Chapter 6

AGRICULTURE PRODUCTIVITY AND RESILIENCE TO EXTERNAL SHOCKS:

An empirical study of selected CAREC countries

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6.1 INTRODUCTION

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The agriculture productivity of most Central Asia Regional Economic Cooperation (CAREC) member countries has been challenged by climate change and other external economic and health shocks over the last two decades (ADB 2019; White et al. 2014; Young et al. 2019). The paper's main objective is to assess the CAREC countries' agriculture resilience to external shocks based on an evaluation of the changes in their agriculture productivity. Here we focus on two external shocks: the global financial crisis (GFC) of 2008 and the recent COVID-19 pandemic.

The study covers eight CAREC countries: Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Pakistan, Tajikistan, and Uzbekistan. China, Afghanistan, and Turkmenistan were not considered among the CAREC countries in the analysis. We omitted China because, unlike the other CAREC countries, it has a big economy; thus, comparing other countries with China might not result in insightful conclusions. Besides, China is overly studied compared with the other countries. On the other hand, Turkmenistan and Afghanistan were omitted because data is unavailable for these countries. Even if available, the data is not consistent for the 20 years under study.

Exploring the agricultural productivity and resilience to shocks of the selected CAREC countries is essential in three major respects. First, agriculture comprises a large share (on average 15 percent) of the national economy of the selected CAREC countries and is above the world average of 4.3 percent (WB, 2022). Second, the agriculture sectors in the selected CAREC countries have undergone a series of policy, institutional, and structural changes over the last three decades. Third, the percentage of the rural population is high (average above 50 percent), which is above the world average percentage (44 percent), and farm jobs remain the major employment opportunities in rural areas of the study countries (WB, 2021).

Since the 1990s, agricultural reforms in the CAREC countries largely consisted of the transition from the socialist legacy to a market-oriented system (especially for the former Soviet Union countries). As a result, the policy reforms in the region transformed the institutional structures of agriculture with new production patterns, including land reform, farm reorganisation, irrigation and water management, price reform, and the development of market institutions (ADB, 2019). The agriculture sector in the CAREC countries is currently diverse, with more high-value agriculture such as horticulture and oilseed production compared to the older agricultural policies that emphasized wheat and cotton production. Wheat is the main agricultural product in the region and an essential crop for regional food security (ADB, 2019). Smallholders dominate the livestock and horticulture production (Lerman and Sedik, 2009). Also, the current agricultural policies of the member countries focus more on modern supply and value chains (Morgan et al., 2019).

In general, the proportion of arable land to the total land area in the CAREC countries is low. Land reforms that redistributed agricultural land from large enterprises to smaller farms led to the emergence of smallholder farming. Accordingly, the average arable land size per person in the region has decreased from 2.13 ha in 1992 to 1.65 ha in 2016. The limited arable land resulted in smaller farmland area per person in the study countries, on average less than (2 ha/person), except for Kazakhstan (15 ha/person) (ADB, 2019; FAO, 2021; WB, 2021).

The GFC of 2007-2008 that originated in developed countries caused a considerable economic slowdown in many countries, including the CAREC member countries. The financial crisis was transferred to the CAREC countries through higher interest rates, sharp changes in commodity price, and reductions in investment, trade, migration, and remittances (Lin and Martin 2010). The GFC hit the economies of the CAREC member countries, which had mostly just recovered from the macroeconomic and institutional problems since the transition in the 1990s. Thus, the risks from the economic shocks reversed the region's gains and exposed it to economic and social vulnerabilities.

The economic slowdown caused by the GFC hit the global agricultural sector, which experienced considerable difficulties owing to the price swing and to low investment (Lin and Martin 2010). Kadlecikova et al. (2012) indicate that the slow economic growth during the GFC influenced the agriculture sector in most countries in Central and Eastern Europe and in Central Asia. The crisis led to a stagnation in demand for agricultural commodities, a decline in public agriculture expenditure, high input prices, fluctuating food prices that rose and then dropped, and reduced food security. The recent global pandemic crisis in 2020 had similar economic effects in many countries. The pandemic triggered income decline, expenditure changes, and financial difficulty in priority sectors, including agriculture. Uncertainty, lockdowns, and mobility restrictions resulted in a drop in demand and supply chains for agricultural commodities. Also, food prices were volatile and high in most CAREC countries (Djanibekov et al., 2021).

The chapter explores the dynamics in the agricultural TFP change for the selected CAREC countries. It then relates the TFP dynamics to the concept of agricultural resilience to shocks using the analytical framework developed by Zawalińska et al. (2021). It is valuable to understand how and why agricultural resilience varies across the selected CAREC countries to draw lessons for similar shocks in the future. This topic is especially relevant when the world is experiencing the COVID-19 pandemic coupled with the recent Russian-Ukrainian war that triggered a global economic and political crisis. Our analysis focuses on differences in the sources of TFP changes. This, in turn, is instrumental in deriving informed policy options that facilitate better-targeted actions. There is limited empirical evidence on agricultural resilience linked to agricultural TFP changes for the CAREC member countries. This study contributes to the growing knowledge about the relationship between agricultural resilience and TFP change in the agriculture sector.

The temporal dynamics in agricultural TFP changes are presented for 20 years from 2000 to 2020. The study results are aggregated and presented across four periods:

(i) before the GFC, between 2000 and 2007;
(ii) during the GFC, between 2008 and 2009 (referred to as external shock 1);
(iii) after the GFC but before the COVID-19 pandemic, between 2010 and 2019;
(iv) 2020, the year of the global COVID-19 pandemic (referred to as external shock 2).

Only 2020 was considered, owing to limited data for 2021.

The chapter is structured into five sections hereafter. Section two provides the conceptual and analytical framework for the study. Section three discusses the methods and data used. Section four presents and discusses the study results. Finally, section five offers conclusions and policy options for building agricultural resilience capacity to shocks.

6.2 CONCEPTUAL AND ANALYTICAL FRAMEWORK

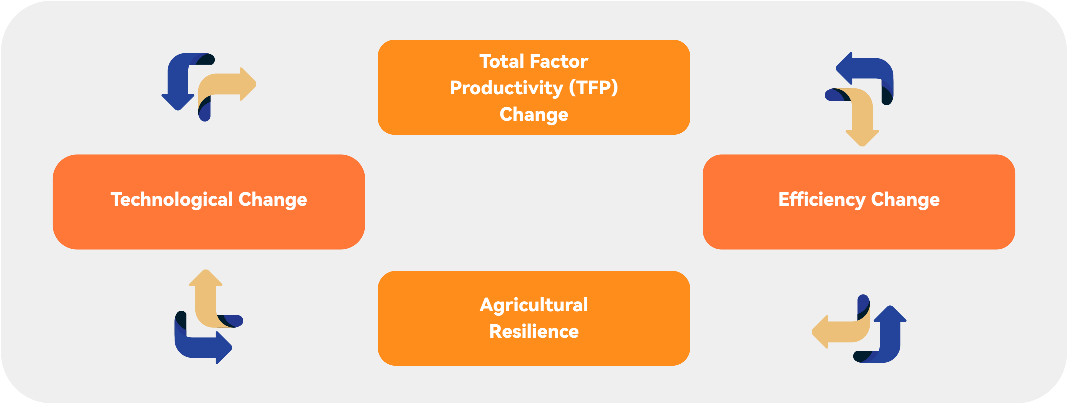
The chapter uses the concepts of agricultural total factor productivity (TFP) and agricultural resilience. In this section, the focus is on the link between the two concepts.

A country's agricultural TFP is an index that gauges the comprehensive agricultural productivity performance, which, in turn, provides insight into the overall efficiency of the agricultural sector production (Conradie et al. 2009). In this chapter, agricultural TFP measures aggregate agricultural output (here, agricultural value-add) per unit of aggregate input (here, labor, land, and capital). The literature on TFP allows the decomposition of the TFP dynamics into technological changes (TCs) and technical efficiency changes (ECs) to distinguish them from the drivers of TFP changes (Coelli and Rao 2005, Cechura et al. 2015, Zawalińska et al. 2021). TC, in our case, is the part of TFP that measures whether the agricultural sector in the studied country is generating technical innovation; it is expressed as the shift in the production frontier in a production function graph. The EC component in the TFP index measures production quality or efficiency. Graphically, it is the extent to which the (agricultural) sector productivity moves toward (or away from) the best practice production frontier; hence, EC can also be interpreted as a catching up or falling behind effect (Chen et al. 2008).

Resilience is the capacity of a system to absorb shock and retain its structure, function, and identity while going through changes (Holling 1973, Walker et al. 2004). Thus, a resilient agriculture system will continue to provide vital services such as food production even when challenged by severe shocks (Lin 2011). The FAO defines agricultural resilience as the ability of people, communities, or systems confronted by crises to withstand damage and recover rapidly.

It is possible to relate TFP changes to the resilience framework owing to the decomposition of the TFP performance into TCs and ECs (Zawalińska et al. 2021). There is a two-way relationship between agricultural system resilience and agricultural TFP change, as illustrated in Figure 6.1 On the one hand, the system's resilience improves the TFP reflected in an enhanced technological or efficiency change. On the other hand, a productive agricultural system positively affects agricultural resilience through externalities and feedback (Zawalińska et al. 2021).

Figure 6.1. Framework linking agricultural TFP with agricultural resilience: two-way relationship



Source: Adapted from Zawalińska et al. 2021

Zawalińska et al. (2021) differentiate between an agricultural system's 'potential resilience' and 'revealed resilience.' They explain that potential resilience is built before a shock period and is manifested in three capacities known as robustness, adaptability, and transformability of the sector (defined in Table 6.1). On the other hand, revealed resilience is measured by observed productivity changes after the shock.

The chapter explores the revealed resilience of the CAREC countries' agriculture sectors to the GFC in 2008 and the COVID-19 crisis in 2020 against their potential resilience capacities (Table 6.1). The current perspective of resilience could be classified as narrow. However, this is done to employ the chosen analytical framework. The authors are aware that there are many more approaches to resilience (some of them are reviewed by Xu and Kajikawa, 2018).

To address the objective of the current study, we calculate the CAREC countries' agriculture TFP changes and assess the TFP and the TC and EC composition changes (if it declines, grows, or stays the same) at times of shock. In doing so, we link and provide the relationships of the three agricultural potential resilience capacities (robustness, adaptability, and transformability) with the actually revealed resilience of the systems. Table 6.1 illustrates the link between the two concepts: productivity and resilience. It provides an easy-to-follow framework to relate agricultural TFP and composition changes to resilience to shock.

Table 6.1. Agricultural TFP and resilience capacities

Resilience capacities	Definition	Relation between the resilience capacity and changes in TFP and its composition
Robust agriculture	When the system has the ability to maintain the essential functions without significant changes to its internal components and processes, despite the presence of external shocks (Urruty et al. 2016).	- If TFP is non-declining (stays the same or grows). - The TC and EC components of the TFP are maintained in similar proportions as before the shock.
Adaptable agriculture	When the agriculture system is able to adapt internal elements and processes in response to changing external circumstances and thus continue to develop along the previous trajectory while maintaining all vital functions (Folke et al. 2010).	- If TFP is non-declining and the TC and EC composition shows substantial changes—such as, TFP that was driven by TC becomes driven by EC—thus, the system adapts its TFP.
Transformable agriculture	When the existing system is unsustainable or dysfunctional, then the system needs to develop or incorporate new elements and processes that alter the operational logic to maintain essential functions (Walker et al. 2004).	- If TFP is declining and the components of the TFP have no substantial contributions to the TFP growth, the system is not robust, so the system needs to adapt. If the TFP is declining even when the TFP adapts and the composition changes, a more extensive adaptation is needed, leading to a transformation of the system.

Source: Adapted from Zawalińska et al. 2021

If we create a range for resilience capacities, robustness is the capacity illustrating the highest resilience, and adaptability follows after. If neither robustness nor adaptability fits the classification, then the system is not resilient and needs transformation.

6.3 METHODS AND DATA

6.3.1 Method

This study uses the Malmquist Productivity Index (MPI) method that uses the data envelopment analysis (DEA) frontier to estimate the agriculture TFP changes for the selected countries over some periods, as described in Färre et al. 1994. The detail of the DEA frontier technique for our Malmquist Index (MI) formula construction is presented in Appendix 6.1.

The MPI estimates the TFP change between two data points. In our case, these data points mean two time periods of a particular CAREC country; hence, the index measures the productivity change over time. The index is calculated by taking the ratio of the distance of each data point relative to a common technology (Coelli and Rao 2005). While estimating the Malmquist TFP index via the DEA method, we assume that each period's best practice production frontier will be constructed as a reference production technology. These measures capture productivity performance relative to the best practice in the sample. The best practice in the sample represents a 'world frontier' (Färe et al. 1994). Our selected eight CAREC countries define the world in the current study. Therefore it is worth mentioning that the estimated TFP values and, hence, resilience discourses of these eight CAREC countries are relative to their sample.

The MPI is further decomposed into TC and EC. When the MPI or any of its decomposition is less than one (1), it means a deterioration in performance. In contrast, an index greater than one (1) signifies performance improvement, and an index equal to one signifies stagnation. Even if other productivity estimation methods that enable similar decomposition exist, they require the specification of a functional form for the technology change. In contrast, we use the MPI approach, which uses DEA, for our study with multiple inputs and outputs, which is nonparametric (Färe et al. 1994).

The MPI is based on the concept of the production function of the maximum possible output production, with respect to a set of inputs (here, capital and labor). The production set assumes for each time *t*, an *Nx1* input vector and an *Mx1* output vector. The closed production set (1) gives the possibilities for a multi-input *(x)* and multi-output production *(y)* process. Following Färe et al. (1994), we assume the standard properties of production sets such as convexity and disposability. *P (x)* is the production technology where the set of all agriculture output vectors *(y)* can be produced by employing the input vectors *(x)*, at time *t*, as illustrated in the expression (2) below. Assuming that for each time t, the $x^{t-s} \in R_{+}^{N}$ are transformed into $y^{t-st-s} \in R_{+}^{M}$, the production possibility set is given in equation (3) where S_{t}^{seq} denotes sequential production technology. Output sets which are defined through S_{t}^{seq} are expressed as in equation (4). Using the DEA approach, the distance function (d^{t}) is as in equation (5) with λ as the smallest factor, with which output vector y^{t} is deflated in the order it can be produced with the given input x^{t} vector with the technology available at time *t*. Based on Färe et al. (1994), we consider the distance function equation (6) as the output-oriented Malmquist TFP index formula. The MI formula in (6) can, however, be decomposed into two components TC and EC as in (7), assuming constant return to scale (CRS).

It is possible to relate TFP changes to the resilience framework owing to the decomposition of the TFP performance into TCs and ECs (Zawalińska et al. 2021). There is a two-way relationship between agricultural system resilience and agricultural TFP change, as illustrated in Figure 6.1. On the one hand, the system's resilience improves the TFP reflected in an enhanced technological or efficiency change. On the other hand, a productive agricultural system positively affects agricultural resilience through externalities and feedback (Zawalińska et al. 2021).

$$S^t=\{(x^t,y^t):x^t \text{ can produce } y^t\} \quad (1)$$

$$P(x)=\{y^t:(x^t,y^t)\in S^t\} \quad (2)$$

$$S_t^{seq}=\{(x^{t-s},y^{t-s}):x^{t-s} \text{ can produce } y^{t-s}\} \text{ with } s=0,1,2,\ldots,t-1 \quad (3)$$

$$P_t^{seq}(x)=\{y^{t-s}:(x^{t-s},y^{t-s})\in S_t^{seq}\} \quad (4)$$

$$d^t(x^t,y^t)=\inf\{\lambda:(\frac{y^t}{\lambda})\in P_t^{seq}(x)\} \quad (5)$$

$$m=\{x^t,y^t,\ x^{t+1},y^{t+1}\}=\left[\frac{d^t(x^{t+1},y^{t+1})}{d^t(x^t,y^t)}\times\frac{d^{t+1}(x^{t+1},y^{t+1})}{d^{t+1}(x^t,y^t)}\right]^{1/2} \quad (6)$$

$$m(x^t,y^t,\ x^{t+1},y^{t+1})=(TC)\times(EC) \quad (7)$$

$$\text{Where } TC=\left[\frac{d^t(x^{t+1},y^{t+1})}{d^{t+1}(x^{t+1},y^{t+1})}\times\frac{d^t(x^t,y^t)}{d^{t+1}(x^t,y^t)}\right]^{1/2} \text{ and } EC=\frac{d^{t+1}(x^{t+1},y^{t+1})}{d^t(x^t,y^t)}$$

We constructed the MPI for the eight countries' agriculture sector directly from our input and output data using the DEA technique on STATA. The application in STATA enables users to measure productivity changes over time. We used the 'dea' command to estimate the MPI using DEA in STATA 14. The syntax of the command is as follows: dea ivars = ovars, rts(vrs) ort(i), where input variables (ivars) were capital (net capital stock) and labor (number of persons employed in agriculture), while output variable (ovar) was the gross agricultural outcome in USD constant price. Land was excluded from the estimations because the land data for 2020 was not available in our dataset, and in general land use data does not alter very much as it is a relatively fixed asset.

After we estimated the eight CAREC countries' agriculture TFP performance for the 20 years, we aggregated the TFP, TC, and EC result in an average of four periods. We then employed the resilience analytical framework developed by Zawalińska et al. (2021) to derive and interpret the implications of the TFP estimates for the revealed resilience during shocks, referring to Tables 6.1 and 6.2. As stated above, the TFP index changes and decomposition (TC and EC) are interpreted as increasing if an index value is above one. If TFP changes and its decomposition (TC and EC) index are equal to one, it means the performance is stagnant, and below one means a decline in performance.

Table 6.2. Categories of agriculture sector TFP performance and revealed resilience to shocks

	No composition change in TFP	**Composition changes in TFP**
TFP non-declining	Robust agriculture.	Adaptable agriculture.
TFP declining	Not robust enough. Need to adapt its TFP.	Not adapted enough. Need to transform.

Source: Adapted from Zawalińska et al. 2021

6.3.2 Data

The study utilises a mix of datasets from 2000 to 2020 drawn from the databases of the FAO and World Bank, and national statistics of the selected CAREC countries to estimate the TFP indices and composition. Table 6.3 provides more detailed information on the variables used in the TFP analyses.

The descriptive statistics, including the sample means, standard deviations, and annual growth rates of the input and output variables for 2000-2020 by country, are presented in Appendix Table A1. We provide the summary statistics for the per capita input ratios (land/labor and capital/labor) in Appendix Table A2. We provide details on the intensity of input use across the eight CAREC countries in the Appendix (Figures A3, A4, and A5). Our datasets indicate that among the eight CAREC countries, Pakistan has the highest number of agricultural laborers in its economy, followed by Uzbekistan. The datasets also show that Pakistan and Kazakhstan are the leading countries in arable land endowments, while Georgia and Tajikistan are the countries with the smallest land endowments. Kazakhstan has the highest average land per capita. Pakistan, Uzbekistan, and Kazakhstan are the top three leading countries in their average total capital investments in agriculture. Nevertheless, Mongolia has the highest per capita capital investment.

Table 6.3. Variables, descriptions, and sources of data used to calculate agricultural TFP

Variable name	Type	Description	Source(s)
Agricultural value-added	Output	The net output of a sector after adding up all outputs and subtracting intermediate inputs. In the current work, we use this estimate measured in millions of USD.	FAO (2021).
Agricultural labor	Input	1,000 agricultural labor persons.	World Bank (2021), national statistics websites of Azerbaijan, Georgia, and Kyrgyzstan.
Land	Input	rable land in 1,000 ha.	FAO (2021).
Capital (net capital stock in agriculture, forestry, and fishery)	Input	The net capital stock is the sum of the written-down values of all the fixed assets still in use. It is described as the net capital stock in agriculture, forestry, and fishery in constant millions of USD.	FAO (2021).

6.4 RESULTS AND DISCUSSION

6.4.1 Agriculture TFP performance for 2000-2020

6.4.1.1 Average changes in TFP and composition

The estimates for the annual average and cumulative TFP index changes and compositions for the eight CAREC countries for 2000-2020 are presented in Table 6.4 and visualised in Figure 6.2. The average annual TFP performance and composition estimates are aggregated into four periods, including the two shock periods (in red font) in Table 6.4. The countries' agriculture TFP change estimates and the source of the changes is explained as follows:

Azerbaijan's average TFP change (TFPCH) over the 20 years was positive and mainly sourced from TC. Azerbaijan was also doing well in catching up with the best practice production frontier, as the respective efficiency index (EC) was non-declining and increased after the third period. However, Azerbaijan's agriculture TFP declined during both shocks, triggered mainly by declines in the TC component. The finding is consistent with a study showing that Azerbaijan's agriculture investment declined during the GFC, as the government diverted to other sectors and foreign investment declined (Mikayilov 2009). Again in 2020, Azerbaijan experienced compounded crises in addition to the pandemic, including the oil price crisis and failed reforms that affected the agriculture sector investment (Ibadoghlu 2020). Specifically, Ibadoghlu indicates that agriculture was not included in the list of economic sectors supported by the government crisis stimuli, and farmers were not entitled to benefit while agriculture production and exports declined.

Georgia's cumulative average TFP change in the observed 20 years was small, next to that of Pakistan. The TFP change was almost perfectly correlated with the index's TC component, which was, on average, below 1. This implies that the small Georgian agriculture productivity changes came from its technological innovations until the COVID-19 pandemic. The Georgian agriculture TFP grew very slightly during the first shock period but declined during the pandemic owing to declines in TC and was below 1. The efficiency component of the TFP on average declined during the period between the GFC and the pandemic shocks, but increased during the pandemic. Paresashvili et al. (2021) characterize the agriculture sector in Georgia as traditional with an absence of modern technological opportunity and an underdeveloped supply chain. A small share of the public budget goes towards funding agriculture. Also, the sector suffers from ambiguous regulatory laws, low compatibility with international market standards, and an underdeveloped insurance system in agriculture (ibid). Papava and Vakhtang (2020) also indicate that the Georgian government's investment in the agriculture sector was not a priority during the pandemic.

Kazakhstan's agriculture TFP grew until the GFC, mainly driven by EC. The agriculture TFP slightly declined during the first shock but was above 1, and it increased consistently after the shock. The TFP decline during the first shock was derived mainly from the decline in technical efficiency (EC) while TC increased. Kazakhstan's TFP increased before and during the second external shock, primarily sourced from the increase in the EC component in the TFP when the TC component declined but was 1. Kazakhstan has devoted substantial public funds to the agricultural sector since early 2000, including during the GFC period. The sector budget is dominated by price support, financing, and innovations (Petrick and Pomfret 2016). Agriculture has been a critical factor in economic diversification, although it accounted for only a small share of GDP. The sector remained a priority development area during the 2020 pandemic. The country experienced steady per capita agricultural production growth in the second decade of our observation.

Kyrgyz Republic's average agricultural TFP increased during the GFC and declined to below 1 in the decade before the pandemic. The TFP change was sourced mainly from TC; hence, all trends in the TC were accordingly reflected in its TFPCH. The country had the lowest cumulative EC. During the second shock, the EC component increased and the TFP was above 1, while the TC further declined below 1. Neither of the external shocks disturbed the country's agricultural productivity performance. After independence, the Kyrgyz Republic rapidly liberalized its economy, including the agriculture sector (Ruziev and Majidov 2013). Nevertheless, Undeland (2010) argues that the fact that the country was not fully integrated into the global economy saved it from getting hurt during the GFC. During the GFC, the government focused on controlling food prices and increasing domestic production. Agriculture is the largest economic sector in the Kyrgyz Republic , and it acts as a shock absorber for the entire economy during times of crisis. The sector relies on labor intensive production (Ruziev and Majidov 2013).

Mongolia's agriculture TFP was doing well during the 20 years, mostly sourced from technical EC. The agriculture sector performed well in terms of efficiency, unlike its TC, which most of the time declined. Mongolia had the highest cumulative EC over the 20 years. Although agriculture TFP was handled well during the GFC, the TFP performance declined below 1 during the pandemic shock owing to significant declines in TC. Although agriculture is an important component of the Mongolian economy, particularly for its self-sufficient food targets, the share of agriculture in the economy declined after 2005 (Khongorzul 2007). The animal subsector and meat exports are an important component (60 percent) of Mongolian agriculture. The sector suffers from a lack of modern technology and climate change challenges (Takahashi et al. 2019).

Pakistan's agricultural TFP index was stagnant and lacked innovation for a long time.

The average TC component index of the TFP was below 1 over the 20 years. The TFP was determined mainly by its non-increasing EC component. Thus, during the 20 years, the production frontier of Pakistan's agriculture sector did not shift upwards. However, the average TFP increased after 2010, and has since been catching up with its best practice frontier by increasing technical efficiency. However, Pakistan has an overall negative cumulative TFP change. During the pandemic shock, the TFP increased above 1, driven by positive changes in the EC. Pakistan shares the challenges regarding low agriculture productivity faced now by many developing and highly populated countries, although the sector is the largest employer in the economy. With high population pressure, growth in agriculture came from labor inputs and not from TFP components. Political and macroeconomic instability and an unstable policy environment (in terms of rules, taxes, and tariffs) contributed to the limited agriculture productivity in Pakistan (Ahmed 2020).

Tajikistan's average TFPCH over the 20 years was positive. The TFP increase until 2010 was sourced mainly by the TC component and then, after that, the EC was a contributor to the TFPCH. Tajikistan moved closer toward the best production frontier by increasing its TC during the GFC shock. However, the country did not generate innovation during the COVID-19 shock (TC value is less than 1). The TFP improvement during the COVID-19 pandemic shock was sourced from EC. Tajikistan has the highest cumulative TFP and TC performance in the 20 years. It benefited from investment from the post-civil war international organisations in the agriculture sector after 1998 (Ruziev and Majidov 2013). The share of agriculture in the economy has increased gradually, and smallholder farms dominate the sector, with a poor permanent link to the upstream market and limited access to finance and technology (Skakova and Livny 2020).

Uzbekistan's TFPCH increased over the 20 years and was triggered only by the index's technical efficiency (EC) component. The TFPCH and EC were perfectly correlated throughout the years, including during the shock periods. The country's agricultural sector was moving towards its potential productivity frontier (catching up) as the EC was continuously increasing, including during the shock periods. On the other hand, the agricultural sector did not generate innovations, as the TC component of the TFPCH was constantly equal to one (1) — therefore it remained stagnant during the 20 years studied. Uzbekistan slowly and cautiously reformed and integrated its agriculture into the global economy after the transition (Ruziev and Majidov 2013). Uzbekistan acted swiftly to protect the agriculture sector from the pandemic crisis through investments from the anti-crisis fund and several policy measures to increase resource use efficiency. The most important policy document to counter the negative impacts of COVID-19 on the agriculture and food sector during 2020 was Presidential Decree No. 4700 (1 May 2020), titled 'Providing food security during the coronavirus pandemic, rational use of available resources, and government support for agriculture.'

Table 6.4. Annual average and cumulative TFP changes and decomposition for the CAREC countries (2000-2020)

Total Factor Productivity Change (TFPCH)						
	2000-2007 average	2008-2009 average	2010-2019 average	2020	2000-2020 average	2000-2020 cumulative
Azerbaijan	0.974	0.965	1.030	0.954	1.023	6.882
Georgia	0.968	1.022	1.035	1.003	1.010	0.607
Kazakhstan	1.067	1.033	1.061	1.120	1.064	12.852
Kyrgyzstan	1.041	1.084	0.997	1.012	1.022	6.786
Mongolia	1.037	1.033	1.096	0.977	1.063	10.175
Pakistan	0.995	0.997	1.000	1.061	1.001	-0.841
Tajikistan	1.080	1.112	1.051	1.098	1.070	16.759
Uzbekistan	1.037	1.041	1.022	1.139	1.035	6.730

Technical Efficiency Change (EC)

	2000-2007 average	2008-2009 average	2010-2019 average	2020	2000-2020 average	2000-2020 cumulative
Azerbaijan	0.951	0.950	1.013	0.825	0.997	2.1474
Georgia	0.952	1.000	1.020	0.864	0.988	-1.166
Kazakhstan	0.989	1.026	1.041	1	1.024	4.5627
Kyrgyzstan	1.030	1.080	0.982	0.871	1.003	4.8791
Mongolia	0.972	0.956	1.056	0.839	1.006	-2.069
Pakistan	0.935	0.923	0.979	0.969	0.958	-10.49
Tajikistan	1.050	1.109	1.036	0.946	1.043	12.221
Uzbekistan	1	1	1	1	1	0

Technological Change (TC)

	2000-2007 average	2008-2009 average	2010-2019 average	2020	2000-2020 average	2000-2020 cumulative
Azerbaijan	1.022	1.017	1.017	1.157	1.028	4.624
Georgia	1.018	1.026	1.017	1.162	1.024	2.005
Kazakhstan	1.078	1.007	1.021	1.12	1.040	8.385
Kyrgyzstan	1.010	1.003	1.017	1.162	1.020	1.975
Mongolia	1.064	1.081	1.038	1.165	1.058	12.274
Pakistan	1.064	1.081	1.022	1.095	1.046	10.389
Tajikistan	1.029	1.003	1.017	1.162	1.027	4.404
Uzbekistan	1.037	1.041	1.022	1.139	1.035	6.730

Figure 6.2 shows the dynamics in the average TFP performances and TC and EC compositions in the eight countries.

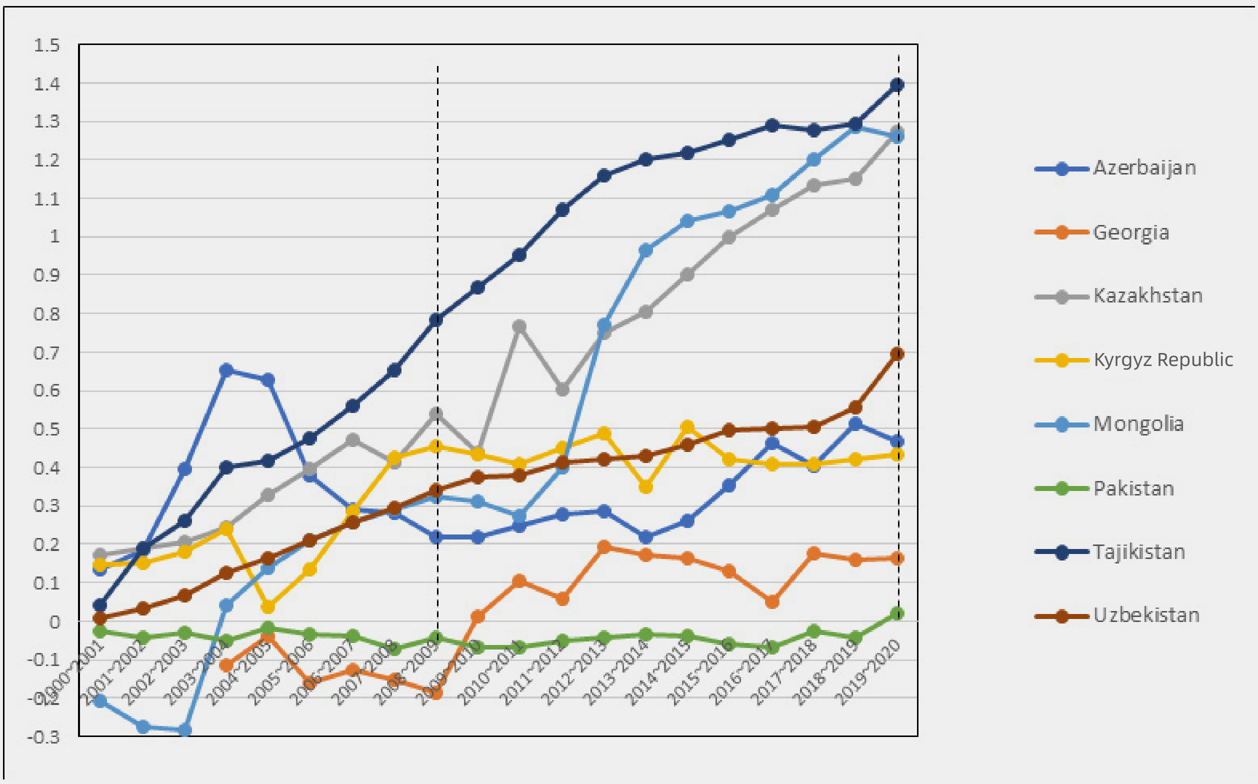
Figure 6.2. Average TFP, TC, and EC changes for selected CAREC countries (2000-2020)

Source: Author's construction

6.4.1.2 Cumulative TFP changes

We observed diverse cumulative TFP performance across the eight studied countries (see Figure 6.3).

Figure 6.3. Average TFP, TC, and EC changes for selected CAREC countries (2000-2020)



Source: Authors' construction

Tajikistan, followed by Kazakhstan and Mongolia, had the highest cumulative TFP performance (above ten) in the 20 years. Azerbaijan, Kyrgyz Republic, and Uzbekistan had similar cumulative TFP changes (almost seven). Georgia had the least (sluggish but positive) cumulative TFP change in the 20 years, while Pakistan had a negative cumulative TFP change. The disparities in the CAREC countries' cumulative TFPs widened over time.

Labor intensity increase coupled with farm reforms explain Tajikistan's productivity improvements. The upward movements in the cumulative agriculture TFP for Kazakhstan and Mongolia (until the pandemic) can be explained by the land and capital intensity in their sectors that increased in the second half of the 20 years (see Figures A3 and A4 in Appendix 6.2). Despite this, the agriculture sector contributes a relatively small portion to the economies of Kazakhstan and Azerbaijan; Kazakhstan's agriculture TFP remained steady and increased, while Azerbaijan's agriculture productivity remained sluggish in the last decade.

6.4.2 Agriculture TFP performance linked to resilience to shocks

We categorise the eight CAREC countries based on estimates of their agricultural TFP performance and changes in their TFP composition across the four phases (see Table 6.5). The combination of 'non-declining TFP' and 'no composition change in TFP' represents the countries and phases with a robust agricultural system. The combination of 'non-declining TFP' and 'composition change in TFP' represents phases and countries with an adaptable agricultural system. The combination of 'declining TFP' and 'no composition change in TFP' represents the countries and phases with insufficiently robust systems that must adapt to the emerging circumstances. Furthermore, the combination of 'declining TFP' and 'composition change in TFP' represents phases and countries that are not adaptable enough and hence need to transform their agricultural systems to become resilient.

Table 6.5. The interfaces between agriculture resilience to shocks and TFP changes during shock periods in the study of CAREC countries

Phases	Productivity performance	Countries with no composition change in TFP	Countries with composition changes in TFP
Phase 1	non-declining TFP	Kazakhstan, Kyrgyz Republic, Tajikistan, Uzbekistan	Mongolia
	declining TFP	Azerbaijan, Pakistan	
Phase 2 (shock 1)	non-declining TFP	Georgia, Kyrgyz Republic, Mongolia, Tajikistan, Uzbekistan	Kazakhstan
	declining TFP	Azerbaijan, Pakistan	
Phase 3	non-declining TFP	Kazakhstan, Pakistan, Tajikistan, Uzbekistan	Azerbaijan, Georgia, Mongolia,
	declining TFP		Kyrgyz Republic
Phase 4 (shock 2)	non-declining TFP	Pakistan, Uzbekistan	Georgia , Kazakhstan, Kyrgyz Republic, Tajikistan
	declining TFP	Azerbaijan	Mongolia

Source: Authors' construction

The assessment of countries' agriculture resilience for the shock periods through their TFP changes and TC and EC composition is further illustrated in Table 6.6.

During the first shock (GFC), the TFP change for all countries was above one (1), did not decline, and had a robust agriculture system, except for Kazakhstan, Azerbaijan, and Pakistan. With this, they demonstrated their agriculture system's ability to maintain the essential functions without significant changes to the sector's internal components, functions, and processes, despite external disturbances. On the other hand, Kazakhstan altered its TC to maintain non-declining TFP (above 1). By doing so, it illustrated the agricultural system's ability to adapt internal elements and processes in response to changing external circumstances and continue to develop along the previous trajectory while maintaining all vital functions. Azerbaijan's agricultural productivity declined below 1, showing it was not robust enough to resist the external shock; it needed to adapt its TFP to be resilient. Pakistan's agricultural TFP was stagnant and below one during the first shock period; it needed to change its TFP composition.

Table 6.6. Assessment of revealed resilience to shocks related to TFP and composition changes

	Azerbaijan	**Georgia**	**Kazakhstan**	**Kyrgyzstan**	**Mongolia**	**Pakistan**	**Tajikistan**	**Uzbekistan**
2008-2009 GFC	TFP<1 TC<EC need to adapt or transform	TFP>1 TC<EC robust	TFP>1 TC>EC adaptable	TFP>1 TC>EC robust	TFP>1 TC<EC robust	TFP<1 TC<EC need to adapt or transform	TFP>1 TC>EC robust	TFP>1 TC<EC robust
2020 COVID-19	TFP<1 TC<EC need to adapt or transform	TFP>1 TC<EC adaptable	TFP>1 TC<EC adaptable	TFP>1 TC<EC adaptable	TFP<1 TC<EC need to transform	TFP>1 TC<EC robust	TFP>1 TC<EC adaptable	TFP>1 TC<EC robust

Source: Author's elaboration

During the second shock (COVID-19 crisis), all countries except Azerbaijan and Mongolia revealed resilience by staying robust or adaptive with their TFP composition. Georgia's TFP declined but was above one by adapting its EC. All countries altered their EC component of the TFP composition to maintain non-declining TFP. Thus, changes in their technical efficiency in production were the source of all the TFP increases during the pandemic. The EC may have come from the efficient use of agricultural resources and anti-crisis interventions during the pandemic crisis. Except for Kazakhstan and Uzbekistan, which had a TFP index of one, the TC component of TFP declined and was less than one for all countries. Azerbaijan and Mongolia faced a declining TFP of less than one. At the same time, Mongolia's agricultural system was not adaptable enough and thus required transformation. Azerbaijan's agriculture sector needed to adapt its TFP in both shocks, while Kazakhstan's was adaptable, and Uzbekistan's agriculture sector was robustly resilient to both shocks.

Adaptation in the TFP change through innovations (TC) (as in Kazakhstan during the GFC) and increased EC regulations for efficient use of resources (as in Georgia, Mongolia, and Uzbekistan) can be a reason for non-declining TFP and resilience to shocks. More so, policies that increased technical ECs (for using labor and land efficiently) announced by governments during shock periods, as in the case of Uzbekistan during the pandemic, may have paid off to increase the TFP and resilience of the agriculture system.

6.5 CONCLUSION AND POLICY OPTIONS

This chapter empirically assessed eight CAREC agriculture systems and revealed resilience to shocks based on their TFP performances. The paper used the MPI method initiated by Färe et al. (1994) to estimate the agriculture TFP and TC and EC composition changes. The decomposed TFP estimation, in turn, enabled the assessment of the revealed resilience to shocks manifested in the TFP changes and its components, as initiated by Zawalińska et al. (2021).

Zawalińska et al. linked TFP with resilience during crisis times. For such inference, they found supportive evidence from the Polish farming sector by comparing different directions of farming with each other. We linked productivity with resilience by following Zawalińska et al. (2021). However, unlike Zawalińska and colleagues, we compared the countries' aggregated agriculture sectors. By narrating the two concepts — TFP changes and resilience to shocks — the paper produces evidence-based policy options to enhance sectoral resilience. Moreover, we contribute to the pool of knowledge with additional insights regarding the varied geography of CAREC countries. Besides, as Zawalińska et al. (2021) suggested for further studies, we studied the effect of the ongoing COVID-19 pandemic on the resilience capacity of the agricultural sector across eight CAREC countries. This study can be furthered by increasing years of observation as external shock 2 (pandemic) is now coupled with another external shock: the war in Ukraine.

From our empirical study, we draw four main conclusions:

· First, although the agricultural TFP changes of the eight CAREC countries varied across the studied 20 years, the average changes were positive.

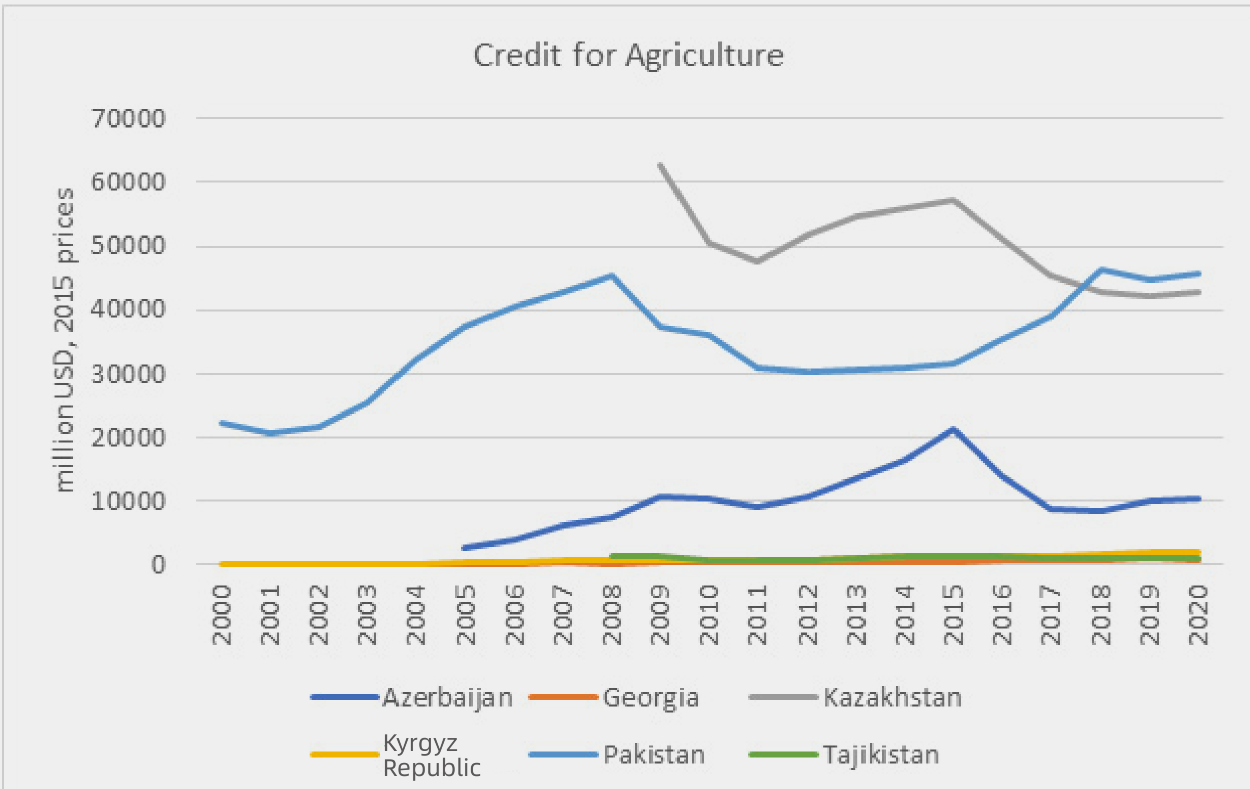
· Second, we observed diversity in the extent of cumulative TFP performance across the eight countries, and the cumulative TFP disparities widened after the second period — 2010.

· Third, except in a few of the studied countries like Tajikistan and Kyrgyzstan, whose changes in technological innovation triggered agricultural TFP growth, the TFPCH in the studied CAREC countries was sourced only from technical efficiency (EC) change. According to Färe et al. (1994), 17 developed OECD countries, on average, experienced growth owing to innovation (TC) rather than improvements in efficiency (EC) between 1979-and 1988. In this way, the 'world frontier' of productivity was always shifted upwards in OECD states. CAREC states, on the other hand, are not pushing the frontiers of agricultural productivity.

· Fourth, countries showed varied revealed resilience during and between the two shocks. Most countries that showed resilience during shocks maintained their TFP growth by increasing efficiency. During the COVID-19 crisis, none of the countries' TFP changes was driven by innovation, as the TC indices were one or below 1. Similar agricultural resilience to crises was detected in the Czech Republic during the global financial crises (Machek and Špička 2013). Machek and Špička found that agricultural productivity does not necessarily follow the domestic economic cycle, implying that global crises hitting the economies do not necessarily affect agricultural productivity and hence the resilience of the sector.

Food has relatively lower price elasticity of demand; hence, the demand for food quantity did not abruptly drop during the crisis periods despite changes in prices, in contrast with the case for products with higher value added (Potori et al. 2011). This, in turn, kept the demand for agricultural products stable and did not push down production, contributing to the sector's productivity-driven resilience. Moreover, during both crises, most CAREC countries' history of credit for the agriculture sector was positive, as Figure 6.4 shows.

Figure 6.4. Credit for agriculture (2000- 2020), CAREC Countries



Source: FAO, 2022

Uzbekistan revealed the highest resilience to shocks among the eight CAREC states, as it revealed robustness during both crises considered. Countries such as Azerbaijan and Mongolia revealed a deterioration in resilience from GFC to the pandemic. Georgia, Kyrgyzstan, and Tajikistan became adaptable during the external shock from being robust in the first crisis. Kazakhstan is the only country in our sample that stayed adaptable during both crises.

Although the current study provided positive messages on resilience to shocks, we must acknowledge certain drawbacks. Because of the data constraints, the TFP estimations did not consider fertilizers, the agricultural input that experienced abrupt price increases during the crisis. Therefore, the inclusion of fertilizers into analyses in future research might complement the current study well and further enhance the practicality of the recommendations. Moreover, the eight CAREC countries were considered as the 'world' while estimating the productivity frontier; hence, the productivity estimates of all countries in the study are inflated. Re-conduction of the analyses with more countries could benefit further studies, as such analyses would give more realistic estimates of productivity at a country level. The estimates for the four observation periods are also averages for the aggregated years; hence, the results ignore the variations across the years in the group.

Moreover, even when the agriculture system of the studied countries is robust or adaptable, the agriculture of these countries might be struggling with sustainability. The reasons behind this are: a lack of incentive mechanisms inducing farmers to invest in productivity and sustainability enhancing solutions; and dysfunctional institutional settings causing the vicious circle of low water use efficiency, biophysical constraints, and deteriorated irrigation infrastructure, as summarized in Amirova (2022).

Based on the study findings and conclusions, we provide policy options to increase the studied countries' agricultural productivity and resilience capacities before and during external shocks as follows:

Azerbaijan needs to acknowledge the value of agriculture functions during shocks and invest in technological innovations in the agriculture sector during crises. Georgia needs to focus on an accelerated increase in its sluggish agricultural productivity performance from small lands. As land fragmentation (land/labor) rises in Georgia over time, the country should invest in intensive and efficient land use. It should also benefit from potential investments in productive technological innovations and improved skills of smallholders.

Kazakhstan needs to keep up its high agriculture TFP performance. The country will need to study ways to use the relatively large land/labor and limited water resources efficiently in the long run. It will need to invest in agricultural technology innovations amid external shocks. Similarly, Kyrgyz Republic needs to preserve the positive changes gained in the agriculture sector from ECs during the pandemic, which calls for policies to maintain and increase production efficiency. The country also needs more technological investment in agriculture productivity to reverse the declining trend over the last decade. The Kyrgyz agriculture TFP can also gain from the development of transport and logistics for the integration of regional transport systems (UN 2022).

Mongolia, the most capital intensive among the eight countries, will need to redirect investment in productive technologies and institutional innovations to build the resilience of the sector dominated by the animal subsector. It should also continue investing in technical efficiency and the sustainable use of land resources vulnerable to climate change. More research needs to be conducted to understand and learn from the determinants of the country's agriculture TFP decline during the pandemic shock; it could be owing to a drop in the investment relations it has with neighboring China and Russia.

Pakistan, with negative cumulative TFP over the last two decades, needs to accelerate productivity. The sector should consider the efficient use of its agricultural resource: land and labor. The country should invest in innovations and policies to increase the productivity of smallholder farmers in harsh environmental conditions. The agriculture sector of Pakistan may need to attract private and foreign aid investment for agricultural technologies and infrastructure projects to increase the TC component.

Although doing well, Tajikistan and Uzbekistan should maintain their TFP gains over the last decade. Although Tajikistan remains the poorest country in Central Asia, the country has proven resilient to diverse shocks. It should keep up the recently revealed highest cumulative TFP (among study countries). The country would benefit from increased momentum in technological reforms to use scarce land resources efficiently. Policies for harnessing increased productivity from diversified agriculture systems are essential. Uzbekistan should maintain and fasten its promising agriculture reforms to improve the TFP that has risen sharply in recent years. Attention to efficient labor and land use and investments in smallholder farms are vital. The country should continue investing in agricultural productivity amid external shocks, including environmental risks.

In summary, the agricultural systems of the studied countries are too diverse to suggest general policy options. Nevertheless, all countries should strive for the right strategies and capital investment to boost their TFP both before and during shocks to build agriculture resilience. As agricultural development increasingly becomes vulnerable to harsh weather and other climate-related shocks, governments should support green innovations in the sector. All the CAREC countries should also invest in the sustainability of land and water resources. This is more important for countries like Mongolia and Pakistan, which are most susceptible to climate change effects.

Farmers need supported access to information, inputs, technical skill, and modern technology to increase their productivity. Smallholder farming is an important sector in most of the countries studied. Thus, agricultural policies focusing on small farmers' technical capacities throughout the region are vital.

Incentives to build resilience must include measures that inject capital into the sector. Investment in public goods and innovations — such as agricultural research and extension, energy use, proper storage, post-harvest management, transportation, processing facilities, and market infrastructure — can stimulate a TC in the sector (Barrett et al. 2019).

To increase technical efficiency, governments should continue to invest in agriculture knowledge. Evidence-based research, accurate and accessible data, and information exchange are all vital for increased agricultural TFP and resilience (Jin and Huffman 2016).

Improving trade logistics will help the countries with diversified agriculture to increase productivity and gain access to product markets. Creating the physical infrastructure and the accompanying institutional and regulatory frameworks will help countries in the study build resilience (Jin and Huffman 2016).

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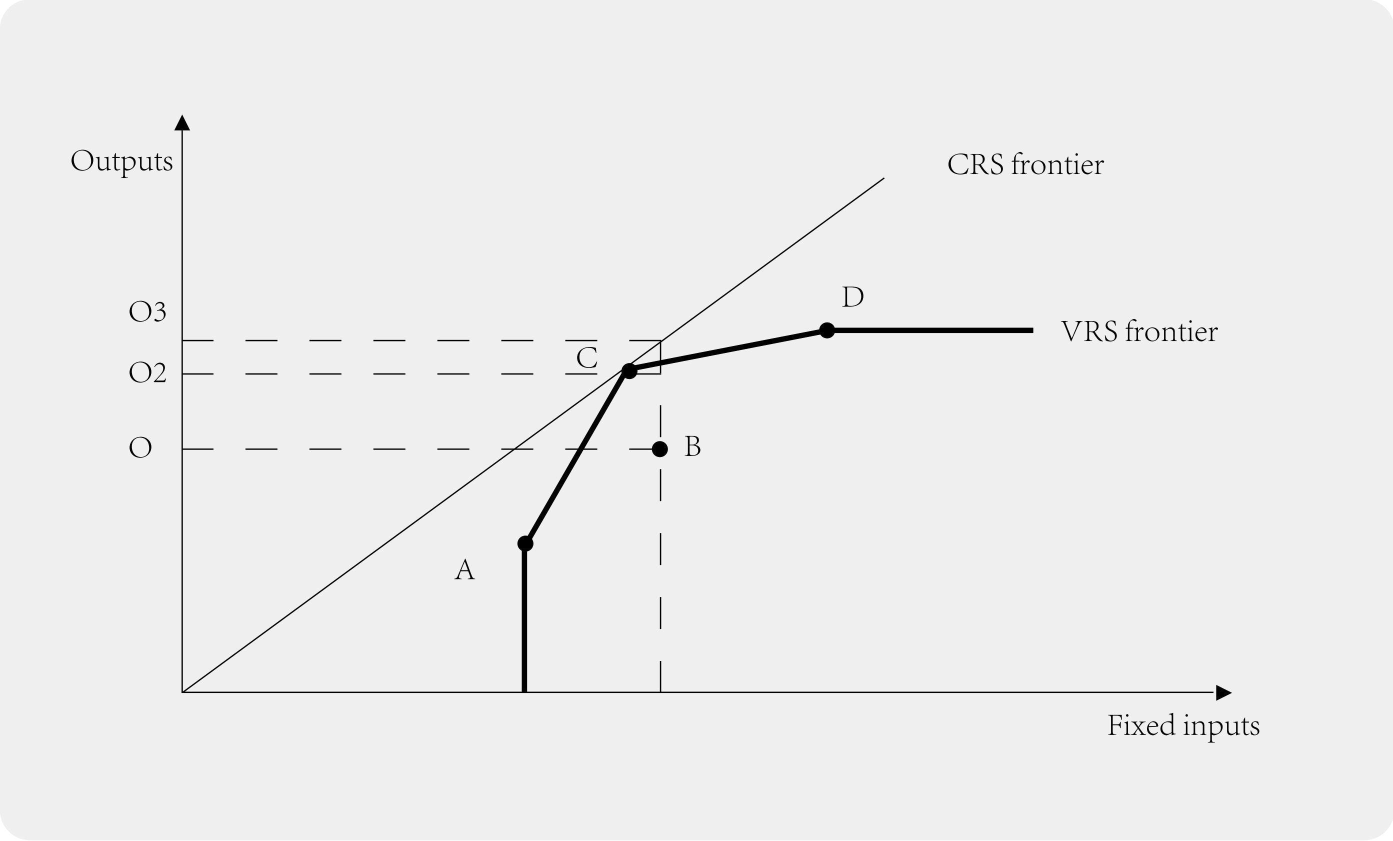
APPENDIX

1. The Malmquist Index using DEA frontier

The Malmquist Index (MI), named after Professor Sten Malmquist, is a bilateral index that can be used to compare the production technology of two economies or periods. The Malmquist Index that uses the data envelopment analysis (DEA) method is the most prevalent method used in TFP assessment since the seminal work of Färe et al. (1994).

Data envelopment analysis (DEA) is a linear programming methodology developed by Charnes et al. (1978), which uses input and output quantity data and constructs a linear surface over the data points. The DEA technique solves a sequence of linear programming (LP) to construct the linear frontier surface. In our case, the program solves one LP per country per period. The method produces each country's degree of technical inefficiency. Such inefficiency degree implies the distance between the observed data point and the linear frontier (slack) (Coelli and Rao 2005). The linear frontier surface will differ upon the model's scale assumption. There are two scale assumptions: constant returns to scale (CRS) and variable returns to scale (VRS). CRS reflects the fact that output will change proportionally to the input change. Meanwhile, VRS encompasses both increasing, constant, and decreasing returns to scale. Figure A1 accordingly illustrates the frontier surface based on CRS and VRS assumptions in time t for input *(x)* and output *(y)*.

Figure A1. CRS and VRS frontiers, input oriented DEA



Source: Cooper et al. 2007

The frontier in Figure A1 defines the full capacity constrained with the fixed number of inputs. If it is CRS, then the frontier is demarcated by point C. All other points that fall below C, in turn, show points that underutilize (are inefficient users of) inputs. On the other hand, if it is VRS, the linear frontier surface is demarcated by points A, C and D. In this case, only point B is below the frontier and hence referred to as the one underutilizing the input capacity.

In the current work context, the points A to D on the frontier represent the TFP of the selected CAREC countries at a certain period, with gross agricultural production (million USD) being the output and agricultural labor, capital (million USD), and land (ha) being input variables.

2. Agriculture input and output in the CAREC countries

Table A1. Summary statistics for input/output variables in selected CAREC countries, 2000-2020

	Output			Input								
	Agricultural value added (million USD)			Labor (1,000 agricultural persons)			Land (cropland 1,000 ha)			Capital (net capital stock in 2015 constant million USD)		
	Mean	Standard development	Average growth rate (%)	Mean	Standard development	Average growth rate (%)	Mean	Standard development	Average growth rate (%)	Mean	Standard development	Average growth rate (%)
2000-2020												
Azerbaijan	2803	135	4.63	1624	19	0.66	2146.4	23.5	0.71	4930	263	2.04
Georgia	1060	27	1.33	812	25	-2.74	512.1	13.9	-4.48	850	6.77	0.36
Kazakhstan	7771	302	4.06	2067	99	-3.26	29200.0	124.3	-0.05	6720	208	-2.19
Kyrgyz Republic	862	21	2.28	726	31	-3.91	1367.4	5.2	-0.22	1190	26.4	0.78
Mongolia	1118	99	5.27	387	9	-1.04	1251.9	15.9	0.67	2540	165	4.26
Pakistan	57024	1806	2.33	23900	700	2.02	31200.0	124.1	-0.06	88600	2010	1.60
Tajikistan	1359	114	7.32	955	14	0.94	871.7	2.2	-0.20	1910	23	0.01
Uzbekistan	19235	1344	5.43	3503	31	0.22	4570.7	35.3	-0.44	12700	892	5.38

2000-2007												
Azerbaijan	2200	86	5.79	1537	6	0.00	2066	2	0.11	3720	363	1.14
Georgia	980	28	-1.15	956	6	-1.64	572	7	-10.92	883	9	2.12
Kazakhstan	6471	237	6.34	2417	22	-0.37	28700	132	-0.73	7600	119	-1.96
Kyrgyz Republic	776	10	2.40	849	34	-3.89	1386	11	-0.71	1230	36	-0.60
Mongolia	732	51	3.30	414	9	0.15	1178	1	0.01	1950	27	1.78
Pakistan	48636	1410	2.72	20400	588	3.27	31400	175	-0.31	80300	583	0.72
Tajikistan	846	51	8.17	888	15	2.03	878	1	-0.21	1990	17	-1.27
Uzbekistan	13127	709	6.38	3523	15	0.00	4747	27	-0.56	8820	369	5.31
2008-2009												
Azerbaijan	2683	46	4.80	1609	11	1.72	2094	7	0.54	5040	310	10.07
Georgia	895	30	-5.43	828	32	-8.13	566	8	-1.65	862	14	-2.63
Kazakhstan	7595	470	3.50	2351	26	-1.21	28700	50	-0.03	7120	26	0.06
Kyrgyz Republic	835	27	3.79	740	11	-2.03	1352	1	-0.09	1040	19	-3.88
Mongolia	1021	18	4.15	434	1	0.78	1209	10	1.73	2220	22	3.54
Pakistan	55658	957	2.65	23900	65	3.01	30300	18	-1.19	84300	512	1.13
Tajikistan	1152	57	9.20	949	6	0.97	878	7	0.65	1880	21	-1.81
Uzbekistan	17069	483	5.27	3315	45	-2.60	4587	19	-0.80	11000	289	4.92
2010-2019												
Azerbaijan	3249	122	3.78	1689	15	0.91	2213	32	1.16	5750	102	1.06
Georgia	1126	22	3.67	752	19	-2.10	477	12	-2.46	834	5	0.25
Kazakhstan	8717	290	2.58	1765	124	-5.70	29600	109	0.43	6020	200	-2.81
Kyrgyz Republic	928	22	1.90	637	33	-4.30	1357	2	0.10	1190	38	2.68
Mongolia	1407	121	6.86	358	7	-2.24	1312	9	0.93	3020	219	6.14
Pakistan	63169	1319	2.00	26300	293	0.94	31200	150	0.34	95200	2130	2.31
Tajikistan	1760	96	6.35	1002	6	0.17	866	3	-0.36	1870	33	1.26
Uzbekistan	23945	1072	4.79	3526	51	0.93	4444	12	-0.29	15800	798	5.53

2020												
Azerbaijan	4049	-	2.89	1647	-	-5.78	-	-	-	6360	-	8.29
Georgia	1245	-	3.65	687	-	7.65	-	-	-	897	-	3.34
Kazakhstan	10346	-	5.60	1274	-	-0.58	-	-	-	4870	-	-9.08
Kyrgyz Republic	1050	-	1.09	411	-	-11.17	-	-	-	1350	-	-0.09
Mongolia	2041	-	6.17	366	-	8.62	-	-	-	4250	-	5.69
Pakistan	70820	-	2.67	24800	-	-5.46	-	-	-	109000	-	2.36
Tajikistan	2432	-	8.80	952	-	-2.00	-	-	-	2080	-	-0.94
Uzbekistan	28782	-	2.96	3166	-	-11.58	-	-	-	20300	-	5.60

Table A1. Summary statistics for input/output variables in selected CAREC countries, 2000-2020

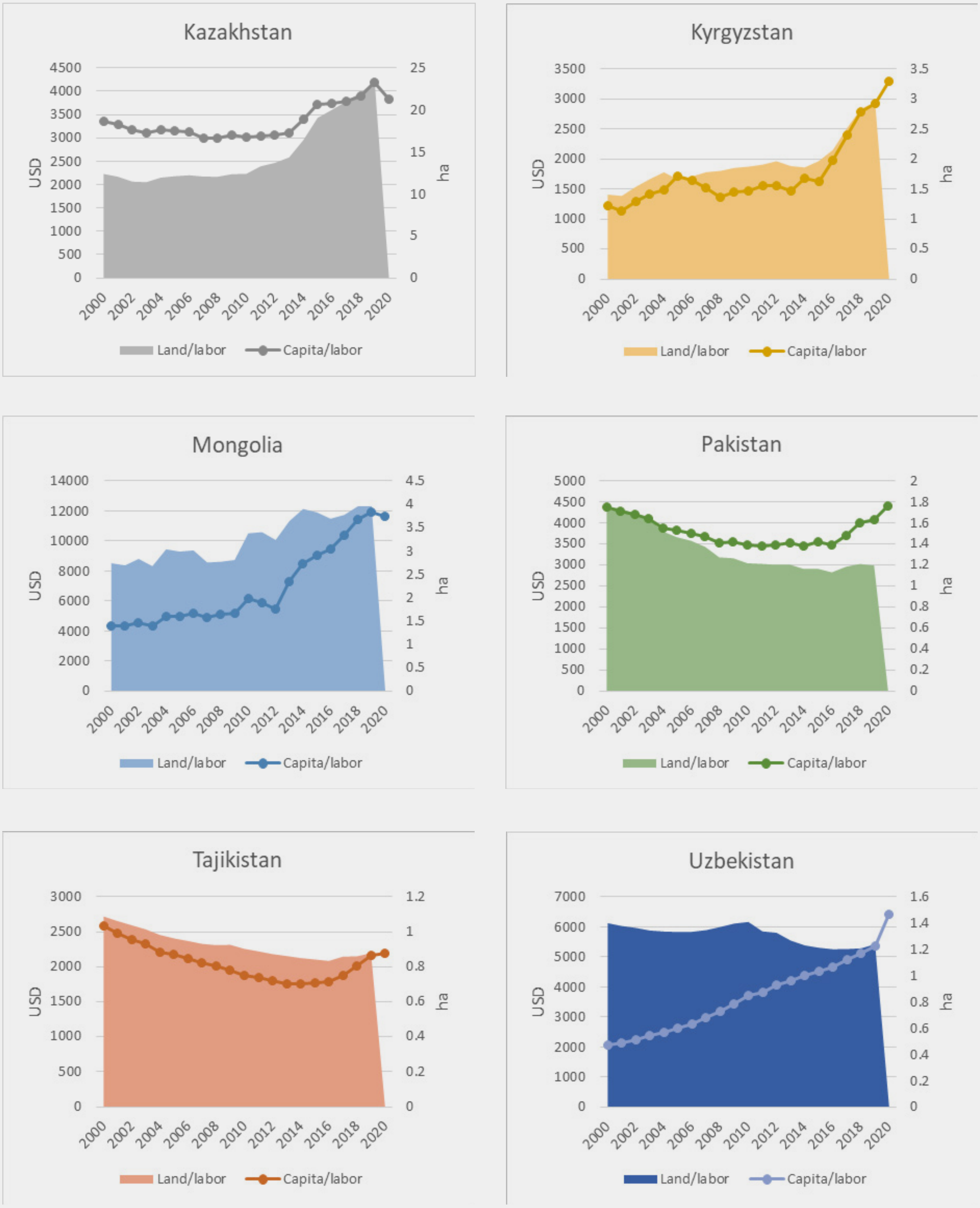
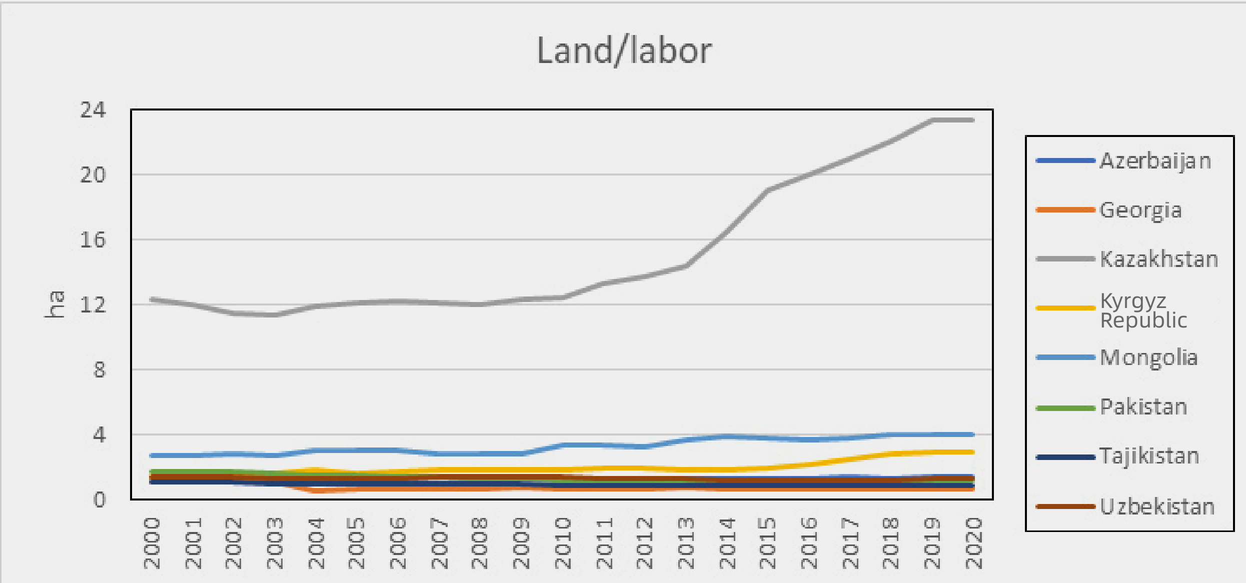

Kazakhstan
USD
ha
Land/labor
Capita/labor
Kyrgyzstan
USD
ha
Land/labor
Capita/labor
Mongolia
USD
ha
Land/labor
Capita/labor
Pakistan
USD
ha
Land/labor
Capita/labor
Tajikistan
USD
ha
Land/labor
Capita/labor
Uzbekistan
USD
ha
Land/labor
Capita/labor

Table A2. Summary statistics for input ratios

	Land/labor		Capital/labor	
	Mean (ha/person)	Average growth rate (%)	Mean (ha/person)	Average growth rate (%)
2000-2020				
Azerbaijan	1.32	0.07	3016	1.40
Georgia	0.70	-1.68	1018	3.21
Kazakhstan	14.91	3.53	3315	1.25
Kyrgyz Republic	1.95	4.12	1709	5.13
Mongolia	3.28	2.19	6776	5.94
Pakistan	1.33	-1.97	3736	-0.33
Tajikistan	0.92	-1.11	2018	-0.88
Uzbekistan	1.31	-0.62	3625	5.18
2000-2007				
Azerbaijan	1.34	0.13	2424	1.17
Georgia	0.81	-6.29	870	3.32
Kazakhstan	11.90	-0.32	3143	-1.56
Kyrgyz Republic	1.65	3.57	1460	3.49
Mongolia	2.85	0.30	4735	2.05
Pakistan	1.55	-3.45	3959	-2.46
Tajikistan	0.99	-2.19	2250	-3.23
Uzbekistan	1.35	-0.55	2506	5.32

2008-2009				
Azerbaijan	1.30	-1.07	3137	8.40
Georgia	0.68	7.06	1042	5.99
Kazakhstan	12.20	1.21	3028	1.30
Kyrgyz Republic	1.83	1.99	1406	-1.81
Mongolia	2.79	0.94	5113	2.73
Pakistan	1.27	-3.99	3531	-1.76
Tajikistan	0.92	-0.31	1981	-2.75
Uzbekistan	1.38	1.85	3310	7.72
2010-2019				
Azerbaijan	1.31	0.26	3406	0.17
Georgia	0.64	-0.20	1118	2.58
Kazakhstan	17.56	6.69	3493	3.20
Kyrgyz Republic	2.19	4.94	1944	7.66
Mongolia	3.67	3.76	8537	9.29
Pakistan	1.19	-0.53	3620	1.45
Tajikistan	0.86	-0.51	1864	1.14
Uzbekistan	1.26	-1.16	4471	4.58
2020				
Azerbaijan	-	-	3862	14.94
Georgia	-	-	1306	-4.01
Kazakhstan	-	-	3825	-8.55
Kyrgyz Republic	-	-	3291	12.47
Mongolia	-	-	11610	-2.70
Pakistan	-	-	4405	8.26
Tajikistan	-	-	2187	1.08
Uzbekistan	-	-	6422	19.43

Figure A3. Combined illustration of land/labor ratio across the eight CAREC countries



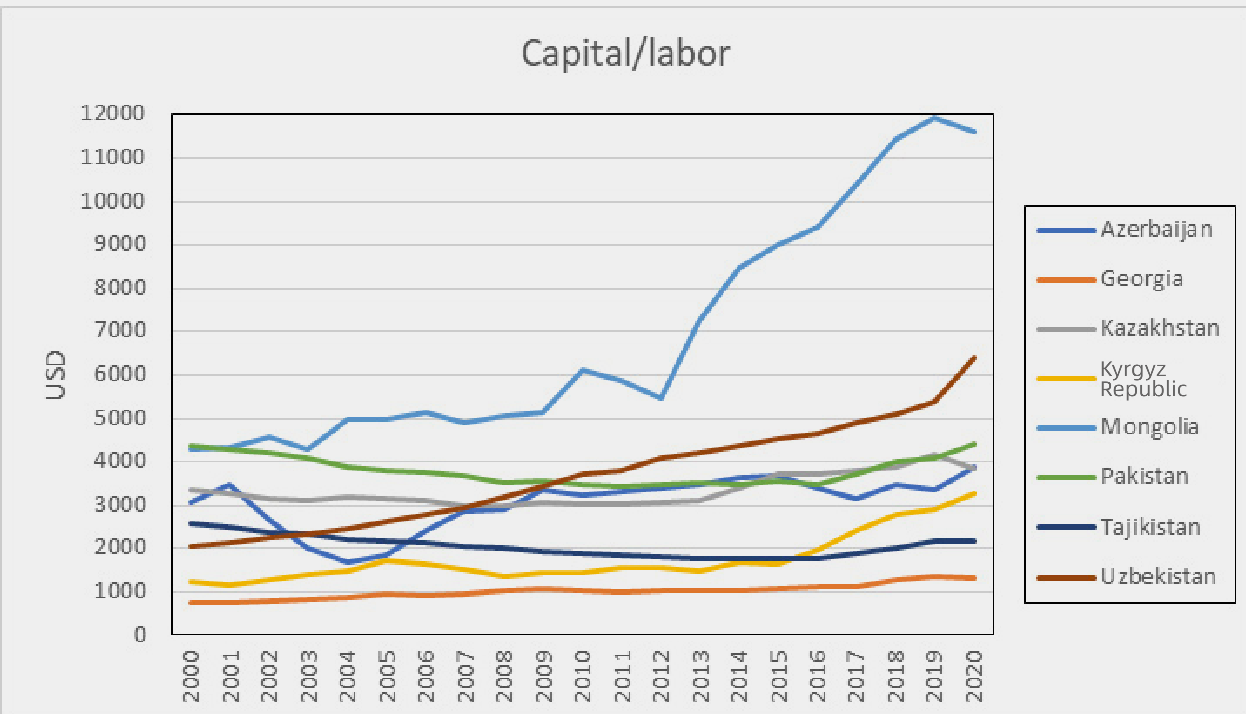


Figure A5. Distribution of labor and land changes between 2000-2020