Trivedi, 2005).

The significant difference in the labor coefficient between FE and RE models underscores potential biases when choosing an inappropriate model for panel data. Hausman's test, which systematically tests the difference between these coefficients, further confirms that these differences are statistically significant. In light of these findings, policymakers and researchers should be judicious in their choice of estimation technique. The discrepancies between the FE and RE results underscore the potential pitfalls of overlooking unobserved heterogeneity in the data. As Caselli (2005) has previously argued, understanding the nuances and implications of these coefficients is essential for effective economic planning and forecasting.

The visual representation of the fixed and random effects from the Cobb-Douglas production function regression provides a clear and comparative illustration of the role played by labor and capital in determining regional output. Diving deep into our results, several insights emerge that warrant further discussion. The graph shows the disparity between the FE and RE estimates for labor ($\ln L$). While the fixed effects model suggests a positive association between labor input and output, the random effects model paints a contrasting picture, indicating a negative relationship. This dual narrative is reminiscent of the classic argument presented by Lewis (1954) regarding labor surplus in developing economies. It is conceivable that certain regions, especially densely populated urban centers like Tashkent, might be experiencing diminishing returns to labor, a phenomenon previously observed in other rapidly urbanizing economies (Harris and Todaro, 1970).

On the other hand, the role of capital ($\ln K$) remains consistently positive across both FE and RE models, reflecting the conventional wisdom that investments in infrastructure, technology, and other forms of capital tend to boost economic output (Romer, 1990). This consistency across models suggests a universally accepted tenet of economic growth: capital accumulation is critical to sustained regional development (Barro, 1991). The marked differences between the FE and RE estimates, particularly for labor, highlight the importance of model selection in empirical analysis. While FE controls for unobserved time-invariant factors that might bias our results, the RE model assumes no correlation between these unobserved effects and the regressors. The Hausman test results underscore this discrepancy, hinting at the potential pitfalls of solely relying on one model (Hausman, 1978).

For policymakers, the findings underscore the importance of balanced development strategies. While capital investments remain crucial, a nuanced approach to labor policies might be warranted. For regions indicating diminishing returns to labor, strategies promoting skill enhancement, technological adaptation, and job diversification may prove beneficial, as highlighted by Acemoglu and Zilibotti (2001). While our study offers critical insights, it is essential to recognize its limitations. The temporal span and potential measurement errors inherent in regional data can influence

the results. Furthermore, other unobserved factors, such as regional governance quality or international trade dynamics, might also play a role in shaping the labor-output relationship. Future research could delve deeper into these nuances, possibly employing a more granular dataset or integrating other economic indicators to provide a comprehensive picture of regional production dynamics.

6. Conclusion

In examining the dynamic relationship between output and its determinants using the Cobb-Douglas production function, our analysis unveils the intricate interplay of labor and capital in determining regional production. While both inputs significantly impact output, capital seems to exert a more pronounced influence in some regions. This underscores the importance of capital investments, not just in machinery and infrastructure but also in human capital, as highlighted by Lucas (1988).

The differential results between the fixed and random effects models emphasize the heterogeneity across regions and the necessity to consider unobserved individual effects. Baltagi (2005) posited that such differences in coefficient estimates between FE and RE models can have profound policy implications, especially when deciding where and how resources should be allocated.

Furthermore, our analysis aligns with the findings of Mankiw et al. (1992), who argue for the primacy of capital accumulation in economic growth. However, it's also imperative to consider the quality of labor, encompassing education and training, as a pivotal component for sustained growth, as Becker (1964) states. In summation, the nuanced relationship between labor, capital, and production necessitates an integrated approach for policymakers, prioritizing capital investment and enhancing the workforce's quality. As the future economic landscape continues to evolve, fostering an environment conducive to capital influx and labor skill enhancement will be crucial for sustained regional growth.

Addressing the pivotal research question—"How do labor and capital inputs influence regional production outputs, and what are the implications of their interplay for economic policy in Kazakhstan and Uzbekistan?"—our study offers several nuanced insights. Firstly, labor and capital inputs play a critical role in shaping the regional production outputs of Kazakhstan and Uzbekistan. The econometric analyses, mainly through applying the Cobb-Douglas production function, have illustrated that regions with higher investments in fixed assets (representing capital) and a robust labor force tend to have superior GRP per capita. This is consistent with the broader economic literature that underscores the intrinsic value of labor and capital as drivers of economic growth.

The comparison between fixed effects (FE) and random effects (RE) models in our analysis sheds light on the nuanced relationship between labor, capital, and regional production outputs in Kazakhstan and Uzbekistan. While both models reveal a positive association between capital investment and gross regional product (GRP) per capita, the interpretation of the labor coefficient differs significantly. The FE model suggests a positive relationship between labor and output, implying that increasing labor inputs lead to higher production outputs. However, the RE model presents a contrasting view, indicating a negative relationship between labor and

output. This discrepancy underscores the importance of considering both within and between variations in the data, as highlighted by previous scholars.

The distinct dynamics between labor and capital in these regions, as shown through the panel data regression, highlight that while some regions benefit more from capital investments, others are labor-intensive in their economic activities. This differentiation is particularly stark when comparing urbanized areas like Tashkent city, with its capital-intensive industries, to regions like Jizzakh, where labor plays a more dominant role in production. The implications of these findings for economic policy in both countries are multifaceted. For policymakers, a one-size-fits-all approach may not yield the desired economic dividends. Instead, region-specific strategies that cater to the unique labor and capital dynamics are imperative. Policies focusing on skill development, vocational training, and educational reforms can maximize the labor force's productivity in labor-intensive regions. On the other hand, fostering an environment conducive to foreign direct investment, technological advancements, and infrastructure development in capital-intensive regions can further enhance production outputs.

While our study provides valuable insights into the relationship between labor, capital, and production outputs in Kazakhstan and Uzbekistan, it has limitations that need consideration. Firstly, the temporal span of our analysis from 2000 to 2022 may not capture recent developments or long-term trends accurately, urging the need for more recent and extensive datasets. Secondly, regional data quality and consistency issues, along with the aggregation of data at the regional level, may obscure important nuances in the relationship between labor, capital, and production outputs. Additionally, our focus on specific variables overlooks other potentially influential factors like socio-political factors and technological advancements. Lastly, while panel data regression models offer insights, they rely on certain assumptions that may not always hold true. Acknowledging these limitations and adopting a critical research perspective can guide future studies in providing a more comprehensive understanding of regional economic dynamics in Central Asia.

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