ESTIMATION OF TOTAL FACTOR PRODUCTIVITY BY GROWTH ACCOUNTING: EVIDENCE FROM THE CENTRAL ASIAN REGION

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ABSTRACT

The Central Asian (CA) countries have been transitioning from a centrally planned economy to a market economy since they gained independence at the beginning of the 1990s. As per the official data for 2022, Uzbekistan, which is located in the center of the CA region, has the Russian Federation (18.6%), China (17.8%), Kazakhstan (9.2%), and Turkiye (6.4%) as its top trading partners. This study evaluates the technological progress by estimating the total factor productivity (TFP) of the CA countries as well as their three major trading countries. The analysis focuses on production factors such as capital, labor, and natural resources. The study uses the recently published data from Penn World Table 10.0 (PWT10.0) for eight countries, covering the period from 1991 to 2019. The main findings are as follows: 1) CA countries have shown steady development and noteworthy TFP growth rates; 2) TFP growth was negative in all countries from 1992 to 1997, except in China and Turkiye. But in terms of TFP growth, they outpaced even China and Turkiye between 1998 and 2007, maintaining high rates from 2008 to 2016, thereby demonstrating the catch-up effect; 3) our estimates of TFP growth rates are consistent with the figures reported by several other studies. 4) the most suitable econometric model is found to be generalized least squares (GLS) compared with pooled OLS (pOLS), fixed effects (FE), or random effects (RE).

Keywords: total factor productivity; growth theory; growth accounting; growth regression; GLS

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INTRODUCTION

The efficiency with which inputs (such as labor and capital) are used to produce output is measured by TFP. TFP captures the technological progress, managerial efficiency, and other factors that affect the overall productivity of an economy, an industry, or a firm. The foundation for neoclassical growth theory was established by Stigler (1947) and Solow (1957), who introduced the growth accounting method (also known as the Solow residual) to estimate TFP. Solow's influential article examined the U.S. economy from 1909 to 1949 and found that 87.5% of the increase in output was attributed to technical change (or technological progress), with the remaining 12.5% attributed to changes in capital (both human and physical).

TFP is an important concept in economics, as it helps to understand and measure the impact of technological progress, innovation, and efficiency improvements on economic growth. It plays a crucial role in analyzing productivity differences across countries, industries, or firms and identifying factors that contribute to long-

term economic development. TFP is often estimated using growth accounting techniques, which decompose the sources of economic growth. The basic idea is to compare the growth in output to the growth in inputs and attribute the remaining growth to changes in TFP. An increase in TFP indicates that the economy, industry, or firm is becoming more efficient in producing output with the given inputs.

The CA region, comprising the former Soviet republics of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan, has been transitioning to a market economy and integrating with the global economic system. A vast amount of literature has analyzed the economic and TFP growth rates of the region using various periods and econometric models, but some research gaps and limitations remain. As outlined in the literature review section, many previous studies have focused on relatively short periods (e.g., 1990-2003, 1990-2017, 1991-2005, 1995-2005) and have employed relatively basic models, such as growth accounting, index methods, pOLS, FE, and RE, for estimating TFP.

The objective of the present study is to evaluate the economic and TFP growth rates of the CA countries over the period 1991-2019, using a more advanced econometric model, the generalized least squares (GLS). Furthermore, the study aims to compare the performance of the CA countries with that of the other major developing economies and initiators of economic projects discussed in the literature review section: China, Turkiye, and Russia. Specifically, this study aims to address the following research questions:

1) How do the economic growth and TFP growth rates of the CA countries compare to those of China, Turkiye, and Russia between 1991 and 2019?
2) Which econometric model – pOLS, FE, RE, or GLS – provides the most robust estimates of economic growth and TFP growth for the CA countries and the other developing countries in the sample?
3) How has the economic and productivity performance of the CA countries evolved over the longer 1991-2019 period compared to shorter time frames?

LITERATURE REVIEW

Tinbergen (1942), one of the founders of econometrics and the first Nobel Prize winner in 1969, was a pioneer in decomposing output growth into contributions of factor inputs and estimating the efficiency (or TFP) of factor inputs that contribute to sustained economic growth. He created the efficiency formula $t = y - 2/3n - 1/3k$, where y, n, and k stand for the average growth rates of production, labor, and capital, respectively, after researching the causes of economic growth in Germany, Great Britain, France, and the United States from 1870 to 1914. He concluded that efficiency explained about a quarter of economic growth, while growths of capital and labor explained the remaining three-quarters. Another influential economist and 1987 Nobel Prize winner, Robert Solow (1957), focused his research on the sources of economic growth of the United States from 1909 to 1949 and employed the TFP formula. $g_A = g_Q - 0.353g_K$, where the growth rates of TFP, output per person-hour, and capital per person-hour are represented by the variables g_A, g_Q, and g_K, respectively. Solow distinguished between two forms of output growth: the production function shifting due to innovation and the production function moving along due to capital deepening.

Inspired by Solow's seminal work (1957), economists have expanded the application of the growth accounting method and estimated TFP to various datasets at different levels of analysis, including firms, industries, and countries. These studies have utilized diverse data types such as cross-sectional, time-series, and panel data. Building on the foundations of neoclassical growth theory, a substantial body of research focused on measuring TFP as an exogenous variable, independent of other variables. However, Romer (1986) and Lucas (1988) argue that TFP is endogenous and depends on human capital.

Ahmed and Bhatti (2020) identified three methods after reviewing the literature on TFP measurement and determinants: growth accounting, index number, and growth regression. Griliches (1996, 1998) and Hulten (2001, 2010) provide an overview of the early history of TFP.

In a recent study, Escosura et al. (2021) noted that research on growth accounting consistently arrives at the same conclusion: long-term economic growth is sustained by TFP growth

rather than by factor accumulation alone. The authors provide a list of growth accounting estimations from various countries, including Japan (1953), the United Kingdom, France, Germany, Denmark, Hungary (1955), Canada (1958), India, China (1995, 2001, 2003, 2014), Turkiye (2008), Spain (2009, 2010), and others. These studies offer insights into the role of TFP in driving economic growth for individual countries as well as for broader samples of countries.

In addition, a number of later studies have looked into the outstanding economic successes of the East Asian Tigers – South Korea, Taiwan, Singapore, and Hong Kong – during their fast-paced period of industrialization and expansion from the 1960s to the 1990s. Instead of a notable increase in TFP, studies by scholars such as Collins and Bosworth (1996), Kim and Lau (1994), and Young (1995) have found that huge increases in labor and capital inputs primarily drove the East Asian Tigers' economic success.

In their study, Hamilton et al. (2019) estimated TFP growth for 74 developing countries between 1994 and 2014. Instead of using the traditional two-factor (labor and capital) model, the researchers employed a three-factor production function that incorporated natural resources as the third factor. The findings showed that, in comparison to the conventional method, the projected TFP growth showed less volatility over time in most nations when natural resources were taken into account. In addition, Kim and Lin (2017) discovered that economies in developing nations with abundant natural resources typically grow more slowly than those in nations with limited resources. Therefore, natural resources often end up being a curse.

Using the technique of synthetic control groups, Muchová and Šuláková (2022) examined the impact of joining the Eurozone with annual data from 1990 to 2019 and discovered that productivity, as measured by GDP over employment, might rise as a result of joining the Eurozone.

Several research studies have examined the economic growth of countries in the CA and CIS regions. A growth accounting experiment was conducted for 27 transition economies in Central and Eastern Europe and the CIS countries between 1990 and 2003 by Rapacki and Próchniak (2009). They discovered that the main factor influencing GDP growth in former socialist nations was shifts in TFP. Yormirzoev (2022) analyzed the long-term economic performance of five CA countries from 1990 to 2017, utilizing a two-factor production function. The average TFP growth rates in the study were 1.7% (Kazakhstan), 1.4% (Uzbekistan), 0.8% (Tajikistan and Turkmenistan), and -0.4% (Kyrgyzstan).

In another study by Iradian (2007), the growth accounting method was employed to estimate TFP growth for 11 CIS countries, including the 5 CA countries, from 1991 to 2005. The study outlined several elements that supported the swift development of the CIS nations, such as enhanced worker productivity, higher capacity utilization, the restoration of previously lost output, favorable commodity prices, and notable rises in remittances. The study also made predictions about future economic growth based on factors such as catch-up potential (relatively low real GDP and average per capita income), further capital accumulation, and relatively higher levels of education compared to other regions.

Izyumov and Vahaly (2008) calculated the rise of TFP for eleven CIS nations and discovered that during the 1995-2005 and 1998-2005 study periods, TFP dynamics were the main driver of GDP growth, with capital growth making a relatively small contribution. Yasmin et al. (2022) estimated TFP in Kazakhstani sectors using input-output data from 2012 to 2017, and they discovered that a number of industries, including manufacturing, food processing, petroleum, and construction, had increased productivity.

There have been three initiatives to promote economic cooperation among the CA countries. In 2009, Turkiye initiated the Organization of Turkic States (OTS). In 2013, the Chinese government launched the Belt and Road Initiative (BRI). In 2014, Russia introduced the Eurasian Economic Union (EAEU). In order to ascertain the prospects for future economic collaboration within the organization, Baghirov (2022) conducted an analysis of the current economic potential and the degree of economic cooperation within the organization. The author discovered that there are many untapped opportunities and that the OTS has a significant and comprehensive economic potential. The grandiose BRI intends to invest in more than 150 nations and international organizations and to promote trade and economic growth, particularly for the CA countries. The BRI

initiative and its expansion were studied by Iqbal et al. (2019) primarily from an Asian standpoint. After examining panel data from 25 countries between 2009 and 2016, the authors concluded that the BRI had a major effect on the expansion of Asian economies. The TFP values for 58 nations in the former Silk Road region were assessed by Ataev (2022), and it found that for the 10 post-Soviet countries, the TFP levels are strongly correlated. Yilmaz (2017) examines the EAEU integration process, which is driven by political and economic factors. The author found that the EAEU has the potential to be successful in the long term.

Our goal in this study is to assess the economic and TFP growth rates of five CA countries between 1991 and 2019 and compare them to the growth of three other developing nations – China, Turkiye, and Russia – that were the primary initiators of economic cooperation. Hence, we intend to address the following research gaps: 1) consider a longer period than many existing studies; 2) apply the most suitable of the 4 models (pOLS, FE, RE, GLS) to provide the robustness of the analysis; 3) conduct a more in-depth analysis of the relatively new research fields on the transitioning CA as well as some of the BRI countries; 4) estimate the capital share of output rather than using the recommended value of 1/3 by Hall and Jones (1999).

METHODOLOGY

We will follow Hamilton et al. (2019) and examine the 3-factor aggregate production function:

$$Y(K, L, N) = AK^{\alpha}L^{\beta}N^{\gamma} \qquad (1)$$

which relates output (Y) to the inputs of capital (K), labor (L), and natural resources (N).

The research methodology will follow a standard growth regression analysis framework, as outlined in the literature review of prior studies, such as the one by Ahmed and Bhatti (2020). To estimate the parameters α, β and γ, we will transform equation (1) into a logarithmic form:

$$\ln Y = \ln A + \alpha \ln K + \beta \ln L + \gamma \ln N \qquad (2)$$

To calculate TFP (A), we use the equation:

$$A = Y/(K^{\alpha}L^{\beta}N^{\gamma}) \qquad (3)$$

To estimate TFP growth, we begin with equation (1) and take the total differential, which we then divide by output (Y). This yields the estimation of TFP growth, represented by the following equation:

$$g_A = g_Y - \alpha g_K - \beta g_L - \gamma g_N \qquad (4)$$

where g_A, g_Y, g_K, g_L, g_N denote the growth of TFP, output, capital, labor, and natural resources, respectively. The coefficients α, β, and γ in equation (4) represent the shares of capital, labor, and natural resources in the production function.

The study used data from PWT10.0 (Feenstra et al., 2015) for variables such as real GDP, capital stock, and labor force. Moreover, the study used data from the World Bank (World Development Indicators, 2023) for the total natural resources.

$$Y(K, L, N) = AK^{\alpha}L^{\beta}N^{\gamma} \qquad (1)$$

A summary of the variables is provided below:

rgdpna (output): real GDP at constant 2017 national prices (in million 2017 U.S. dollars).

rnna (capital): capital stock at constant 2017 national prices (in a million 2017 U.S. dollars).

emp (labor): number of persons engaged (in millions).

rtfpna (TFP): total factor productivity at constant national prices, with 2017 set as the reference year.

totnatres: total natural resources rents, the income generated from the extraction and use of natural resources (coal rents, forest rents, mineral rents, natural gas rents, and oil rents expressed as a percentage of GDP) in a country.

All calculations and the generation of tables and figures were performed using Stata 14 software.

DISCUSSION

Based on Table 1, we note that capital, on average, is the largest of the four variables on a logarithmic scale. The standard deviations for all variables indicate a considerable spread of data points around the means.

Table 1. Descriptive statistics.

Variables	Obs.	Mean	St. dev.	Min	Max
ln(output)	232	12.52	2.18	9.04	16.84
ln(capital)	232	14.02	2.05	10.84	18.44
ln(labor)	232	2.57	1.94	0.44	6.68
ln(totres)	232	9.47	2.61	3.25	13.95

Source: Author's calculations.

Table 2 reveals strong positive correlations between the dependent and independent variables, as well as the absence of multicollinearity by VIF.

Table 2. Correlation matrix.

Variables	Total				Variance inflation factor (VIF)
	ln(output)	ln(capital)	ln(labor)	ln(totres)	
ln(output)	1				
ln(capital)	0.93	1			5.33
ln(labor)	0.94	0.89	1		4.71
ln(totres)	0.81	0.70	0.74	1	2.24
Note: VIF stands for low correlation (< 5), moderate correlation ($3 - 5$), and high correlation (> 10).					

Source: Author's calculations.

From Table 3, we observe that all three variables in all four models are statistically significant. However, we must select the most suitable model among them. We determine that the FE/RE model is appropriate since the Breusch and Pagan test is significant (H0: Pooled OLS is better, Ha: FE/RE is better, p=0.00). The FE model is suitable because the Hausman test is significant (H0: RE is better, Ha: FE is better, p=0.00). GLS model is optimal since the Wooldridge serial correlation test is significant (H0: no correlation, Ha: correlation, p=0.004) and the heteroscedasticity test is significant (H0: homoscedasticity, Ha: heteroscedasticity, p=0.00).

Table 3. Comparison of pOLS, RE, FE and GLS models.

Dep.Var.:ln(output)	pOLS	RE	FE	GLS
ln(capital)	0.4117*** (0.0326)	0.4139*** (0.0324)	0.3670*** (0.0313)	0.5402*** (0.0343)
ln(labor)	0.4945*** (0.0368)	1.0162*** (0.0979)	1.4841*** (0.1184)	0.4017*** (0.0391)
ln(totres)	0.1824*** (0.0176)	0.1687*** (0.0176)	0.1299*** (0.0176)	0.0432*** (0.0086)
R^2	0.9543	0.8633	0.8710	not applicable
p-value (F-test)	0.000	0.000	0.000	0.000
n	232	232	232	232
Note: $* p < 10\%$, $** p < 5\%$, $*** p < 1\%$. Standard errors are enclosed in brackets.				

Source: Author's calculations.

Once again, due to the presence of serial correlation and heteroscedasticity, the optimal model is the GLS. All three input factors are statistically significant at 1%. Consequently, when labor and natural resources are held constant, a 1% increase in capital results in a

0.5402% rise in output, according to the regression coefficient of 0.5402, which measures the output elasticity of capital. Hence, the formula for estimating TFP is as follows:

$$A = \frac{Y}{K^{\alpha}L^{\beta}N^{\gamma}} = \frac{Y}{K^{0.5402}L^{0.4017}N^{0.0432}}$$

Table 4 displays that from 1991 to 2019, China, Kazakhstan, Turkiye, and Turkmenistan experienced upward transitions, moving from lower income to upper middle income. Conversely, Kyrgyzstan, Russia, and Uzbekistan maintained their income levels. Only Tajikistan experienced a downward transition, moving from lower middle to low-income status. However, it is important to note that these transitions were not consistent or stable but rather volatile. The majority of CIS countries faced challenges and had to adapt during the 1990s and 2000s as they transitioned from centrally planned to market economies.

Table 4. Transition of income levels for different countries.

Countries	91	2	3	4	5	6	7	8	9	00	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	19
China																													
Kazakhstan																													
Kyrgyzstan																													
Russia																													
Tajikistan																													
Turkiye																													
Turkmenistan																													
Uzbekistan																													

Source: The World Bank. Note: high income, upper middle, lower middle, and low income countries.

Furthermore, as the accompanying Figure 1 illustrates, these nations' economies have suffered greatly from local and global crises, including the Arab Spring (2010-2012), the Syrian Civil War (2011-present), the Russian-Ukrainian War (2014-present), the Asian Financial Crisis (1997-1998), and the Global Financial Crisis (2008-2009):

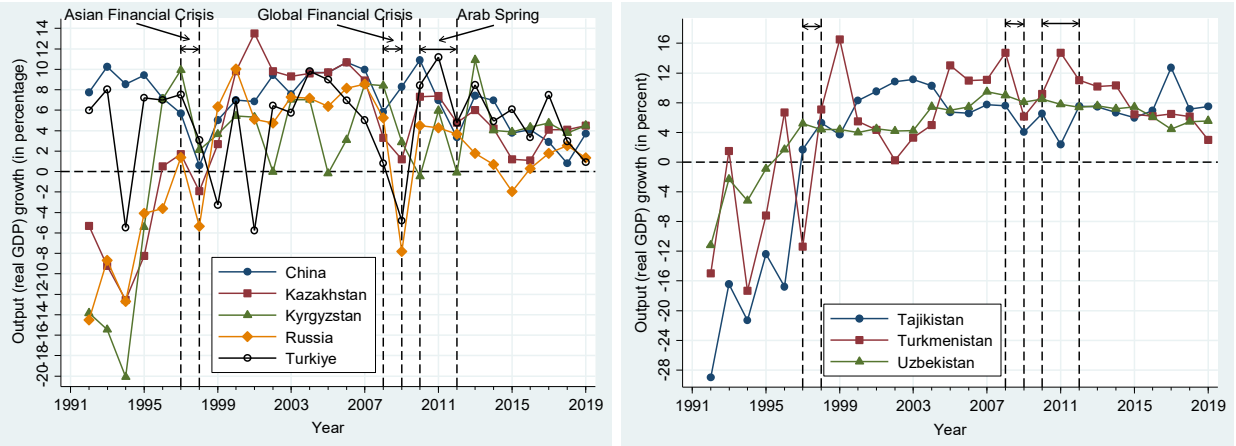

Figure 1. Output growth of sampled countries over 1992-2019.
Source: Author's calculations.

OECD (2018) observed that CA has registered impressive economic growth since 2000, with its aggregate GDP growing at an average rate of 7% during 2000-2016. Our findings also confirm this observation. The movement of countries across income levels and the patterns of economic growth are closely linked to the TFP of their economies. This correlation is evident in Figure 2

below, which demonstrates a positive relationship between the average outputs and average TFP levels of the sampled countries.

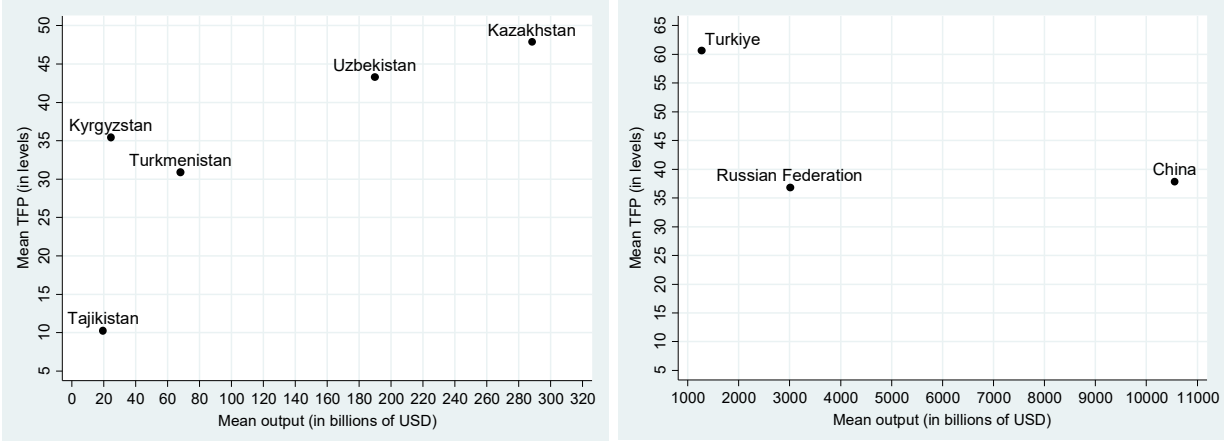

Figure 2. Mean TFP and mean output of sampled countries over 1991-2019.
Source: Author's calculations.

It is worth noting that Turkiye exhibits the highest TFP figure, while China and Russia have higher TFP figures compared to Kyrgyzstan, Turkmenistan, and Tajikistan. In general, a higher TFP figure indicates greater technological progress for a country. The catch-up effect, sometimes referred to as "convergence theory," explains the greater TFP figures seen in Uzbekistan and Kazakhstan when compared to China and Russia. This theory suggests that less developed countries have the potential to grow at a faster pace than more developed countries, allowing them to narrow the gap in terms of economic growth and development. Supporting this idea, the World Bank (2021) states that in 2019, middle-income countries achieved an average GDP growth of 3.6%, while low-income countries experienced a growth rate of 4.0%, compared to the 1.6% growth rate observed in high-income countries.

The catch-up effect can be explained by the ability of less developed countries to adopt and adapt existing technologies and knowledge from more advanced economies. As a result, they are able to attain faster rates of economic growth. The catch-up effect suggests that countries with lower initial income levels have the potential for rapid economic growth by investing in infrastructure, education, technology, and institutional development. As they enhance their productivity and adopt more efficient production methods, they can reduce the gap with more advanced economies.

However, it is important to note that the catch-up effect is not automatic or guaranteed for all countries. Factors such as governance, institutions, access to capital, human capital development, and technological capabilities play significant roles in determining the pace and success of catch-up growth. These factors may help explain the low TFP figure and slow economic growth observed in Tajikistan. Wu et al. (2018) noted that policy, technology, and resources are the three factors that enable developing countries to catch up with developed ones. The authors recommended that the developing countries focus on their own advantages and build the capacities necessary for successful catch-up.

Based on Figure 3, during the first period, 1992-1997, all CIS countries experienced negative TFP growth, while China and Turkiye exhibited positive TFP growth. This can be attributed to the collapse of the centrally planned economy of the USSR and the subsequent transition to independent market economies. The reforms implemented in the CIS countries began to bear fruit in the next period, 1998-2007, during which they surpassed even China and Turkiye in terms of TFP growth. Furthermore, in the subsequent period, 2008-2016, the CIS countries were able to maintain high rates of TFP growth. Once again, the catch-up effect played a key role in this development.

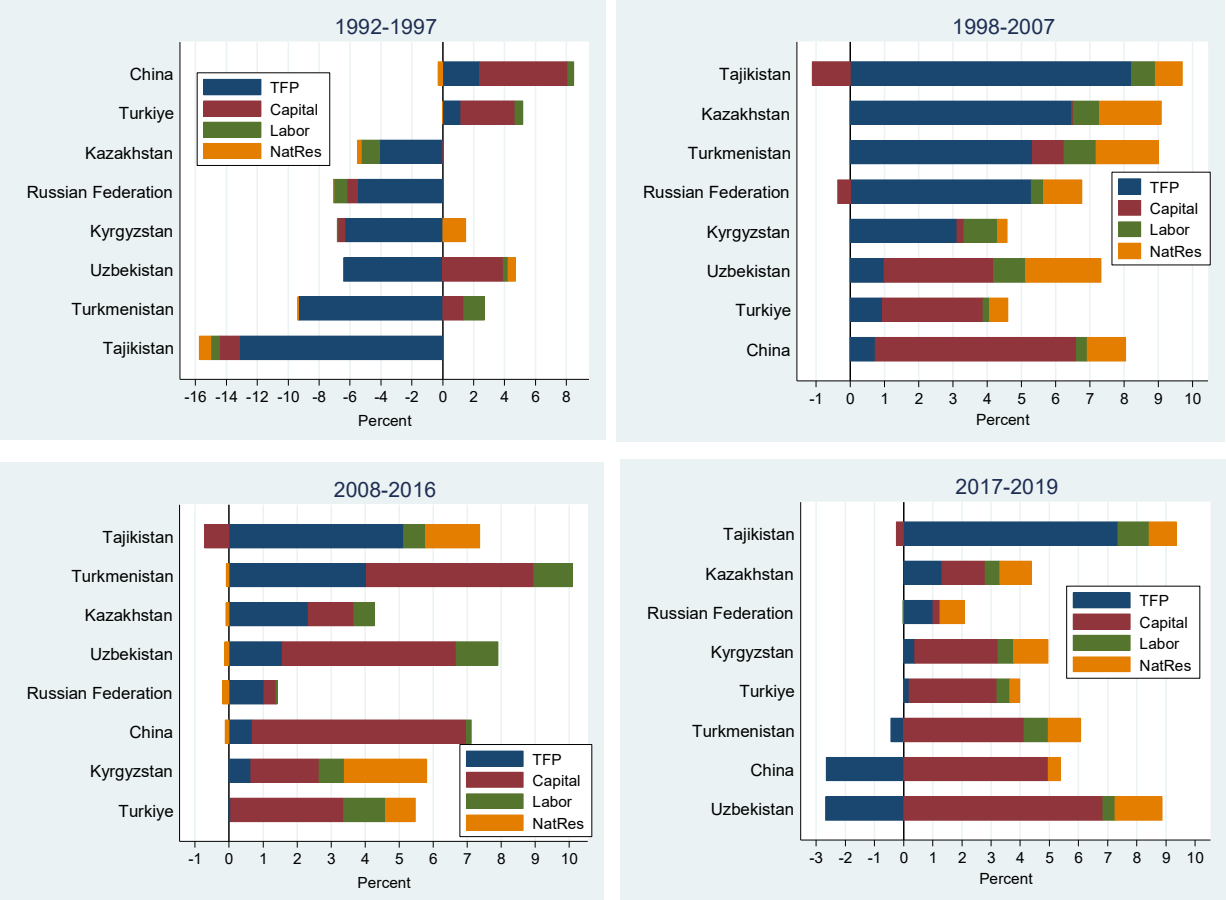

Figure 3. Growth decomposition in four periods.
Source: Author's calculations.

However, during the last period, 2017-2019, Turkmenistan, China, and Uzbekistan experienced negative TFP growth for various reasons. The four periods are influenced by global factors like the Asian and Global Financial Crises of 1997 and 2008, as well as local factors like the launch of a car-manufacturing joint venture in 1996 in Uzbekistan, the end of the civil war in Tajikistan in 1997, Kyrgyzstan's accession to the WTO in 1998, the extensive reforms (such as trade and currency liberalization, privatization and deregulation, banking sector reforms, education and healthcare reforms, among others) implemented by the new Uzbek government since 2016, and others. The political, economic, social, technological, environmental, and other initiatives during these periods account for the differences in TFP estimations among the CA countries. Some of the initiatives are discussed below.

China initiated economic reforms and restructuring measures to rebalance its economy. In 2010, the Chinese government unveiled its 12th Five-Year Plan, emphasizing the need to shift towards a more sustainable and consumption-driven growth model. These reforms aimed to reduce overreliance on investment and exports while promoting domestic consumption and innovation. China's demographic changes, including an aging population and a declining working-age population, became more pronounced during the 2010s. The working-age population started to decline in 2012, posing challenges to sustaining high levels of economic growth. This demographic shift has significant implications

for labor supply, productivity, and the overall economy. China experienced a rapid increase in debt levels, particularly in the corporate sector and local governments, following the Global Financial Crisis. By the mid-2010s, concerns over rising debt and potential financial risks started to emerge. In 2017, the Chinese government introduced measures to control debt and reduce financial vulnerabilities, which contributed to a moderation of economic growth. Additionally, China faces growing environmental challenges due to its rapid industrialization and urbanization. The government recognized the need to address these environmental issues and promote sustainable development. In 2014, China declared a "war on pollution" and introduced stricter environmental regulations, leading to slower growth in those areas.

Uzbekistan is a resource-rich country, with commodities such as natural gas, gold, and cotton playing a significant role in its economy. The decline in global commodity prices during the mid-2010s, including a drop in oil and gas prices, had a negative impact on the country's export revenues and overall economic growth. Midway through the 2010s, Uzbekistan started implementing a series of economic reforms and policy changes in an effort to enhance the business climate, draw in foreign capital, and encourage the growth of the private sector. However, the implementation of these reforms and the adjustment period can temporarily impact economic growth as the country transitions to a new economic model. For instance, in 2017, Uzbekistan implemented significant reforms to liberalize its foreign exchange market, moving from a heavily controlled exchange rate system to a more market-oriented approach. This transition involved adjusting exchange rates and removing currency restrictions. While these reforms aimed to improve the investment climate and attract foreign capital in the long run, they initially caused economic uncertainty and affected the pace of economic growth during the adjustment period. Additionally, Uzbekistan initiated efforts to promote private-sector development and reduce state involvement in the economy.

Regional and geopolitical dynamics significantly influence Uzbekistan's economic performance. Tensions or conflicts in neighboring countries, changes in trade policies, or geopolitical uncertainties can affect Uzbekistan's trade relations and overall economic growth. Uzbekistan shares borders with several countries, including Afghanistan and Kyrgyzstan. Regional conflicts and security concerns in these neighboring countries can have spillover effects on Uzbekistan's economy. For example, the conflict in Afghanistan and its impact on regional stability can affect trade routes, cross-border activities, and investor sentiment, creating economic uncertainties for Uzbekistan.

Turkmenistan heavily relies on natural gas exports as a major source of revenue. During the mid-2010s, global energy prices, including natural gas prices, declined significantly. This decline in commodity prices had a negative impact on Turkmenistan's export earnings and overall economic growth. Turkmenistan's economy has been relatively concentrated in the hydrocarbon sector, with limited diversification into other industries. The lack of economic diversification makes the country vulnerable to fluctuations in energy prices and exposes it to risks associated with overreliance on a single sector. Limited progress in diversification efforts during the mid-2010s contributed to the economic slowdown. Turkmenistan has a predominantly state-controlled economy, and private sector development has been limited. The government's tight control over the economy, including restrictions on foreign investments and business activities, can hinder private sector growth and entrepreneurship, which are essential for economic diversification and innovation. Additionally, Turkmenistan has faced governance challenges and issues related to economic mismanagement, including a lack of transparency and accountability. These factors can undermine investor confidence, hinder foreign direct investment (FDI), and negatively impact economic growth.

In turn, various factors can explain the high TFP levels and growth rates of Turkiye, Russia, and Kazakhstan. In the early 2000s, Turkiye implemented significant reforms aimed at achieving macroeconomic stability. These reforms included fiscal discipline, monetary policy reforms, and measures to reduce inflation and stabilize the currency. These policies helped to restore confidence in the economy, attract foreign investment, and create a more stable macroeconomic environment. Turkiye pursued closer integration with the global economy

during the 2000s. It actively sought to join the European Union (EU) and implemented policies to align its economic regulations and standards with EU requirements. This integration opened up new markets, increased trade flows, and attracted FDI, which stimulated economic growth and productivity. Turkiye made significant investments in infrastructure during the 2010s. Large-scale projects, such as the construction of highways, airports, railways, and energy facilities, aim to enhance connectivity, improve logistics, and support economic growth. The investments in infrastructure helped boost productivity, efficiency, and competitiveness in various sectors. Additionally, in the 2010s, Turkiye focused on technological advancements and innovation. The government implemented policies to promote research and development, foster collaboration between academia and industry, and support entrepreneurship. These efforts aimed to increase the adoption of advanced technologies, enhance productivity, and drive economic growth.

In the early 2000s, Russia implemented stabilization measures and economic reforms to address the economic crisis of the 1990s. These reforms included fiscal discipline, tax reforms, and efforts to improve the business environment. Stabilization policies helped restore macroeconomic stability and laid the foundation for subsequent economic growth. Russia is a major global producer and exporter of oil and gas. The energy sector played a crucial role in driving economic growth during the 2000s. Rising global oil prices and increased oil production contributed to increased government revenues, investment inflows, and improved productivity in the energy sector. Throughout the 2000s, Russia made significant investments in industrial facilities, energy infrastructure, and transportation networks. The objectives of these initiatives were to advance economic growth, increase logistical efficiency, and improve connectivity. Infrastructure modernization contributed to increased productivity and facilitated economic growth in various sectors. Russia focused on technological advancements and innovation during the 2010s. The government implemented policies to promote research and development, support high-tech industries, and foster innovation ecosystems. These efforts aimed to increase the adoption of advanced technologies, enhance productivity, and drive economic growth in sectors such as information technology, aerospace, and manufacturing. Additionally, in the 2010s, Russia worked to diversify its economy and lessen its reliance on gas and oil. This included promoting domestic industries, import substitution, and supporting sectors such as agriculture, manufacturing, and technology. Diversification efforts aim to stimulate productivity growth in non-resource sectors and reduce vulnerability to commodity price fluctuations. Russia made investments in training and education to raise the caliber of its labor force. Efforts were made to improve the education system, promote science, technology, engineering, and math (STEM) education, and increase the availability of skilled labor. Developing human capital contributes to higher productivity levels and supports economic growth.

Kazakhstan is rich in natural resources, particularly oil and gas. During the 2000s, the country experienced significant growth in its energy sector, attracting foreign investment and increasing oil production. This expansion in the energy sector contributed to economic growth and improved productivity, as well as attracting technological advancements and expertise. According to Yasmin et al. (2022), the economy of Kazakhstan is robust, with significant deposits of mining and petroleum serving as growth catalysts. Kazakhstan actively sought FDI in various sectors, including energy, mining, and manufacturing. The government implemented policies to attract investment, including tax incentives, streamlined regulations, and investment promotion activities. Foreign investment brought advanced technologies, managerial expertise, and capital, which contributed to productivity growth and economic development. Kazakhstan pursued a policy of economic diversification during the 2010s to reduce dependence on natural resources, particularly oil and gas. The government implemented measures to develop non-oil sectors, such as manufacturing, agriculture, and services. These diversification efforts aim to stimulate productivity growth in these sectors and reduce the vulnerability of the economy to commodity price fluctuations. Kazakhstan made investments in training and education to improve the quality of its labor force. This includes efforts to advance STEM education as well as educational reforms and programs for vocational training. Improving

human capital contributed to higher productivity levels and supported economic development.

Finally, Table 5 indicates that our calculations of TFP growth rates align closely with the estimates provided by several studies.

Table 5. Comparison of TFP growth estimates among four studies.

Countries	Author		Izyumov and Vahaly		Hamilton et al.		Yormirzoev	
	98-07	08-16	95-05	98-05	96-06	07-14	00-09	10-17
China	0.73%	0.68%			5.1%	4.5%		
Kazakhstan	6.46%	2.32%	6.0%	8.1%	5.1%	2.4%	5.8%	2.2%
Kyrgyzstan	3.11%	0.64%	4.0%	3.2%	2.7%	2.5%	2.2%	2.4%
Russia	5.28%	1.03%	4.1%	6.7%				
Tajikistan	8.21%	5.13%	4.9%	8.4%	5.2%	6.6%	6.9%	5.5%
Turkiye	0.95%	0.04%			1.5%	-0.9%		
Turkmenistan	5.34%	4.05%					4.9%	4.3%
Uzbekistan	0.99%	1.56%	2.6%	3.1%			3.7%	3.5%
Correlation			**0.83**	**0.95**	**0.56**	**0.76**	**0.85**	**0.87**

Source: The work of Author, Izyumov and Vahaly (2008), Hamilton et al. (2019) and Yormirzoev (2022).

The final row in Table 5 presents the correlations between our estimates and those provided by three other authors for the corresponding periods. The discrepancies in the estimation figures can be attributed to slight mismatches in the periods analyzed. For example, our estimate of Kazakhstan's TFP growth rate of 6.46% in the first period falls between the estimates of the first author (8.1%) and the last two authors (5.1% and 5.8%). Similarly, our estimate of 2.32% for the second period falls between the estimates of 2.4% and 2.2%.

CONCLUSION AND RECOMMENDATION

The study examines the economic growth and TFP growth of five CA countries and their three main trading partners. The findings suggest that despite global crises, these five CA countries have demonstrated consistent development and achieved notable TFP growth rates. It was observed that middle-income countries experienced the catch-up effect, whereby they were able to grow faster compared to higher-income countries. The analysis reveals a positive correlation between TFP growth and an upward shift in income levels. TFP growth was negative in all of CA and Russia from 1992 to 1997, except in China and Turkiye. However, in terms of TFP growth, the CA countries outpaced even China and Turkiye between 1998 and 2007, and they kept up the high rates from 2008 to 2016, thus demonstrating the catch-up effect. Our estimates of TFP growth rates are in good agreement with the figures given by several other studies.

The analytical findings of this study highlight several significant ramifications and connections that have not received much attention in the body of literature currently available on the CA nations. Although the economic and TFP growth rates in the area have been studied before, the current analysis, which makes use of the more sophisticated GLS model, provides new insights that were not attainable through the relatively short-term and basic modeling techniques of previous studies. The study's conclusions draw attention to subtleties and links that exist between the CA economies' growth performance and the more significant economic circumstances and changes they have gone through, which warrant further exploration and discussion.

The recommendations for policymakers are to motivate innovation by optimizing the national research and development system and further reforming the educational system to promote innovation. Additionally, fostering collaboration between research institutions, universities, and industries can promote knowledge transfer and accelerate the development and adoption of new technologies. Moreover, encouraging international trade and collaboration can open up new markets, facilitate knowledge exchange, and promote technology transfer. Policymakers can negotiate trade agreements, reduce trade barriers, and provide support for businesses to engage in international trade. Additionally,

fostering collaboration with other countries through research collaborations and joint innovation projects can accelerate technological advancements and promote productivity growth. Developing countries such as China, Turkiye and Russia tend to be at the forefront of technological advancements and innovation. Engaging in trade with these countries can facilitate the transfer of advanced technologies, technical know-how, and best practices. This can assist local businesses in modernizing their manufacturing procedures, using more effective techniques, and raising productivity levels.

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