OPEN ACCESS
Saudi Journal of Economics and Finance
Abbreviated Key Title: Saudi J Econ Fin
ISSN 2523-9414 (Print) |ISSN 2523-6563 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://saudijournals.com

Original Research Article

The Cereal Production as an Indicator of Agricultural Land Use Efficiency and Economic Growth in Central Asia: Evidence from A Generalized Method of Moments (GMM) Panel Data Analysis of the Environmental Kuznets Curve (EKC)

Bolor-Erdene Turmunkh[1*]

[1]School of Economics and Trade, Hunan University, Changsha city, Hunan Province, 410006, PR China

DOI: 10.36348/sjef.2021.v05i12.002 | **Received:** 12.11.2021 | **Accepted:** 16.12.2021 | **Published:** 19.12.2021

***Corresponding author:** Bolor-Erdene Turmunkh

Abstract

This study examines the Environmental Kuznets Curve (EKC) hypothesis in Central Asian countries as well as validates or invalidates the consistency of the different estimation results, using data, over the period 1992 to 2020. The study achieved this objective by employing various econometrics techniques such as Pooled Ordinary Least Squares (POLS) and Fixed-Effects Regression with Driscoll-Kraay standard errors, Panel Fully Modified Least Squares (FMOLS) Cointegrating Regression, Panel Vector Autoregression (PVAR) with Generalized Method of Moments (GMM) estimation, and Dynamic Panel-data estimation, One-Step system GMM. An empirical analysis uses the panel Unit Root tests to test the basics of the data unit based on this information. Following the best econometric practices, the descriptive statistics, Correlation matrix were computed to understand the characteristics of the variables and countries under analysis and to ensure that the necessary conditions for the estimation were fulfilled. The PVAR specification was based on the results of the Lag-order selection criteria, and the stability of the PVAR model was checked through the observation of the Instrumental variables GMM regression. The results of this study indicate that the GMM score supports the EKC hypothesis. This confirms the validity of the assumptions in the two inverse U-shaped EKC models between Gross Domestic Product (GDP) per capita in Central Asian countries and cereal production and agricultural land use. The results of this study show that the GMM assessment. That suggests that governments in Central Asia need to take the necessary initiatives to conserve agricultural land and encourage farmers to increase their arable land to meet the food needs of a growing population.

Keywords: Cereal Production; Agricultural land use; Generalized Method of Moments (GMM); Environmental Kuznets Curve (EKC); Central Asia.

1. INTRODUCTION

Cereal production, economic growth, and cooperation need to be defined to create policies that protect the environment and ensure sustainable agricultural growth around the world. Agriculture is an ancient tradition that has shaped the lives of people, their incomes, the economy, culture, and mentality of the country. Similarly, for Central Asian countries, agriculture is a way of developing rural areas and accelerating economic growth. The cereal and agricultural sectors of Central Asia produce a wide range of products, including milk, dairy products, vegetables, fruits, as well as the mining industry, and export them to neighboring countries. The growing demand for agricultural products and the rapid growth of world trade has led to the rapid development of the agricultural sector and agriculture around the world. Central Asia is located in the arid and semi-arid regions of the world, occupying about 35% of the world's land and providing a third of the world's population with cereal. The region accounts for about 18% of world wheat production and 22% of exports of the same wheat. While the agricultural sector is considered a key pillar of the national economy, it is also shrinking due to increased urbanization, overpopulation and increased fertilizer consumption, traditional farming practices, carbon emissions, and climate change. The transition from traditional agriculture to modern agriculture is necessary to use agricultural land to improve agricultural production and meet nutritional needs. A growing agricultural sector supports rural employment in the country's economy, reducing poverty and providing livelihoods. Although agriculture is wholly in the hands of the private sector, public policy plays an important role in the growth of sectors in developing countries, which are largely driven by resource-poor agricultural communities.

Only a few studies of the literature explore Agricultural Land Use studies in Central Asian countries (Akhmadiyeva and Herzfeld, 2021; Eltazarov *et al*., 2021; Feng *et al*., 2022; Jiang *et al*., 2020; Leng *et al.*, 2021; Li and Liu, 2021; Liu *et al*., 2021; Sun *et al*., 2019; Swinnen *et al*., 2017). For example, Liu *et al*. (2021) evaluated, among Central Asian countries and China, the water and land footprints, virtual water and land trades, as well as potentials in enhancing water and land efficiency related to sixteen primary crop products, four primary animal products, and twelve derivative products production and trade over the period 2000 to 2014. Their found that the blue water footprint and land footprint per unit product in Central Asian countries were up to 61- and 17-times higher than in China. Through enhancing water and land efficiency without further intervention in water and land endowments, the scenario for Central Asian countries shows an additional food supply for feeding 387 million people or half the starving population in the world. Moreover, Swinnen *et al.* (2017) showed interdisciplinary literature and empirical evidence, predictions of production potential and impacts of climate change; and discuss the potential of the region to become a reliable breadbasket of the world. From a biophysical perspective, under different scenarios of increased yields, land use, and climate change effects, Central Asia could produce an additional 40 to 110 million tons of wheat compared to current production, which would be a substantial additional production. However economic incentives, in particular the evolution of food prices and competition from other crops, are likely to significantly constrain these potentials. Later on, Li and Liu (2021) showed that although different land policy reforms were implemented by five Central Asian countries, the cultivated land areas tended to be stable after 2010. The cultivated land increased by approximately 7.02×104 square kilometer in Central Asia. After 2000, cultivated land slowly increased and the degree of land degradation rapidly decreased, illustrating that the turning point for the quantity and quality of cultivated land change caused by these policies occurred in 2000.

EKC is one of the key principles for modeling economic growth and environmental dynamics. The EKC hypothesis is a general approach to studying the relationship between economic growth and environmental degradation. The EKC is a hypothetical relationship between environmental quality and national economic growth (Grossman and Krueger, 1995). The EKC anticipates that environmental degradation will increase as per capita income rises in the early stages of economic development. This study is based on the EKC theory, which summarizes the efficiency of cereal production and arable land, for example, in Central Asia. This study explores the EKC (the presence of the environmental Kuznets curve) hypothesis for cereal production in Central Asia using data from 1992 to 2020. Previous studies did not include studies on the relationship between cereal production, agricultural land use, and GDP per capita according to the EKC hypothesis based on Central Asian countries. The researcher used the GMM estimation method with a lagging independent variable to solve an endogenous problem. The GMM score allows us to monitor time-series dynamics and country characteristics in the data, while monitoring various endogenous states and missed variable bias. Most importantly, endogenous evolutionary biases can be caused by different causes, and there are different ways to combat them. The results of this study confirmed the EKC hypothesis in Central Asian countries, and the empirical results using the GMM show an inverse U-shaped EKC relationship between GDP per capita and crop production (Figure 1). This study aims to examine the relationship between cereal production in Central Asia and the efficiency of agricultural land use and economic growth. To this end, the researcher is examining the impact on Cereal production and agricultural land use efficiency that arose from factors such as Land under cereal production, Crop production index, Cereal yield, Agriculture, value-added (% of GDP), Fertilizer consumption, per capita GDP (constant 2010 US dollar), Employment in agriculture, and Rural population. Also, In this, an empirical analysis uses the Panel Unit Root test, Panel Pooled Ordinary Least Squares (POLS), Fixed-Effects Regression, The Fully Modified Least Squares (FMOLS) Cointegrating Regression, and Panel vector Autoregression (PVAR) of the data unit based on this information. The novelty of this empirical study is that Driscoll and Kraay (1998) proved a standard model for the impact of errors using data from Central Asian countries. The article is divided into six sections. Following this introduction in Section 1, there is a review of related literature in Section 2. Section 3 discusses the methodology and data. Section 4 examines the data analysis. Section 5 is the discussion of the findings, while Section 6 concludes with some recommendations and suggestions for future research.

2. LITERATURE REVIEW

The existing literature related to this research is reviewed under the following three categories: (I) the studies on the Agricultural Land Use Efficiency and Economic Growth, using the different variables (II), the studies on Environmental Kuznets Curve (EKC) for different countries, and (III) the studies on causal effect using A Generalized Method of Moments (GMM) estimation. A more detailed analysis is presented in the following categories.

The first category of existing literature on the effect of agricultural land use efficiency and economic growth on based Chinese studies (Chen *et al*., 2021; Guo *et al*., 2021; Li and Ito, 2021; Xue, 2020; Zhang *et al*., 2020; Zhao *et al*., 2021) and comparative regional studies combined a set of similar income countries, such as panel and time-series data of using fertilizers on agriculture land studies (Guo *et al*., 2021; Koondhar *et al*., 2021; Möhring *et al*., 2020; Tsiboe *et al*., 2021; Yu et al., 2021; Zhai *et al*., 2021; Zheng *et al*., 2020), and other papers of cereal production studies, see (Bengochea *et al*., 2020; Haider *et al*., 2020; Kumi *et al*., 2021; Kurowska *et al*., 2020; Prabhakar, 2021; Wang, 2021). For example, Li and Ito (2021) analyze the factors that influence the land exchange in Gansu province whose land rental ratio was among the lowest in China at the start of the 2010s. Their contribution to the literature is to provide empirical insights into the factors that promote and impede the development of land rental markets. They draw the following conclusions from the analysis. First, agricultural cooperatives have a positive impact on land rental development, suggesting that non-farm household producers are the major contributors to the demand side of farmland exchange. Second, transaction costs have a detrimental effect on the land exchange, as theoretically supported by this study as well as empirical findings in the literature. Koondhar *et al.* (2021) investigate asymmetric causality between agricultural carbon emissions, energy consumption, fertilizer consumption, and cereal food production in Pakistan. The secondary time series data over the period from 1976 to 2018 was used to estimate the nonlinear-autoregressive distributed lag model. The empirical results of the linear Granger causality test confirm that the causality is running from energy consumption and fertilizer to cereal food production. Haider et al. (2020) use the EKC to investigate N_2O emissions, including those resulting from agriculture, economic growth, agricultural land use, and exports. Two groups of data are extracted from the panel data: the first group contains the top 15 countries, ranked by N_2O emissions, measured in thousand metric tons of CO_2, while the second group contains the top 18 countries, ranked by share of agriculture in GDP. The results show that N_2O emissions and economic growth are co-integrated in both panels, providing evidence in favor of the EKC. In addition, agricultural land use has a positive and significant effect on N_2O emissions.

The second category of the country-specific and multi-countries many studies that were conducted using the EKC. The EKC was first examined by (Kuznets, 1955) who deducted the relationship between income and inequality given rise to an inverted U-shaped curve. Since then, researchers have been using this template as an inspiration to analyze the long-term relationship between per capita income and environmental quality/damage. Among the many researchers that used different variables, different data span, different estimation techniques, and find the existence of partial environmental Kuznets curve or U-shape hypothesis include: Bimonte (2017) and Pontarollo and Muñoz (2020). Contrary to the findings of partial EKC, Jiang *et al*. (2019), Pontarollo and Serpieri (2020), Bimonte and Stabile (2017), Riti *et al*. (2017), and are among those that reveal full support of the EKC proposition. For example, Bimonte (2017) uses a heuristic approach to analyze the relationship between per capita income and land consumption, as proxied by the number of Building Permits issued by public authorities. Using data from the Italian regions, we run a panel data regression model to test whether the EKC hypothesis holds. Results confute it, evidencing a U-shaped relationship. In the authors' opinion, the combined effect of market conditions, lifestyle evolution, and institutional and political factors have produced an adverse effect on the environment. On this basis, the paper claims that, when social and intergenerational aspects are involved, a balanced mix of market, policies, and institutional architecture is needed. An overview of the multi-country (panel data) literature on EKC indicates that a plethora of surveys abound (Ajanaku and Collins, 2021; Boubellouta and Kusch-Brandt 2021; Gan *et al.*, 2021; Katz, 2015; Moutinho *et al*., 2017; Nepal *et al*., 2021; Tenaw and Beyene, 2021; Wang *et al*., 2021; Yang and Ma, 2021). For example, Moutinho et al. (2017) showed the relationship between economic growth and environmental variables is analyzed under two non-linear specifications, a quadratic and a cubic specification. The study is conducted for Portugal and Spain in the period 1975 to 2012, using data for 13 sectors. Gross value-added is used as a proxy for income, while energy use and carbon dioxide account for environmental degradation. There is evidence for an inverted U-shaped EKC. However, there are also other inverted N–shaped functions that explain the relationship between economic growth and emissions. Altogether, empirical results do indicate particular differences between the Portuguese and Spanish sectors. The results are of interest not only for researchers but also for policy-makers. Political mitigation measures are also analyzed. In a related development, Gan *et al*. (2021) use the generalized three-stage least squares (GS3SLS) method to establish a spatial simultaneous equation model to explore the interaction mechanism between haze and economic development. Regarding the entire country, the relationship between $PM_{2.5}$ and per capita GDP presents an inverted U-shaped curve, which verifies the existence of the EKC. Haze pollution also reacts to economic development and has an inhibitory effect on economic development. Moreover, Ajanaku and Collins (2021) examine statistical evidence for the EKC hypothesis as applied to deforestation occurring within Africa from 1990 to 2016. Changes in forest cover data are explained with GMM estimators to overcome the endogeneity problems arising from reverse causality. The empirical results of Panel GMM confirm the EKC hypothesis is valid for deforestation in Africa with a turning point estimated to be 3000 US dollars. Heterogenous panel non-causality findings suggest that Africa could deter and reverse deforestation through appropriate land use and forest products trade policies, and the consequences of these policies would not impact their economic growth. Furthermore, Boubellouta and Kusch-Brandt (2021) found some support for the existence of an EKC, but results are highly dependent on the choice of datasets and statistical techniques. Results are also sector-specific and EKC curves prove to be poor indicators of individual country behavior. As such, the study points to limitations of EKC's in terms of water use policy and planning.

The third category of the literature investigates the many studies that were conducted using the Generalized Method of Moments (Akbar and Jamil, 2012; Banto and Monsia, 2021; Jha, 2019; Khan *et al*., 2019; Mittal and Garg, 2021; Nepal *et al*., 2021; Siddiqui and Ahmed, 2013; *Ullah et al*., 2018; Zouaoui and Zoghlami, 2020). For example, Akbar and Jamil (2012) examine the agricultural growth by developing a model using the data from the agricultural sector of Pakistan for the period 1972 to 2010. The model is primarily based on the input-output reduced form structural equations approach. It is then estimated by GMM, validated, and used for deterministic simulation analyses. Finally, the validated model is used to critically analyze the impact of fiscal, monetary, and energy policies on agricultural output. They concluded that recent fiscal and monetary policies should be continued, while the energy policy needs to be modified to improve the agricultural GDP and reduce the rural poverty situation in the country. Jha (2019) found that policy reforms targeted towards financial liberalization reduce corruption. This result is robust to the inclusion of several control variables and the choice of the GMM estimator. Interestingly, the financial liberalization index is found to be positively correlated with corruption though this relationship is not robust. The findings also indicate that legal origins do not impose a binding constraint on the effectiveness of financial reforms in reducing corruption. Zouaoui and Zoghlami (2020) employ the PVAR approach in a GMM framework. Moreover, they use the impulse response functions tool to better understand the reaction of bank market power aftershocks on revenue diversification and vice-versa. Finally, they supplement our analysis by the forecast error variance decompositions of our variables. Overall, the results show that the level of bank market power declines in response to positive revenue diversification shocks.

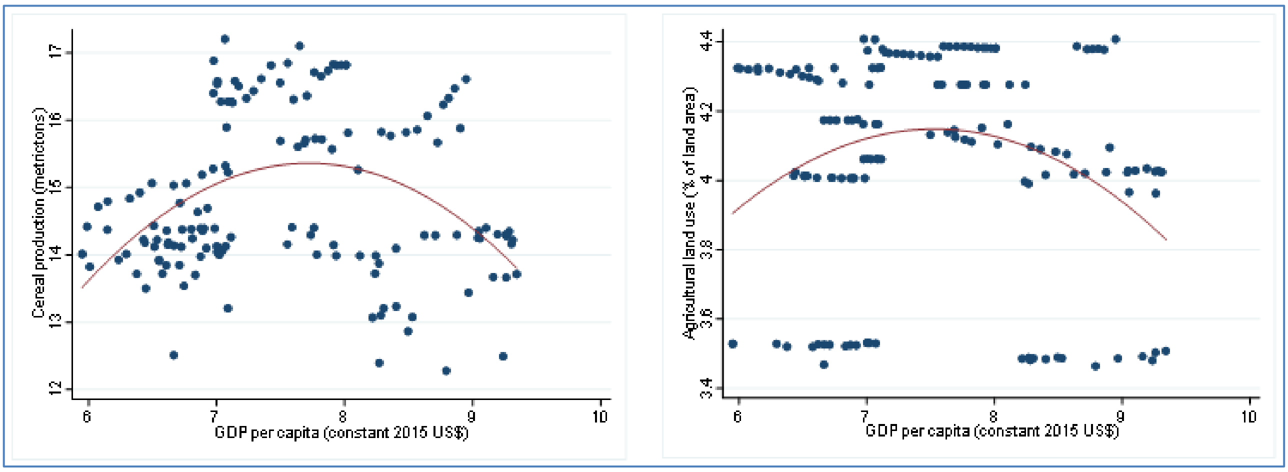

Fig-1: Relationship between Cereal production, Agricultural land use and GDP per capita. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

3. METHODOLOGY AND DATA

3.1. Source of Data and Model

The present study follows from this literature on EKC and economic growth. It seeks to extend knowledge on this topic and underline the roles of economic growth and Cereal Production, and Agricultural Land Use, using a broad range of the latest data. To study examine the relationship between economic growth and Cereal Production, and Agricultural Land Use, panel data for Central Asian Countries was used, covering 29 years. This study collected data from official sources, including the World Development Indicators (WDI), Food and Agriculture Organization (FOA), International Monetary Fund (IMF) database, International Labor Organization (ILO) database, electronic files, and web site. The author used the average Cereal production (*lnCEP*) and Agricultural land (*lnAGL*) levels at the Central Asian countries, as reported in the official database, to measure the dependent variables of this study. The author calculated the annual average dependent variable for each country from 1992 to 2020 and sorted the results by country. The study uses the Land under cereal production (hectares), Crop production index (lnCPI), Cereal yield (*lnCEY*), Agriculture, value-added (*lnAVA*), Fertilizer consumption (*lnFCL*), GDP per capita (*lnGDP*), Employment in agriculture (*lnEAG*), and Rural population (*lnPOR*) as independent variables. The purpose of hypothesizing the inverted U-shaped relationship between per Cereal production/Agricultural land efficiency and environmental pollution otherwise known as the EKC for Central Asian countries between 1992 to 2020. It was adopted based on the EKC, Pooled Ordinary least squares (OLS), and Fixed-effects regression, Panel FMOLS Cointegrating Regression, Panel PVAR with GMM estimation, Dynamic panel data estimation, One-Step system GMM estimations, and reports some findings. This paper is focused on economic activities. The key contribution of the present research to the existing literature will be to shed light on and quantify Cereal Production as an Indicator of Agricultural Land Use Efficiency, and economic growth in Central Asia. Following the theoretical basis of the Environmental Kuznets curve hypothesis, the form of the models is specified as:

$$CEP_t = f(LCP_t, AVA_t, FCL_t, CPI_t, GDP_t, EAG_t, lnPOR_t)\omega_i \quad (1)$$

$$AGL_t = f(CEY_t, AVA_t, FCL_t, CPI_t, GDP_t, EAG_t, lnPOR_t)\omega_i \quad (2)$$

The model is then converted to a natural logarithm to bring the data to the same units, reduce the variance as well as interpret the coefficients in terms of elasticities.

$$lnCEP_t = \alpha_0 + \alpha_1 lnLCP_t + \alpha_2 lnAVA_t + \alpha_3 lnFCL_t + \alpha_4 lnCPI_t + \alpha_5 lnGDP_t + \alpha_6 lnEAG_t + \alpha_7 lnPOR_t + \omega_1 \quad (3)$$

$$lnAGL_t = \beta_0 + \beta_1 lnCEY_t + \beta_2 lnAVA_t + \beta_3 lnFCL_t + \beta_4 lnCPI_t + \beta_5 lnGDP_t + \beta_6 lnEAG_t + \beta_7 lnPOR_t + \omega_2 \quad (4)$$

In the Equation (1) and (2), where, t is time period of 1992 to 2020. α_i and β_i are the respective coefficients of dependent variables, and ω_i represents white noise error processes.

3.2. Unit Root tests

This section shows graphically the overall statistics of quantitative data in the survey. The different axes show the different units of measure of the variables, and the graphs for each are converted to natural logarithmic values. The simplest study of data properties begins with a study of relative averages and variances of the data. The descriptive statistics and correlation matrix in Table 1 show the logarithmic variable data. Table 2 presents the overall mean values and units of measure for the 29 years of the survey between 1992 and 2020. The author performed unit tests using the variables included in the Breitung (2000) unit-root test, Harris-Tzavalis (1999) unit-root test, and Hadri LM (2000) test at a significance level of 10% (shown in Table 3). In this study, the Bayesian information criterion (BIC) or Schwarz criterion performed relatively well, so the Author used the Akaike information criterion (AIC) to determine the optimal number of latencies for the conditional ECM. Table 4 also shows the Akaike information criterion (MAIC), Bayesian information criterion (MBIC), sequential modified CD test, coefficient of determination (CD) test (each test at 5% level), J - Hansen's J statistic, J p-value - Hansen's J statistics p-value (Hansen, 1982), and the Quinn information criterion (MQIC) introduced by Andrews and Lu (2001) the test was conducted for first- to third-order panel VAR using the first four lags of the regressors as instruments.

3.3. Panel POLS and Fixed-effects Regression with Driscoll-Kraay standard errors

Although Driscoll and Kraay's (1998) covariance matrix estimator is perfectly general and by no means limited to the use with linear panel models. In contrast to Driscoll and Kraay's original formulation, the estimator below is adjusted for use with both balanced and unbalanced panel datasets, respectively. The respective fixed-effects estimator is implemented in two steps. In the first step all model variables $z_{it} \epsilon (y_{it}, x_{it})$ are within-transformed as follows:

$$\tilde{z}_{it} = z_{it} - \bar{z}_i + \bar{\bar{z}} \quad (5)$$

Where

$$\bar{z}_i = T_i^{-1} \sum_{t=t_{i1}}^{T_i} z_{it}$$

and

$$\bar{\bar{z}} = \left(\sum T_i\right)^{-1} \sum_i \sum_t z_{it}$$

Recognizing that the within-estimator corresponds to the OLS estimator of the second step then estimates the transformed regression Equation in (5) by POLS estimation with Driscoll and Kraay standard errors.

$$\widetilde{z_{it}} = \tilde{x}'_{it}\theta + \tilde{\varepsilon}_{it} \quad (6)$$

3.4. The Fully Modified Least Squares (FMOLS) Cointegrating Regression

The Fully Modified Ordinary Least Square (FMOLS) regression was originally designed in work by Phillips and Hansen (1990) to provide optimal estimates of cointegrating regressions. The method modifies least squares to account for serial correlation effects and for the endogeneity in the regressors that results from the existence of a cointegrating relationship. The FMOLS have recently been adopted and preferred to the OLS because they are quite effective when it comes to solving the endogeneity problem of the explanatory variables and autocorrelation of the residuals thereby enabling the variables to be asymptotic (Pedroni, 2001 and Pedroni, 2004). While the FMOLS estimator applies the non-parametric method to solve the problem of endogeneity and serial correlation, the DOLS estimator on the other hand applies the parametric method to eliminate the difficulty inherent in the estimation. Following Pedroni (2001), the panel FMOLS method is presented as follows:

$$\hat{\beta}_{FLOMS} = \left(\sum_{i=1}^{N} \hat{L}_{22i}^{-2} \sum_{t=1}^{T} (x_{it} - \bar{x}_i)^2\right)^{-1} \cdot \sum_{i=1}^{N} \hat{L}_{11i}^{-1} \hat{L}_{22i}^{-1} \left(\sum_{t=1}^{T} (x_{it} - \bar{x}_i)\, y_{it}^{*} - T\hat{\delta}_i\right) \quad (7)$$

In Equation (7), where,

$$y_{it}^{*} = (y_{it} - \hat{y}_i) - \left(\frac{\hat{L}_{21i}}{\hat{L}_{22i}}\right) \Delta X_{it} + \left(\frac{\hat{L}_{21i} - \hat{L}_{22i}}{\hat{L}_{22i}}\right) \beta (x_{it} - \bar{x}_i) \quad (8)$$

and the serial correlation adjustment parameter $\hat{\delta}_i$ is given as follows:

$$\hat{\delta}_i = \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^{0} - \left(\frac{\hat{L}_{21i}}{\hat{L}_{22i}}\right) (\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^{0}) \quad (9)$$

3.5. Panel vector Autoregression with GMM Estimation

The Panel Vector Auto Regression (PVAR) model with GMM Estimation is also available for this section's purpose. The PVAR model was introduced by Holtz-Eakin et al. (1988) extend their equation-by-equation estimator for a PVAR model with only endogenous variables that are lagged by one period. In this case, the author must implement the PVAR model with GMM Estimation as follows:

$$Y_{it} = Y_{it-1}A_1 + Y_{it-2}A_2 + Y_{it-3}A_3 + \cdots + Y_{it-p}A_p + X_{it}B + u_i + e_{it}\ ;\ i\epsilon\{1,2,3,\ldots n\}, t\epsilon\{1,2,3,\ldots T_i\} \quad (10)$$

In Equation (10), where, Y_{it} is dependent variable, X_{it} is a vector of exogenous covariates, u_i and e_{it} are vectors of dependent variable-specific panel fixed-effects and idiosyncratic errors, respectively. The matrices $A_1, A_2, A_3, \ldots, A_p$ and the B are to be estimated.

3.6. Dynamic panel-data models

In a dynamic panel-data model, lagged values of the dependent variable are included as regressors. Here we consider a simple model with one lag of the dependent variable y as a regressor and a vector of strictly exogenous regressors, x_{it}:

$$y_{it} = py_{i,t-1} + x_{it}'\beta + u_i + \varepsilon_{it} \quad (11)$$

u_i can be either a fixed-effect or a random-effect term, in the sense that we do not require x_{it} to be independent of it. Even with the assumption that ε_{it} is an independent and identically distributed, the presence of both $y_{i,t-1}$ and u_i in (Equation 11) renders both the standard fixed-effect and random-effects estimators to be inconsistent because of the well-known Nickell (1981) bias. OLS regression of y_{it} on $y_{i,t-1}$ and x_{it} also produces inconsistent estimates, because $y_{i,t-1}$ will be correlated with the error term.

3.7. Diagnostic Analysis

Here the author refits our model of rents by using the GMM estimator, allowing for heteroskedasticity in this section. See Equation (12) below for a discussion of robust covariance matrix estimation in the GMM framework.

$$\hat{S} = \frac{1}{N} \sum_{c\epsilon C} q_c q_c' \quad (12)$$

In the equation, where C denotes the set of clusters and

$$q_c = \sum_{c\epsilon C} \hat{u}_i z_i$$

Where c_j denotes the j th cluster. This weighting matrix accounts for the within-person correlation among observations, so the GMM estimator that uses this version of S_0 will be more efficient than the estimator that ignores this correlation.

4. RESULT

4.1. Unit root tests Results

The descriptive statistics of the variables are provided in Table 1, respectively. A look at the descriptive analysis shows that the investigated variables display some insignificant variances in the statistics. For dependent variables (*lnCEP* and *lnAGL*), the standard deviation values of *lnCEP and lnAGL* are 1.1884 and 0.3095 respectively. The average values of *lnCEP and lnAGL* are 14.8327 and 4.0643 respectively. The average and standard deviation values of *lnGDP* stand at 23.5520 and 1.3417 respectively. *lnAVA*, *lnCPI*, and *lnEAG* use have mean values of 2.8563, 4.1871, and 3.5705 respectively, while the respective standard deviations are 0.6159, 0.4666, and 0.3081 respectively. The large standard deviations of the variables are indications of large variations of the values around their averages, hence, large disparities. To test the distribution properties of these variables, the study uses Jarque-Bera, Skewness, and Kurtosis as indicators. In a normal distribution Kurtosis is 3, and skewness is 0. In what follows, more properties of these variables are presented.

Table-1: Descriptive statistics of variables.

	Mean	Std. Dev.	Min	Max	Variance	Skewness	Kurtosis	Jarque-Bera
lnCEP	14.8327	1.1884	12.28041	17.20494	1.4123	0.2883	2.1017	0.0320
lnLCP	14.0629	1.6526	2.079442	16.91345	2.7311	-2.0979	20.4329	0.0000
lnAGL	4.0643	0.3095	3.463787	4.408396	0.0958	-0.8763	2.4497	3.7e-05
lnCEY	7.6005	0.5252	6.329899	8.487084	0.2758	-0.2358	2.0362	0.0309
lnAVA	2.8563	0.6159	1.455897	3.835522	0.3793	-0.8013	2.6591	3.0e-04
lnFCL	3.4806	1.6469	-0.90561	5.712081	2.7125	-0.5169	2.3071	0.0093
lnCPI	4.1871	0.4666	3.167583	4.933754	0.2177	-0.6150	2.1794	0.0014
lnGDP	7.5413	0.9342	5.949625	9.341611	1.8001	0.3446	2.0090	0.0123
lnEAG	3.5705	0.3081	2.698673	4.089667	0.0949	-0.3092	2.9051	0.3064
lnPOR	4.0248	0.1843	3.745472	4.297272	0.0339	0.0789	1.7016	0.0057

Notes: All variables are expressed in their logarithms. Std. Dev.=standard deviation, Min=minimum, and Max=maximum. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

The correlation coefficient between *lnCEP* and *lnLCP* is 0.7477, implying that the relationship between *lnCEP* and *lnLCP* is 74.8%. The relationship between *lnAGL* and *lnGDP* is approximately 68.9%. The relationship between *lnLCP* and *lnAVA* is approximately strongly by 50.9% in a positive direction, while the relationship between *lnAVA* and *lnCPI* and *lnGDP* is 37.3% and 66.1% in a positive direction. The relationship between *lnCEY* and *lnFCL* and *lnPOR* is approximately 43.9% and 34.6%. The relationship between *lnCPI* and *lnGDP* is approximately 23.6%. The relationship between *lnGDP* and *lnEAG* and *lnPOR* are approximately strongly by 69.1% and 91.8% in a positive direction. The correlation matrix of all variables is shown in Table 2.

Table-2: Correlation matrix of variables.

	lnCEP	*lnLCP*	*lnAGL*	*lnCEY*	*lnAVA*	*lnFCL*	*lnCPI*	*lnGDP*	*lnEAG*	*lnPOR*
lnCEP	1.0000									
lnLCP	0.7477	1.0000								
lnAGL	0.6509	0.5659	1.0000							
lnCEY	-0.0356	-0.3844	-0.2804	1.0000						
lnAVA	-0.4893	-0.5086	-0.4880	0.5539	1.0000					
lnFCL	-0.3640	-0.3890	-0.0519	0.4386	0.5271	1.0000				
lnCPI	0.2384	0.0403	0.1880	0.2507	-0.3727	-0.1237	1.0000			
lnGDP	0.0152	0.0998	-0.1002	-0.1918	0.1040	-0.1803	-0.2499	1.0000		
lnEAG	-0.5536	-0.3171	-0.6946	0.0370	0.5899	-0.0690	-0.5302	-0.6911	1.0000	
lnPOR	-0.8275	-0.7357	-0.8872	0.3460	0.6092	0.1455	-0.1656	-0.9179	0.7129	1.0000

Notes: All variables are expressed in their logarithms. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

The author uses the second-generation non-stationary unit root test of Hadri's (2000) LM test and Harris-Tzavalis (1999) to objectively explore the integration properties of the variables. The Hadri (2000) LM test uses panel data to test the null hypothesis that the data are stationary versus the alternative that at least one panel contains a unit root. Also, Breitung (2000) is a modified test that is robust to cross-sectional dependence. These tests are used to explore the degree to which cross-sectional dependence influences the outcome of the tests. Table 3 presents the results of the unit root tests at a significance level of 10%.

Table-3: Unit Root tests.

VAR	Breitung unit-root test		Harris-Tzavalis unit-root test			Hadri LM test	
	Lambda stat.	p-value	rho stat.	z stat.	p-value	z stat.	p-value
lnCEP	0.2678	0.6056	0.7798	-2.5739	0.0050	24.5405	0.0000
lnLCP	0.1456	0.5579	0.8813	-0.4014	0.3441	3.5768	0.0002
lnAGL	2.1163	0.9828	0.9462	0.9888	0.8386	34.0862	0.0000
lnCEY	0.2992	0.6176	0.7929	-2.2929	0.0109	26.0649	0.0000
lnAVA	0.9472	0.8282	0.8072	-1.9885	0.0234	30.4581	0.0000
lnFCL	-1.4139	0.0787	0.7174	-3.9105	0.0000	13.6489	0.0000
lnCPI	2.2279	0.9871	0.9432	0.9260	0.8228	33.9128	0.0000
lnGDP	4.9234	1.0000	1.0312	2.8110	0.9975	37.2726	0.0000
lnEAG	6.5275	1.0000	1.0761	3.7707	0.9999	32.4147	0.0000
lnPOR	5.1550	1.0000	0.9776	1.6627	0.9518	36.0402	0.0000

Notes: All variables are expressed in their logarithms. stat. – statistic. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

Regarding the PVAR estimation, the last preliminary test is related to the optimal lag-order selection. It is one of the challenging tasks to utilize the PVAR to find out a selection of the optimal lag length. The result of the test of lag-order selection criteria can be seen in Table 4. It requires precision, as the addition of lags to time series models has a direct impact on the estimation process, and the test was conducted for first- to third-order PVAR using the first four lags of the regressors as instruments. The likelihood ratio, sequential modified coefficient of determination (CD) test, the J test (Hansen 1982), which is a statistical test used for testing over-identifying restrictions following the J p-value, the MBIC- Bayesian information criterion, the Akaike information criterion (MAIC), and the Quinn information criterion (MQIC) selected lag 4 as shown at the 0.05 significance level. This is sufficiently long for a panel data study to capture the dynamic relationship so that the MAIC statistic could then be used to choose the estimation of a first-order PVAR.

Table-4: Lag length selection order criteria

Lag	CD	J	J p-value	MBIC	MAIC	MQIC
Model 1: Cereal Production						
1	0.9999943	0.341175	0.9521073	-13.32046	-5.658825	-8.754699
2	0.9999935	0.5758483	0.9019384	-13.08578	-5.424152	-8.520025
3	0.999994	0.5724796	0.9027026	-13.08915	-5.42752	-8.523394
4	0.9999941	0.5111617	0.9977	-26.8121	-11.48884	-17.68059
Model 2: Agricultural Land Use Efficiency						
1	0.9997151	4.763457	0.1899603	-8.898173	-1.236543	-4.332416
2	0.999773	7.019318	0.0712846	-6.642312	1.019318	-2.076555
3	0.9998105	9.069865	0.1696868	-18.2534	-2.930135	-9.121882
4	0.9998204	10.97783	0.2772316	-30.00706	-7.022169	-16.30979

Notes: This procedure gives us the CD test (each test at 5% level). All variables are expressed in their first difference of logarithm. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

4.2. POLS and Fixed-effects Regression with Driscoll-Kraay standard errors Result

The author starts by presenting estimation results from the POLS and the fixed-effects OLS regressions (Table 5). Standard errors are clustered at the country-level to account for potential correlation between countries' errors over time in both types of regression. Note that while these estimates are inconsistent due to the presence of a lagged dependent variable as an explanatory variable, they are informative since the coefficients of the lagged dependent variables from the POLS and the fixed-effects OLS regression are biased in opposite directions. The autoregressive coefficient is biased upwards in the POLS estimation while being biased downwards in the fixed-effects estimation. Therefore, the consistent estimates of the autoregressive coefficient should lie between the fixed-effects and the POLS estimates of the autoregressive coefficient, which is a useful check. The POLS estimates are presented in the first columns of Table 5. The Model 1 results of POLS indicate that a 1% increase in lnAVA, *lnFCL*, *lnGDP*, *lnEAG*, and *lnPOR* all things being equal will lead to a 1.039% increase, 0.312% decrease, 0.724% increase, 0.588 decreases, and 1.04% decrease in *lnCEP* respectively. Moreover, the Model 2 result of POLS indicates that a 1% increase in *lnGDP* and *lnPOR* all things being equal will lead to a 0.224 decrease, and a 2.825% decrease in *lnAGL* respectively. Columns 3 and 4 report the results of the fixed-effects estimation given by equation (5). Furthermore, the Model 1 result of fixed-effects OLS regression indicates that a 1% increase in *lnCPI* and *lnGDP* all things being equal will lead to a 1.261% increase, and 0.429% decrease in *lnCEP* respectively. Also, the Model 2 result of fixed-effects OLS regression indicates that a 1% increase in *lnPOR* all things being equal will lead to a 0.738% increase in *lnCEP* respectively. As discussed earlier, concerning the coefficients on the lagged dependent variables, the FE estimates are likely to be biased downwards and the POLS estimates upwards, and hence, the consistent estimates of the coefficient on the first lag should lie between 1.26 and 1.04, and those of the second lag should lie between -2.83 and -0.61.

Table-5: POLS and Fixed-effects Regression with Driscoll-Kraay standard errors

Model 1: Dependent variable: *lnCEP* (Cereal Production)						
	POLS regression			Fixed-effects OLS regression		
VAR	Coefficient	Std.Err.	Prob.	Coefficient	Std.Err.	Prob.
lnLCP	0.0575(1.10)	0.0521	0.280	0.0155(0.93)	0.0166	0.362
lnAVA	1.039***(12.06)	0.0861	0.000	0.0478(0.42)	0.1146	0.680
lnFCL	-0.312***(5.83)	0.0535	0.000	-0.0802(1.62)	0.0495	0.117
lnCPI	0.208(1.80)	0.1151	0.082	1.261***(35.48)	0.0355	0.000
lnGDP	0.724***(12.58)	0.0575	0.000	-0.429***(-6.12)	0.0700	0.000
lnEAG	-0.588* (-2.32)	0.2531	0.028	0.0302(0.18)	0.1662	0.857
lnPOR	-1.04* (-2.11)	0.4929	0.044	-0.605 (-1.21)	0.5010	0.237
Constant	0.513 (0.15)	3.4263	0.882	21.9*** (6.71)	3.2646	0.000
Model 2: Dependent variable: *lnAGL* (Agricultural Land Use)						
lnCEY	0.0802(1.73)	0.0464	0.096	0.0058(0.39)	0.0148	0.699
lnAVA	-0.061(-1.34)	0.0456	0.192	0.00192(0.35)	0.0054	0.727
lnFCL	0.000069(0.01)	0.0058	0.991	0.00271(1.17)	0.0023	0.251
lnCPI	0.0064(0.16)	0.0394	0.872	-0.00449(-0.16)	0.0277	0.873
lnGDP	-0.224***(-12.41)	0.0180	0.000	0.0203(1.16)	0.0175	0.257
lnEAG	-0.0947(-1.81)	0.0522	0.081	0.0111(0.74)	0.0149	0.466
lnPOR	-2.825***(-23.07)	0.1224	0.000	0.738***(14.63)	0.0504	0.000
Constant	20.58***(33.68)	0.6111	0.000	0.537(0.93)	0.5756	0.359

Notes: *, ** and *** indicate significant of the variables at 1, 5 and 10% significance level. All variables are expressed in their logarithm. Std.Err. - Standard error. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

4.3. Panel Fully Modified Least Squares (FMOLS) Cointegrating Regression Result

Table 6 reports the estimation results of the dynamic specification using FMOLS. The analysis starts with estimating the relationship between *lnCEP* and *lnAVA* in the basic EKC model. The Model 1 results of FMOLS indicate that a 1% increase in *lnAVA*, *lnFCL*, *lnGDP*, and *lnEAG*, all things being equal will lead to a 1.143% increase, 0.377% decrease, 0.784 increase, and 1.186% decrease in *lnCEP* respectively. Similar results from Model 2 shows that a 1% increase in lnGDP contributes 0.312% to *lnAGL* in the positive direction. However, a 1% increase in *lnPOR* contributes 3.307% to *lnAGL* in the positive direction. Furthermore, similar results regarding the *lnGDP* in terms of the magnitudes of the estimated coefficients are found (Model 1 and 2); this is another evidence of robust results. Overall, the results obtained from different specifications are consistent across different estimators (dynamic and static); the robustness of the results is a piece of clear evidence for the existence of the EKC between *lnCEP* and *lnAGL* in Central Asian countries.

Table-6: Fully Modified Least Squares (FMOLS) Cointegrating Regression

Model 1: lnCEP (Cereal Production)				**Model 2: lnAGL (Agricultural Land Use)**			
VAR	Coef. (Std.Err.)	z	Prob.	VAR	Coef. (Std.Err.)	z	Prob.
lnLCP	0.0311(0.55)	0.55	0.581	*lnCEY*	0.134(1.40)	1.40	0.162
lnAVA	1.143***(7.51)	7.51	0.000	*lnAVA*	-0.125(-1.18)	-1.18	0.237
lnFCL	-0.377***(-4.02)	-4.02	0.000	*lnFCL*	-0.00872(-0.17)	-0.17	0.866
lnCPI	-0.0873(-0.59)	-0.59	0.553	*lnCPI*	0.0377(0.45)	0.45	0.656
lnGDP	0.784***(5.40)	5.40	0.000	*lnGDP*	-0.312***(-4.31)	-4.31	0.000
lnEAG	-1.186**(-3.15)	-3.15	0.002	*lnEAG*	-0.0987(-0.51)	-0.51	0.612
lnPOR	-0.323(-0.35)	-0.35	0.724	*lnPOR*	-3.307***(-6.92)	-6.92	0.000
Linear	0.00201(0.56)	0.56	0.579	Linear	0.000353(0.18)	0.18	0.860
Constant	-0.287(-0.04)	-0.04	0.966	Constant	24.25***(6.96)	6.96	0.000

Notes: *, ** and *** indicate significant of the variables at 1, 5 and 10% significance level. All variables are expressed in their logarithm. Coef. – Coefficient, Std.Err. - Standard error. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

4.4. Panel Vector Autoregression with GMM Estimation Result

In Table 7, Model 1 results of GMM (1) indicate that a 1% increase in *lnLCP*, *lnAVA*, *lnCPI*, *lnGDP*, and *lnPOR*, all things being equal will lead to a 0.184% decrease, 0.209% decrease, 0.59% increase, 0.36% decrease, and 2.01% decrease in *lnCEP* respectively. It appears that the crop production index has a positive and significant impact on cereal production. GMM (2) that a 1% increase in *lnLCP*, *lnAVA*, *lnFCL lnCPI*, *lnGDP*, *lnEAG*, and *lnPOR*, all things being equal will lead to a 2.753% decrease, 0.785% decrease, 0.807% increase, 4.704% decrease, 1.447% increase, 3.762% increase, and 26.02% decrease in *lnCEP* respectively. In cereal production in Central Asia, economic growth, fertilizer use, and agricultural employment play a positive and important role in increasing production. Similar result from GMM (3) indicate that a 1% increase in *lnLCP*, *lnAVA*, *lnFCL*, *lnCPI*, *lnGDP*, and *lnEAG*, all variables being equal will lead to a 0.664% increase, 0.725% increase, 0.158% decrease, 0.462% increase, 0.862% decrease, and 1.152% decrease in *lnCEP* respectively. These results show that the area land under cereal production, agricultural value-added, and the crop production index play an important role in cereal production. GMM (4) reports that a 1% increase in *lnLCP*, *lnFCL*, *lnCPI*, *lnGDP*, *lnEAG*, and *lnPOR*, all things being equal will lead to a 0.422% decrease, 0.742% increase, 0.0642% decrease, 0.393% decrease, 1.255% decrease, and 3.226% decrease in lnCEP respectively. Equation GMM (4) once again demonstrates that the use of fertilizers has a positive effect on cereal yield. In GMM (5), this result show that a 1% increase *lnLCP*, *lnAVA*, *lnFCL lnCPI*, *lnGDP*, and *lnPOR*, all things being equal will lead to a 0.133% decrease, 0.164% decrease, 0.0776% decrease, 1.056% increase, 0.274% decrease, and 1.695% decrease in *lnCEP* respectively. As in GMM (6) reports that a 1% increase in *lnAVA*, *lnFCL*, *lnGDP*, and *lnPOR*, all things being equal will lead to a 0.107% decrease, 0.0622% decrease, 0.923% increase, and 0.604% decrease in *lnCEP* respectively. This result also shows that economic growth has a positive effect on cereal production. Furthermore, GMM (7) also reports that a 1% increase in *lnAVA*, *lnCPI*, *lnGDP*, *lnEAG*, and *lnPOR*, all things being equal will lead to a 0.0392% increase, 0.0636% increase, 0.0267% decrease, 1.059% increase, and 0.159% decrease in *lnCEP* respectively. The results show that agricultural value-added, crop production index, and agricultural employment have a positive effect on cereal production. In addition, GMM (8) all reports that a 1% increase in *lnLCP*, *lnAVA*, *lnFCL*, *lnCPI*, *lnGDP*, *lnEAG*, and *lnPOR*, all things being equal will lead to a 0.00453% decrease, 0.00172% decrease, 0.00461% increase, 0.0186% increase, 0.00706% decrease, 0.0206% increase, and 0.89% increase in *lnCEP* respectively. These results show that additional fertilizer use, crop production index, agricultural employment, and rural population play an important role in cereal production.

Model 2 results of GMM (A) indicate that a 1% increase in *lnCEY*, *lnAVA*, *lnFCL*, *lnCPI*, *lnGDP*, and *lnPOR*, all things being equal will lead to a 0.0125% increase, 0.00194% increase, 0.00199% increase, 0.0206% decrease, 0.00566% increase, and 0.0578% decrease in *lnAGL* respectively. The results show that crop yields, agricultural value-added, additional fertilizer use, and economic growth all have a positive effect on agricultural land use. GMM (B) shows that a 1% increase in *lnCEY*, *lnAVA*, *lnCPI*, *lnGDP*, *lnEAG*, and *lnPOR*, all things being equal will lead to a 0.463% increase, 0.202% decrease, 0.654% increase, 0.321% decrease, 0.391% increase, and 2.25% decrease in *lnAGL* respectively. The results show that cereal yield, and therefore the crop production index and agricultural employment, have a very positive effect on agricultural land use. As reported in GMM (C), the indicate that a 1% increase in *lnAVA*, *lnFCL*, *lnCPI*, *lnGDP*, and *lnEAG*, all things being equal will lead to a 0.913% increase, 0.316% decrease, 0.211% increase, 0.728% decrease, and 1.528% decrease in *lnAGL* respectively. Interestingly, the agricultural value-added and the crop production index play an important role in the use of agricultural land. GMM (D) present the result that a 1% increase in *lnCEY*, *lnFCL*, *lnCPI*, *lnGDP*, *lnEAG*, and *lnPOR*, all things being equal will lead to a 0.262% increase, 0.742% increase, 0.161% decrease, 0.456% decrease, 1.35% decrease, and 2.113% decrease in *lnAGL* respectively. This emphasizes the use of high-quality organic fertilizers to obtain rich crops from the fields, which positively affects the use of agricultural land. When applying GMM (E), the results show that a 1% increase in *lnCEY*, *lnAVA*, *lnCPI*, *lnGDP*, and *lnPOR*, all things being equal will lead to a 0.141% decrease, 0.211% decrease, 1.303% increase, 0.326% decrease, and 2.822% decrease in *lnAGL* respectively. The results show that the crop production index has a positive effect on the use of agriculture. On the other hand, GMM (F) also show that that a 1% increase in *lnCEY*, *lnAVA*, *lnCPI*, *lnGDP*, *lnEAG*, and *lnPOR*, all things being equal will lead to a 0.0937% decrease, 0.192% decrease, 0.261% increase, 0.825% increase, 0.337% increase, and 2.708% decrease in *lnAGL* respectively. The crop production index, economic growth, and agricultural employment confirm that they play an important role in the use of agricultural land. Of course, employment-related economic growth will improve living standards in rural Central Asia. Regarding GMM (G), this finding show that a 1% increase in *lnAVA*, *lnEAG*, and *lnPOR* will increase *lnAGL* by 0.0556%, 0.999%, and 0.264% respectively. The results show that agricultural value-added, agricultural employment, and rural populations play a vital role in the use of arable land and, as noted above, have a growth advantage. Furthermore, GMM (H) shows that a 1% increase in *lnAVA*, *lnFCL*, *lnCPI*, *lnGDP*, and *lnPOR*, all things being equal will lead to a 0.00305% increase, 0.00217% increase, 0.00624% increase, 0.00562% decrease, and 1.041% increase in *lnAGL* respectively. Overall, as in previous results, it was shown that agricultural value-added, fertilizer use, crop production indices, and rural population size positively influence farmland observations.

Table-7: GMM results with Cereal Production and Agricultural Land Use Efficiency

Model 1: GMM results with Cereal Production (*lnCEP*)								
VAR	GMM (1)	GMM (2)	GMM (3)	GMM (4)	GMM (5)	GMM (6)	GMM (7)	GMM (8)
lnCEP	0.564***	4.128***	-0.258**	0.0760	0.0303	0.120***	-0.0512***	-0.0107***
(lag 1)	(0.120)	(0.467)	(0.121)	(0.150)	(0.0803)	(0.0397)	(0.0113)	(0.00182)
lnLCP	-0.184**	-2.753***	0.664***	-0.422***	-0.133**	0.00519	0.00719	-0.00453***
	(0.0909)	(0.489)	(0.0764)	(0.124)	(0.0518)	(0.0220)	(0.00693)	(0.00168)
lnAVA	-0.209***	-0.785***	0.725***	0.0691	-0.164***	-0.107***	0.0392***	-0.00172**
	(0.0546)	(0.292)	(0.0515)	(0.0897)	(0.0354)	(0.0153)	(0.00676)	(0.000859)
lnFCL	-0.0194	0.807***	-0.158***	0.742***	-0.0776***	-0.0622***	0.00396	0.00461***
	(0.0300)	(0.155)	(0.0232)	(0.0497)	(0.0181)	(0.00860)	(0.00332)	(0.000451)
lnCPI	0.590***	-4.704***	0.462**	-0.0642	1.056***	-0.0574	0.0636***	0.0186***
	(0.150)	(0.777)	(0.182)	(0.206)	(0.0976)	(0.0552)	(0.0160)	(0.00263)
lnGDP	-0.360***	1.447***	-0.862***	-0.393***	-0.274***	0.923***	-0.0267**	-0.00706***
	(0.0935)	(0.556)	(0.133)	(0.116)	(0.0564)	(0.0314)	(0.0105)	(0.00211)
lnEAG	0.108	3.762***	-1.152***	-1.255***	-0.239	-0.0366	1.059***	0.0206***
	(0.257)	(1.067)	(0.177)	(0.320)	(0.174)	(0.0478)	(0.0263)	(0.00273)
lnPOR	-2.010***	-26.02***	0.306	-3.226***	-1.695***	-0.604***	-0.159***	0.890***
	(0.493)	(5.091)	(0.643)	(1.077)	(0.316)	(0.159)	(0.0610)	(0.0144)
Model 2: GMM results with Agricultural Land Use Efficiency (*lnAGL*)								
VAR	GMM (A)	GMM (B)	GMM (C)	GMM (D)	GMM (E)	GMM (F)	GMM (G)	GMM (H)
lnAGL	0.967***	3.350***	-0.871	0.395	2.302***	2.381***	-0.349***	-0.118***
(lag1)	(0.0355)	(1.089)	(1.583)	(1.047)	(0.845)	(0.535)	(0.127)	(0.0139)
lnCEY	0.0125***	0.463***	-0.0946	0.262**	-0.141***	-0.0937***	-0.000874	-0.00124
	(0.00185)	(0.0954)	(0.0794)	(0.107)	(0.0520)	(0.0214)	(0.00723)	(0.000769)
lnAVA	0.00194*	-0.202***	0.913***	0.0673	-0.211***	-0.192***	0.0556***	0.00305***
	(0.00112)	(0.0557)	(0.0607)	(0.0563)	(0.0365)	(0.0177)	(0.00501)	(0.000586)
lnFCL	0.00199**	0.0233	-0.316***	0.742***	-0.0164	-0.00781	-0.00178	0.00217***
	(0.000917)	(0.0349)	(0.0332)	(0.0348)	(0.0236)	(0.0155)	(0.00289)	(0.000298)
lnCPI	-0.0206***	0.654***	0.211**	-0.161*	1.303***	0.261***	-0.00968	0.00624***
	(0.00273)	(0.0979)	(0.0901)	(0.0899)	(0.0549)	(0.0303)	(0.00971)	(0.000969)
lnGDP	0.00566*	-0.321***	-0.728***	-0.456***	-0.326***	0.825***	0.000911	-0.00562***
	(0.00337)	(0.0826)	(0.142)	(0.124)	(0.0554)	(0.0514)	(0.00879)	(0.000714)
lnEAG	-0.00511	0.391*	-1.528***	-1.350***	0.137	0.337***	0.999***	-0.00149
	(0.00675)	(0.200)	(0.248)	(0.288)	(0.142)	(0.112)	(0.0210)	(0.00171)
lnPOR	-0.0578**	-2.250*	-0.193	-2.113*	-2.822***	-2.708***	0.264**	1.041***
	(0.0294)	(1.163)	(1.517)	(1.095)	(0.873)	(0.477)	(0.123)	(0.0138)

Notes: *, ** and *** indicate significant of the variables at 1, 5 and 10% significance level. All variables are expressed in their logarithm. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

4.5. Dynamic Panel-data estimation, One-Step system GMM Result

Table 8 shows the dynamic panel data estimation using one-step difference GMM. First, the coefficient of Cereal Production (*lnCEP*) and Agricultural Land Use Efficiency (*lnAGL*) is negative and significant at the 5% significant level. The results of Model 1 indicate that a 1% increase in *lnLCP* and *lnCPI*, all things being equal will lead to a 0.142% increase, 1.562% decrease in *lnCEP* respectively. Second, only in the Model 1 and Model 2 case does this test statistic suggest that the author should reject the null hypothesis of no first-order serial correlation (0.048 and 0.055) but the author should not reject the null of no second-order serial correlation (0.458 and 0.727). *lnCEP* and *lnAGL* were highly statistically significant predictors of economic growth in Central Asian countries (0.869 and 1.006). This result holds conditional on the control variables of the study and the robust estimation framework author used. Sargan's test result suggested that internal instruments (IV) used, were valid. In contrast, however, the Arellano-Bond test of first-order autocorrelation (AR1) that was supposed to be significant, was indeed not significant. Even though *lnCEP* and *lnAGL* were significant as the sole independent variable, *lnCPI* was insignificant and positively related to the current economy in Central Asia.

Table-8: Dynamic panel-data estimation, One-Step system GMM

Model 1: Cereal Production				**Model 2: Agricultural Land Use Efficiency**			
VAR	Coef. (Std.Err.)	t-stat	Prob.	VAR	Coef. (Std.Err.)	t-stat	Prob.
lnCEP	0.869***(0.0456)	19.07	0.000	*lnAGL*	1.006***(0.0126)	79.64	0.000
lnLCP	0.142*(0.0527)	2.69	0.054	*lnCEY*	0.00813(0.00508)	1.60	0.185
lnAVA	0.0549(0.0572)	0.96	0.391	*lnAVA*	-0.00421(0.00592)	-0.71	0.516
lnFCL	0.0426(0.0315)	1.35	0.248	*lnFCL*	-0.000463(0.00123)	-0.38	0.727
lnCPI	-1.562***(0.126)	-12.35	0.000	*lnCPI*	-0.0142(0.00678)	-2.09	0.105
lnGDP	0.184(0.296)	0.62	0.567	*lnGDP*	-0.00558(0.0150)	-0.37	0.728
lnEAG	0.145(0.435)	0.33	0.756	*lnEAG*	-0.0138(0.0130)	-1.06	0.351
lnPOR	0.228(2.368)	0.10	0.928	*lnPOR*	-0.364(0.323)	-1.13	0.322
Constant	-3.990(2.146)	-1.86	0.137	Constant	-0.0244(0.326)	-0.07	0.944
Sargan test of overid. restrictions			0.002				0.000
Arellano-Bond Tests							
1st order autocorrelation (AR1)			0.048				0.055
2nd order autocorrelation (AR2)			0.458				0.727

Notes: *, ** and *** indicate significant of the variables at 1, 5 and 10% significance level. All variables are expressed in their logarithm. Coef. – Coefficient, Std.Err. - Standard error, overid. - Overidentify. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

4.6. Instrumental variables GMM regression Result

The Model 1 results of Instrumental variables GMM regression (Table 9) indicate that a 1% increase in A 1% increase in *lnAVA* contributes 1.039% to *lnCEP* respectively. It is natural for individuals and organizations engaged in agricultural activities to sell agricultural products with added value in the cereal production process. A 1% increase in *lnFCL* contributes 0.312% to *lnCEP* in the negative direction. Fertilizer and pesticide impacts are negative by reducing cereal production and ensuring environmental quality. A 1% increase in *lnCPI* contributes to a 0.208% rise in *lnCEP*. The crop production index of previous years has the advantage of increasing the volume of cereal production and the advantage of controlling the production process. A 1% increase in *lnGDP* leads to a 0.724% rise in *lnCEP*. Cereal production increases with the growth of the economy. As a result, soil erosion and crop pollution are likely to increase, and the Kuznets curve hypothesis in Central Asia is supported by this example from Central Asia. As the economy grows, the need to improve the quality of the environment grows. A 1% increase in *lnEAG* contributes 0.588% to *lnCEP* in the negative direction. These results indicate that agricultural employment can reduce cereal production. This notion shows efficiency and technological change in the process of cereal production and consumption. Also, a 1% increase in *lnPOR* contributes 1.04% to *lnCEP* in the negative direction. The rural population is slightly reducing cereal production. It depends on the growth of the population of Central Asia. Furthermore, In Model 2, the similar results of regression indicate that a 1% increase in *lnCEY*, *lnAVA*, *lnGDP*, *lnEAG*, and *lnPOR*, all things being equal will lead to a 0.0802% increase, 0.061% decrease, 0.224% decrease, 0.0947% decrease, and 2.825% decrease in *lnAGL* respectively. Getting more crops increases the use of agricultural land. A larger crop will yield a bountiful harvest, but a high-quality crop will have a positive impact on future results. In contrast, agricultural value-added in Central Asia, agricultural employment, rural population, and economic growth appear to reduce the efficiency of agricultural land, but the opposite is true. The time for human participation in crop production has passed, and this is directly related to the progress of new technologies. Thanks to technological advances, it is natural that value-added products are reaching consumers in the agricultural sector. In addition, in the case of the rural population, as noted above, population growth is directly related to the use of agricultural land and the consumption of cereals. However, it is still important for ordinary rural households to supply the city market with fruits and vegetables. In addition, as the economy grows, so does the use of arable land as human consumption of cereal and the variety of products they consume increases. Recently, farmers in Central Asia have been using more energy to produce cereal, which is another driving force behind the economy.

Table-9: Instrumental variables GMM regression

Model 1: *lnCEP* (Cereal Production)				**Model 2: *lnAGL* (Agricultural Land Use)**			
VAR	Coef. (z)	Std.Err.	Prob.	VAR	Coef. (z)	Std.Err.	Prob.
lnLCP	0.0575(1.03)	0.0558	0.304	*lnCEY*	0.0802**(2.82)	0.0284	0.005
lnAVA	1.039***(14.11)	0.0736	0.000	*lnAVA*	-0.0610*(-1.99)	0.0306	0.047
lnFCL	-0.312***(-9.67)	0.0322	0.000	*lnFCL*	0.000069(0.01)	0.0049	0.989
lnCPI	0.208*(2.42)	0.0859	0.016	*lnCPI*	0.0064(0.22)	0.0285	0.823
lnGDP	0.724***(13.08)	0.0553	0.000	*lnGDP*	-0.224***(-12.52)	0.0178	0.000
lnEAG	-0.588***(-3.59)	0.1640	0.000	*lnEAG*	-0.0947* (-2.29)	0.0413	0.022
lnPOR	-1.040*(-2.36)	0.4413	0.018	*lnPOR*	-2.825***(-21.57)	0.1309	0.000
Constant	0.513 (0.18)	2.8485	0.857	Constant	20.58***(27.55)	0.7470	0.000

Notes: *, ** and *** indicate significant of the variables at 1, 5 and 10% significance level. All variables are expressed in their logarithm. Coef. – Coefficient. Data source: Compiled by the author based on WDI, IMF, FOA, and IEA database (1992-2020).

5. DISCUSSION

Central Asia is a country with a high level of agricultural production, 60% of the population lives in rural areas, while agriculture accounts for more than 45% of the total employment and on average almost 25% of GDP. In Central Asia, arable land is usually located in desert and mountain pastures. Suitable arable land accounts for about 20 percent of the total agricultural land area. Agricultural land use in Central Asia can be broadly divided into three parts and is used by rural households in the form of mining, agricultural, and livestock holdings. This study will focus on agricultural use and cereal production in the agricultural sector only. While Kazakhstan, Kyrgyzstan, and Turkmenistan have supported land privatization since independence in the early 1990s, Tajikistan and Uzbekistan are still working to privatize land (Zhai *et al.*, 2018). As a result, different Central Asian countries are pursuing different land, agriculture, and forestry policies, which have different impacts on the spatial and temporal dynamics of arable land. In addition, in 2005, Kazakhstan announced a “1 Billion US dollars Agricultural Prosperity Plan” to stabilize agricultural prices and increase agricultural sales in domestic and foreign markets (Petrick and Pomfret, 2016). As a result, significant support was provided for the expansion of arable land by 17,423.8 square kilometer. As a result of the implementation of the policy adopted by the Minister of Agriculture, Water Resources and Processing Industry of Kyrgyzstan in 2008, the cultivated area in Kyrgyzstan increased by a total of 876.51 square kilometer until 2010. Similarly, the Government of Turkmenistan implemented the Law on “Forests of Turkmenistan” (2011) and the “National Forestry Program of Turkmenistan (2013-2020)” in 2010 to increase forest cover, resulting in a gradual increase in the arable land area of Turkmenistan to about 98.28 square kilometer. The essence of land reform in Tajikistan and Uzbekistan, countries where land has become state property, is the redistribution of state agricultural land, giving farmers only land use rights. Compared to Kazakhstan, Turkmenistan, and Kyrgyzstan, the sown area in Tajikistan has slightly decreased by 0.63 square kilometer, and in Uzbekistan - by 18.83 square kilometer. In addition, the 1992 “Law of Tajikistan on Farms” and the 1993 Uzbekistan Order on the “Reorganization of State Farms” increased the number of farms from less than 2,000 in 1991 to 50,000 in 2001. These farms were mainly engaged in the production of livestock products and vegetables and did little to contribute to the cultivation of cereals. Currently, the two most important crops in Central Asia are rice and wheat. Apart from these two main crops, the Central Asia region produces a wide range of products such as barley, corn, flax, grapes, potatoes, rice, sugar beets, sunflowers, tobacco, apricots, pears, plums, apples, cherries, pomegranates, and melons. In addition, Central Asia is mostly a desert, where most of the agricultural production is cotton production. More than 80 percent of arable land in Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan is irrigated and only wheat is produced. Further large-scale exports of fruits and vegetables to the European Union and neighboring countries will play an important role in the economy, and the agricultural sector will become an increasingly important player in the trade sector. Cotton growing made a significant contribution to the economies of Uzbekistan, Turkmenistan, and Tajikistan in the 1990s. The cotton sector accounts for about 18 percent of Uzbekistan's GDP, almost 25 percent in Turkmenistan, and almost 10 percent in Tajikistan. In Tajikistan and Uzbekistan, cotton accounts for about 5 percent of GDP, and in Turkmenistan about two percent. However, cotton-growing remains important in these countries. Today, in addition to growing cotton, these countries have become important producers of fruits and vegetables. Most rural households keep one or two cows and use dung as a fuel source instead of fertilizer, which is why Central Asian countries use less organic fertilizers such as dung. Disruptions in support of agricultural production are associated with fertilizers and pesticides. Moreover, most countries are forced to import fertilizers and pesticides. In recent years, fertilizers and pesticides used in Tajikistan have been imported from Uzbekistan, Russia, Pakistan, and China, but recently a Chinese company has invested in rebuilding an old fertilizer plant in Tajikistan. Farmers need to pay attention to soil fertility, weed control, and crop cycles to achieve high yields. This study confirmed the EKC's hypothesis of the relationship between economic growth in cereal production and the efficiency of agricultural land use. Surprisingly, agricultural land use is now considered one of the main causes of land degradation. Therefore, we emphasize that planning the use of agricultural land is important for the sustainability of the socio-ecological system. In addition, our results show that socially and environmentally sound agricultural land use policies are important for achieving sustainability. Agricultural production in Central Asia can benefit millions of rural residents. However, the sector's inability to diversify exports will allow it to play a more important role in the economies of Central Asia. In addition, further research is needed to examine the impact of agricultural activities on other areas of water and land use. To ensure sufficient food and feed supplies for a growing population and an intense market, it is important to manage limited water and land resources in the interest of sustainable quantity and quality.

6. CONCLUSION AND RECOMMENDATIONS

The main objective of this paper is to examine the environmental Kuznets curve (EKC) hypothesis in Central Asian countries as well as to validate or invalidate the consistency of the different estimation results, using panel data, over the period 1992 to 2020. The EKC survey is a basic econometric research method that determines whether there is a strong correlation between economic growth and environmental sustainability. Most of the EKC studies have examined the relationship between environmental pollution and economic growth. In this study, the researcher also used differences and Generalized Method of Moments (GMM) estimation calculations to examine causal economic impacts on cereal production and agricultural land use. The GMM dynamic panel data model extends the persistent exposure model and, in addition to the internal transformation process, also includes deprecated dependent variable values as a means of managing dynamic internal state. In this study, the researcher used cereal production and agricultural land use as environmental indicators and theoretically considered resource use to be similar to pollution. This study aims to examine the relationship between cereal production in Central Asia and the efficiency of agricultural land use and economic growth. The study achieved this objective by employing various econometrics techniques such as Pooled Ordinary least squares (POLS) and Fixed-effects Regression with Driscoll-Kraay standard errors, Panel Fully Modified Least Squares (FMOLS) Cointegrating Regression, Panel Vector Autoregression (PVAR) with GMM Estimation, and Dynamic Panel-data estimation, One-Step system GMM. An empirical analysis uses the Breitung, Harris-Tzavalis, and Hadri LM Panel Unit Root tests to test the basics of the data unit based on this information. Following the best econometric practices, the descriptive statistics, Correlation matrix were computed to understand the characteristics of the variables and countries under analysis and to ensure that the necessary conditions for the estimation were fulfilled. Also, The PVAR specification was based on the results of the Lag-order selection criteria, and the stability of the PVAR model was checked through the observation of the Instrumental variables GMM regression. The results of this study indicate that the GMM score supports the EKC hypothesis. These inverse U-shaped EKCs between GDP per capita in Central Asia and cereal production and agricultural land use support the assumptions in both models. The EKC forecast confirms that economic growth in Central Asia is harming cereal production and agricultural land use. On the other hand, the cointegration correlation shows the results of a sequential experiment from the index of agricultural land use and food production to green growth in cereal food production. The agricultural sector is essential for the livelihoods of people in developing countries. Therefore, if agricultural lands in Central Asia continue to improve and cereal yields increase, they can become a global “breadbasket”. As the world's population is expected to grow over the next decade, adaptive agricultural management will become more important and reduce the potential risk of future socio-ecological disasters. Improving agricultural land use requires a sustainable approach to increasing crop yields and further strengthening the balance of economic development. To increase the yield of cereal crops, it is necessary to introduce high-yielding, early-maturing varieties that are resistant to the harsh climatic conditions of Central Asia. These models can be improved by continuing to use them in the agricultural analysis of Central Asia. Finally, these countries need to design effective economic development policies and focus on their implementation in line with policies to improve agricultural land use. Economic growth is not a cure for improving the quality of the environment, and policies to support economic growth are not a substitute for environmental policies.

REFERENCES

- Ajanaku, B. A., & Collins, A. R. (2021). Economic growth and deforestation in African countries: Is the environmental Kuznets curve hypothesis applicable? *Forest Policy and Economics*, 129, 102488. https://doi.org/10.1016/j.forpol.2021.102488
- Akbar, M., & Jamil, F. (2012). Monetary and fiscal policies' effect on agricultural growth: GMM estimation and simulation analysis. *Economic Modelling*, 29(5), 1909-1920. https://doi.org/10.1016/j.econmod.2012.06.001
- Akhmadiyeva, Z., & Herzfeld, T. (2021). How does practice matches land laws in Central Asia? Land Use Policy, 109, 105726. https://doi.org/10.1016/j.landusepol.2021.105726

- Andrews, D. W., & Lu, B. (2001). Consistent model and moment selection procedures for GMM estimation with application to dynamic panel data models. *Journal of econometrics*, *101*(1), 123-164. https://doi.org/10.1016/S0304-4076(00)00077-4
- Banto, J. M., & Monsia, A. F. (2021). Microfinance institutions, banking, growth and transmission channel: A GMM panel data analysis from developing countries. *The Quarterly Review of Economics and Finance*, 79, 126-150. https://doi.org/10.1016/j.qref.2020.06.004
- Bengochea Paz, D., Henderson, K., & Loreau, M. (2020). Agricultural land use and the sustainability of social-ecological systems. *Ecological Modelling*, 437(C). https://doi.org/10.1016/j.ecolmodel.2020.109312
- Bimonte, S. (2017). EKC and the income elasticity hypothesis Land for housing or land for future? Ecological Indicators, 73, 800-808. https://doi.org/10.1016/j.ecolind.2016.10.039
- Bimonte, S., & Stabile, A. (2017). Land consumption and income in Italy: a case of inverted EKC. *Ecological Economics*, 131, 36-43. https://doi.org/10.1016/j.ecolecon.2016.08.016
- Boubellouta, B., & Kusch-Brandt, S. (2021). Relationship between economic growth and mismanaged e-waste: Panel data evidence from 27 EU countries analyzed under the Kuznets curve hypothesis. *Waste Management*, *120*, 85-97. https://doi.org/10.1016/j.wasman.2020.11.032
- Breitung, J. (2001), "The local power of some unit root tests for panel data", *Emerald Group Publishing Limited*, Bingley, pp. 161-177. https://doi.org/10.1016/S0731-9053(00)15006-6
- Chen, W., Zeng, J., & Li, N. (2021). Change in land-use structure due to urbanization in China. *Journal of Cleaner Production*, 321, 128986. https://doi.org/10.1016/j.jclepro.2021.128986
- Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics*, 80(4), 549-560. https://doi.org/10.1162/003465398557825
- Eltazarov, S., Bobojonov, I., Kuhn, L., & Glauben, T. (2021). Mapping weather risk–A multi-indicator analysis of satellite-based weather data for agricultural index insurance development in semi-arid and arid zones of Central Asia. *Climate Services*, 23, 100251. https://doi.org/10.1016/j.cliser.2021.100251
- Feng, W., Lu, H., Yao, T., Guan, Y., Xue, Y., & Yu, Q. (2021). Water environmental pressure assessment in agricultural systems in Central Asia based on an Integrated Excess Nitrogen Load Model. *Science of The Total Environment*, 803, 149912. https://doi.org/10.1016/j.scitotenv.2021.149912
- Gan, T., Yang, H., & Liang, W. (2021). How do urban haze pollution and economic development affect each other? Empirical evidence from 287 Chinese cities during 2000–2016. *Sustainable Cities and Society*, *65*, 102642. https://doi.org/10.1016/j.scs.2020.102642
- Gene M. Grossman, Alan B. Krueger (1995), Economic Growth and the Environment, *The Quarterly Journal of Economics*, Volume 110, Issue 2, Pages 353–377, https://doi.org/10.2307/2118443
- Guo, L., Li, H., Cao, X., Cao, A., & Huang, M. (2021). Effect of agricultural subsidies on the use of chemical fertilizer. *Journal of Environmental Management*, 299, 113621. https://doi.org/10.1016/j.jenvman.2021.113621
- Guo, X. X., Zhao, D., Zhuang, M. H., Wang, C., & Zhang, F. S. (2021). Fertilizer and pesticide reduction in cherry tomato production to achieve multiple environmental benefits in Guangxi, China. *Science of The Total Environment*, 148527. https://doi.org/10.1016/j.scitotenv.2021.148527
- Hadri, K. (2000). Testing for stationarity in heterogeneous panel data. The Econometrics Journal, 3(2), 148-161. https://doi.org/10.1111/1368-423X.00043
- Haider, A., Bashir, A., & ul Husnain, M. I. (2020). Impact of agricultural land use and economic growth on nitrous oxide emissions: Evidence from developed and developing countries. *Science of the Total Environment*, 741, 140421. https://doi.org/10.1016/j.scitotenv.2020.140421
- Hansen, L. P. (1982). Large sample properties of generalized method of moments estimators. *Econometrica: Journal of the econometric society*, 1029-1054. https://doi.org/10.2307/1912775
- Harris, R.D.F. and Tzavalis, E., 1999, Inference for Unit roots in Dynamic Panels where the Time Dimension is Fixed, *Journal of Econometrics*, 91, 201-226. https://doi.org/10.1016/S0304-4076(98)00076-1
- Holtz-Eakin. D (1988). Testing for individual effects in autoregressive models. *Journal of Econometrics*, 39(3), 297-307. https://doi.org/10.1016/0304-4076(88)90060-7
- Jha, C. K. (2019). Financial reforms and corruption: Evidence using GMM estimation. *International Review of Economics & Finance*, 62, 66-78. https://doi.org/10.1016/j.iref.2019.03.003
- Jiang, J. J., Ye, B., Zhou, N., & Zhang, X. L. (2019). Decoupling analysis and environmental Kuznets curve modelling of provincial-level CO2 emissions and economic growth in China: A case study. *Journal of Cleaner Production*, 212, 1242-1255. https://doi.org/10.1016/j.jclepro.2018.12.116
- Jiang, Y., Qiao, G., & Lu, J. (2020). Impacts of the new international land–sea trade corridor on the freight transport structure in China, central Asia, the ASEAN countries and the EU. *Research in Transportation Business & Management*, 35,

100419. https://doi.org/10.1016/j.rtbm.2019.100419

- Katz, D. (2015). Water use and economic growth: reconsidering the Environmental Kuznets Curve relationship. *Journal of Cleaner Production*, 88, 205-213. https://doi.org/10.1016/j.jclepro.2014.08.017
- Khan, H. U. R., Islam, T., Yousaf, S. U., Zaman, K., Shoukry, A. M., Sharkawy, M. A., & Hishan, S. S. (2019). The impact of financial development indicators on natural resource markets: Evidence from two-step GMM estimator. *Resources Policy*, 62, 240-255. https://doi.org/10.1016/j.resourpol.2019.04.002
- Koondhar, M. A., Aziz, N., Tan, Z., Yang, S., Abbasi, K. R., & Kong, R. (2021). Green growth of cereal food production under the constraints of agricultural carbon emissions: A new insights from ARDL and VECM models. *Sustainable Energy Technologies and Assessments*, 47, 101452. https://doi.org/10.1016/j.seta.2021.101452
- Koondhar, M. A., Udemba, E. N., Cheng, Y., Khan, Z. A., Koondhar, M. A., Batool, M., & Kong, R. (2021). Asymmetric causality among carbon emission from agriculture, energy consumption, fertilizer, and cereal food production–a nonlinear analysis for Pakistan. *Sustainable Energy Technologies and Assessments*, 45, 101099. https://doi.org/10.1016/j.seta.2021.101099
- Kumi, S., Addo-Fordjour, P., Fei-Baffoe, B., Belford, E. J., & Ameyaw, Y. (2021). Land use land cover dynamics and fragmentation-induced changes in woody plant community structure in a mining landscape, Ghana. *Trees, Forests and People*, 4, 100070. https://doi.org/10.1016/j.tfp.2021.100070
- Kurowska, K., Kryszk, H., Marks-Bielska, R., Mika, M., & Leń, P. (2020). Conversion of agricultural and forest land to other purposes in the context of land protection: *Evidence from Polish experience*. Land Use Policy, 95, 104614. https://doi.org/10.1016/j.landusepol.2020.104614
- Kuznets, S. (1955). Economic Growth and Income Inequality. *The American Economic Review*, 45(1), 1–28. http://www.jstor.org/stable/1811581
- Leng, P., Zhang, Q., Li, F., Kulmatov, R., Wang, G., Qiao, Y., ... & Khasanov, S. (2021). Agricultural impacts drive longitudinal variations of riverine water quality of the Aral Sea basin (Amu Darya and Syr Darya Rivers), Central Asia. *Environmental Pollution*, 284, 117405. https://doi.org/10.1016/j.envpol.2021.117405
- Li, Q., & Liu, G. (2021). Is land nationalization more conducive to sustainable development of cultivated land and food security than land privatization in post-socialist Central Asia? *Global Food Security*, 30, 100560. https://doi.org/10.1016/j.gfs.2021.100560
- Li, X., & Ito, J. (2021). An empirical study of land rental development in rural Gansu, China: The role of agricultural cooperatives and transaction costs. *Land Use Policy*, 109, 105621. https://doi.org/10.1016/j.landusepol.2021.105621
- Liu, Y., Zhuo, L., Varis, O., Fang, K., Liu, G., & Wu, P. (2021). Enhancing water and land efficiency in agricultural production and trade between Central Asia and China. *Science of The Total Environment*, 780, 146584. https://doi.org/10.1016/j.scitotenv.2021.146584
- Mittal, A., & Garg, A. K. (2021). Bank stocks inform higher growth—A System GMM analysis of ten emerging markets in Asia. *The Quarterly Review of Economics and Finance*, 79, 210-220. https://doi.org/10.1016/j.qref.2020.06.002
- Möhring, N., Dalhaus, T., Enjolras, G., & Finger, R. (2020). Crop insurance and pesticide use in European agriculture. *Agricultural Systems*, 184, 102902. https://doi.org/10.1016/j.agsy.2020.102902
- Moutinho, V., Varum, C., & Madaleno, M. (2017). How economic growth affects emissions? An investigation of the environmental Kuznets curve in Portuguese and Spanish economic activity sectors. *Energy Policy*, 106, 326-344. https://doi.org/10.1016/j.enpol.2017.03.069
- Nepal, R., Musibau, H. O., & Jamasb, T. (2021). Energy consumption as an indicator of energy efficiency and emissions in the European Union: A GMM based quantile regression approach. *Energy Policy*, 158, 112572. https://doi.org/10.1016/j.enpol.2021.112572
- Nickell, S. (1981). Biases in Dynamic Models with Fixed Effects. *Econometrica*, 49(6), 1417–1426. https://doi.org/10.2307/1911408
- Pedroni, P. (2001), "Fully modified OLS for heterogeneous cointegrated panels", Baltagi, B.H., Fomby, T.B. and Carter Hill, R. (Ed.) Nonstationary Panels, Panel Cointegration, and Dynamic Panels (Advances in Econometrics, Vol. 15), Emerald Group Publishing Limited, Bingley, pp. 93-130. https://doi.org/10.1016/S0731-9053(00)15004-2
- Pedroni, Peter. "Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis." *Econometric theory* (2004): 597-625. http://www.jstor.org/stable/3533533
- Peter C. B. Phillips, Bruce E. Hansen (1990), Statistical Inference in Instrumental Variables Regression with I (1) Processes, *The Review of Economic Studies*, Volume 57, Issue 1, Pages 99–125. https://doi.org/10.2307/2297545
- Petrick, Martin; Pomfret, Richard (2016), Agricultural policies in Kazakhstan, Discussion Paper, No. 155, *Leibniz Institute of Agricultural Development in Transition Economies*. http://hdl.handle.net/10419/130714

- Pontarollo, N., & Muñoz, R. M. (2020). Land consumption and income in Ecuador: A case of an inverted environmental Kuznets curve. *Ecological indicators*, 108, 105699. https://doi.org/10.1016/j.ecolind.2019.105699
- Pontarollo, N., & Serpieri, C. (2020). Testing the Environmental Kuznets Curve hypothesis on land use: The case of Romania. *Land use policy*, 97, 104695. https://doi.org/10.1016/j.landusepol.2020.104695
- Prabhakar, S. V. R. K. (2021). A succinct review and analysis of drivers and impacts of agricultural land transformations in Asia. *Land Use Policy*, 102, 105238. https://doi.org/10.1016/j.landusepol.2020.105238
- Riti, J. S., Song, D., Shu, Y., & Kamah, M. (2017). Decoupling CO2 emission and economic growth in China: is there consistency in estimation results in analyzing environmental Kuznets curve? *Journal of Cleaner Production*, 166, 1448-1461. https://doi.org/10.1016/j.jclepro.2017.08.117
- Siddiqui, D. A., & Ahmed, Q. M. (2013). The effect of institutions on economic growth: A global analysis based on GMM dynamic panel estimation. *Structural Change and Economic Dynamics*, 24, 18-33. https://doi.org/10.1016/j.strueco.2012.12.001
- Sun, J., Li, Y., Suo, C., & Liu, Y. R. (2019). Impacts of irrigation efficiency on agricultural water-land nexus system management under multiple uncertainties—A case study in Amu Darya River basin, Central Asia. *Agricultural Water Management*, 216, 76-88. https://doi.org/10.1016/j.agwat.2019.01.025
- Swinnen, J., Burkitbayeva, S., Schierhorn, F., Prishchepov, A. V., & Müller, D. (2017). Production potential in the "bread baskets" of Eastern Europe and Central Asia. *Global Food Security*, 14, 38-53. https://doi.org/10.1016/j.gfs.2017.03.005
- Tenaw, D., & Beyene, A. D. (2021). Environmental sustainability and economic development in sub-Saharan Africa: A modified EKC hypothesis. *Renewable and Sustainable Energy Reviews*, 143, 110897. https://doi.org/10.1016/j.rser.2021.110897
- Tsiboe, F., Egyir, I. S., & Anaman, G. (2021). Effect of fertilizer subsidy on household level cereal production in Ghana. *Scientific African*, 13, e00916. https://doi.org/10.1016/j.sciaf.2021.e00916
- Ullah, S., Akhtar, P., & Zaefarian, G. (2018). Dealing with endogeneity bias: The generalized method of moments (GMM) for panel data. *Industrial Marketing Management*, 71, 69-78. https://doi.org/10.1016/j.indmarman.2017.11.010
- Wang, H. (2021). Role of environmental degradation and energy use for agricultural economic growth: Sustainable implications based on ARDL estimation. *Environmental Technology & Innovation*, 102028. https://doi.org/10.1016/j.eti.2021.102028
- Wang, K., Zhu, Y., & Zhang, J. (2021). Decoupling economic development from municipal solid waste generation in China's cities: Assessment and prediction based on Tapio method and EKC models. *Waste Management*, *133*, 37-48. https://doi.org/10.1016/j.wasman.2021.07.034
- Xue, Y. (2020). Empirical research on household carbon emissions characteristics and key impact factors in mining areas. *Journal of Cleaner Production*, 256, 120470. https://doi.org/10.1016/j.jclepro.2020.120470
- Yang, H., & Ma, J. (2021). Correlation analysis between regional economic differences and environmental pollution based on Kuznets curve model. Environmental Technology & Innovation, 22, 101444. https://doi.org/10.1016/j.eti.2021.101444
- Yu, X., Keitel, C., & Dijkstra, F. A. (2021). Global analysis of phosphorus fertilizer use efficiency in cereal crops. *Global Food Security*, 29, 100545. https://doi.org/10.1016/j.gfs.2021.100545
- Zhai, L., Ma, J., Li, G., 2018. Evolution and outlook of agricultural policies in central asian countries. *Agric*. Outlook 14 (6), 29–33. https://doi.org/10.1109/ICMTMA.2018.00014
- Zhai, Y., Zhang, T., Bai, Y., Ji, C., Ma, X., Shen, X., & Hong, J. (2021). Energy and water footprints of cereal production in China. *Resources, Conservation and Recycling*, 164, 105150. https://doi.org/10.1016/j.resconrec.2020.105150
- Zhang, J., Mishra, A. K., Zhu, P., & Li, X. (2020). Land rental market and agricultural labor productivity in rural China: A mediation analysis. *World Development*, 135, 105089. https://doi.org/10.1016/j.worlddev.2020.105089
- Zhao, Q., Bao, H. X., & Zhang, Z. (2021). Off-farm employment and agricultural land use efficiency in China. *Land Use Policy*, 101, 105097. https://doi.org/10.1016/j.landusepol.2020.105097
- Zheng, W., Luo, B., & Hu, X. (2020). The determinants of farmers' fertilizers and pesticides use behavior in China: An explanation based on label effect. *Journal of Cleaner Production*, 272, 123054. https://doi.org/10.1016/j.jclepro.2020.123054
- Zouaoui, H., & Zoghlami, F. (2020). On the income diversification and bank market power nexus in the MENA countries: Evidence from a GMM panel-VAR approach. *Research in International Business and Finance*, 52, 101186. https://doi.org/10.1016/j.ribaf.2020.101186