Journal of Human Dynamics (JHD)
ISSN: 3007-2816 (E), 3007-2808 (P)

ROOTS PRESS

Check for updates

ResearchArticle

Analyzing the Technical Efficiency of Infrastructure and its Effects on Agricultural Productivity in OECD Economies

Ammarah Aslam[1], Omer Chaudhry[2]

[1]PhD Scholar, Department of Economics, The Women University Multan,Pakistan.
[2]Vice Chancellor, Government College University, Lahore, Pakistan.

ABSTRACT

The agricultural sector holds significant importance even for developed nations, such as those within the OECD, due to its role in meeting food supply requirements. Thus, infrastructure serves as a significant determinant of economic growth in general and agricultural productivity in particular. This study encompasses the impact of infrastructure on agriculture productivity by using DEA Data Envelop Analysis and Truncated regression, 28 OECD countries over the time period of 2017-2025. The DEA results show a strong impact of infrastructure on agricultural productivity in OECD countries. The truncated regression analysis embodies strong relationship of the variables selected to represent infrastructure on the target variable of agriculture growth. Road density, rail density, electricity consumption, and mobile subscription are variables that have demonstrated a significant impact on the agricultural sector. The developed countries like OECD countries shows that there is strong need of well-maintained infrastructure for the agricultural efficiency to assure.Thus, the findings of this study suggest the need of the infrastructure maintenance for even developed countries to achieve the most wanted goals of international market integration, high productivity and poverty eradication by agriculture growth.

Key Words: Agriculture Productivity, Data Envelopment Analysis (DEA), Efficiency Analysis, Infrastructure, Truncated Regression.

OPEN ACCESS

Correspondence
Ammarah Aslam
ammarahfiaz15@gmail.com

Article History
Received: March 07, 2026
Accepted: March 30, 2026
Published: March 31, 2026

Copyright: *© 2026 by the authors.* ***Licensee:*** *Roots Press, Rawalpindi, Pakistan.*

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license:
https://creativecommons.org/licenses/by/4.0

INTRODUCTION

There are enough studies done on the impact and influence of such infrastructures on various sectors of the economy in developing countries, where it is concluded that there is a scarcity of resources and higher costs are involved in developing strong infrastructures, which act as a hindrance to economic growth (Desai and Namboodari 1998, Ali (2004). There is a need to investigate and analyze the impact of well-developed infrastructures to determine whether it acts as a constraint in terms of costs, as in the case of developing countries, or it acts as a binding factor even in those developed countries that are known to possess well-developed infrastructures and strong human capital formation. This study aims to bridge the research gap in finding the technical efficiency of physical infrastructures on agriculture productivity in OECD countries over a time period of 9 years, i.e., 2017-2025. OECD countries are known to possess well-developed infrastructures and have invested a lot in human capital formation, which in turn results in a diverse capacity to develop and sustain well-developed infrastructures that act as a consequential factor in the growth of the agricultural sector. This two-stage approach is intended to improve the analysis of computational efficiency

(Simar and Wilson 2007). Data Envelopment Analysis has been used to build the technical efficiency scores for agriculture production, considering land, labour, capital, fertilizers, and technology as inputs for the first stage.The estimated results for the technical efficiency scores are regressed on the infrastructure variables using truncated regression rather than Ordinary Least Square to avoid baisedness. The infrastructure variables used are road and railways density, electricity consumption per head, and mobile subscriptions. The findings of the study reflect the positive and significant role played by infrastructure variables for agriculture production, with results indicating that one standard deviation in road density results in 9 percent increase in efficiency scores.

Significance of the Study

Globalization has turned out to be an essential economic objective with integration as a means to attain it, and integration is only made possible through an advanced infrastructure system, both hard and soft. It assists in eliminating variations in prices, ensures proper utilization of resources, and helps to meet supply demand at appropriate times with increasing demand. With infrastructure development, there is systematic movement of agricultural products to other sectors, and through rapid communication, the world is linked as one entity. For developing countries, infrastructure solves the major problem of connecting remote areas with markets of high demand. Infrastructure is generally classified into two groups: physical (roads, railways, air transportation, electricity, telecommunications, and water supply) and social (health, education, R&D, nutrition, and sanitation). As an indirect factor of production, it is not as important in itself, but it is important in that it seeks to convert the disadvantages of remote areas into economic opportunities and social welfare. An increase in investment in rural infrastructure can quickly increase agricultural output. Emphasis should also be placed on the quality and efficiency of infrastructure in addition to quantity, as highlighted in the World Development Report (1994). International efforts to increase investment in infrastructure include the UN Millennium Development Goals, WTO initiatives, and OECD/WTO definitions of trade-related infrastructure to facilitate easier market access of agricultural products and reduce trade barriers. Investment in hard infrastructure like transportation (roads, rails, and ports), communication (telephone, mobile, internet), and power generation (coal, oil, and electricity) is critical for accessing developed markets, developing agriculture, and reducing poverty. Research and development, education, and health services are examples of soft infrastructure. It is a multidimensional construct and not the sole driver of production growth, but it represents higher living standards and is a principal way of economic expansion. Transportation and electricity consumption are critical variables in determining agricultural technical efficiency (Felloni, 2001; Ali & Tahir, 2017), and government investment in infrastructure (public capital) is critical for poverty reduction and productivity growth (Fan et al., 2000; Picci, 1999), which is critical for globalization.

Question

Is the availability of infrastructure helping substantially to accelerate the agriculture productivity?

LITERATURE REVIEW

Realist scholars focus on balance of power relationships and mutual security interests:

Productivity is conceived as a process of collective production, which is often represented by the aggregate production function, with the most commonly used function being the Cobb-Douglas function for measuring the contribution of different factors to agricultural output. A number of studies have identified land, labor, mechanical inputs, human capital, agricultural research, and infrastructure as important determinants of agricultural output. The foundational studies by Hayami and Ruttan, 1985; Evenson, 1986; Antle, 1982; Ali, 2019) and others established these variables as critical factors for explaining the differences in agricultural productivity between less-developed and developed countries. The measurement and determinants of agricultural productivity continue to be critical for contemporary agriculture because it serves as the base for many economies, providing employment and welfare to millions of people.The literature is broadly categorized into two strands: one that focuses on the determinants of agricultural productivity and another that focuses on measuring it (Mugera and Ojede, 2011). Total Factor Productivity (TFP) is often used as the most preferred measure of technical progress in the literature, as it shows changes in the production function over time. In the context of Asia, particularly in South and Southeast Asia, TFP analysis and input methods have been used extensively. For instance, in Dholakia and Dholakia (1993), it was shown that with modern inputs, cropping intensity and resource use efficiency can be optimized to raise output and TFP.Some studies point to the influence of policy and institutional variables. For instance, using cross-country data and estimating Cobb-Douglas production models, Hu and Antle (1993) found that trade protection has a negative influence on productivity, whereas subsidies and taxes have mixed effects depending upon the specific context of a country. In Pakistan, price policies were found to act as incentives or disincentives by several researchers, such as Chaudhry et al. (1996), along with biological and technological improvements. Similarly, using data from several developing countries, Desai and Namboodiri (1998) found that non-price variables like infrastructure, extension services, education, research, regulated markets, government investments, etc., have a significant influence on productivity. In particular, they found that a high share (about 86 percent) of total factor productivity fluctuations could be attributed to agricultural research and extension services. Trade liberalization was also found to influence productivity in a favorable way in several studies. Comparative studies in various Asian economies, such as India and Pakistan (Bashir & Ahmad, 2000; Sardar, Zinaz & Ali, 2026) and Thailand, Indonesia, and Philippines (Mundlak et al., 2002), highlighted the need to efficiently allocate resources from agriculture to other sectors of the economy, gross capital formation, and investments in infrastructures to facilitate the adoption of infrastructure efficiency.

Studies Related to Asian Countries

The Total Factor Productivity (TFP) in agriculture, focusing on its use as an indicator of technological progress and efficiency, which measures the growth of output beyond the expansion of inputs. The research literature works cover different geographic areas, such as the U.S., Latin America/Caribbean, Europe, and use different methodologies, including index numbers, production function approaches, Malmquist indices, and Data Envelopment Analysis (DEA). Ball et al. (1997) developed production accounts for U.S. agriculture to compute TFP indices using gross output, capital, labor, and intermediate inputs. Ball et al. found average annual TFP growth of close to 2% between 1948 and 1994, attributing this to the main cause of economic growth in agriculture, exceeding contributions from input expansion. Ruttan (2002) identified approaches to measuring agricultural productivity, developing them into three stages of partial productivity ratios, indices, and multifactor TFP estimation via production function methods or non-parametric methods such as the Malmquist index. Ruttan identified differences between developed and developing countries in terms of resource availability, technical inputs, and human capital, attributing the main cause of positive growth to technical change. Latin American and Caribbean studies also pointed out the diversity of TFP performance. In the study conducted by Bravo-Ortega and Lederman (2004), using Translog and panel data for the period 1961-2000, the results indicated that there was varied and positive growth for different income groups. In the model, the electricity generating capacity had a significant and positive impact on TFP, whereas the effects of roads and illiteracy were negative. Moreover, the increasing gap between the productivity of developed and developing countries was explained by the differences between these two groups at the international level. In the study conducted by Ebata (2011), using both parametric (Translog and OLS) and non-parametric (Malmquist index), and conventional inputs such as land, labor, machinery, fertilizers, and livestock, and efficiency factors such as irrigation and life expectancy, the results pointed out the strong and positive elasticities for fertilizers and high significance for efficiency variables, indicating that the increase in irrigated areas and labor quality positively contribute to productivity.In the study conducted by Fuglie et al. (2007), using Translog and U.S. data for the period 1948-2004, the results pointed out that the growth in agricultural TFP averaged 1.8% annually.

Studies Related to Developed Countries

Ball et al. (1997) computed production accounts for agriculture in the US to derive TFP indices for gross output, capital stock, labor, and intermediate inputs. They found that between 1948 and 1994, the US agriculture experienced close to 2 percent annual TFP growth and concluded it was the major contributor to output and economic growth in agriculture, significantly surpassing input growth. Ruttan (2002) presented three steps in measuring agricultural productivity: partial productivity ratios/indices (such as land and labor), and multifactor TFP through production functions and non-parametric methods like the Malmquist index. He attributed differences in agricultural productivity between developed and less-developed countries to differences in resource endowments, technical inputs, and human capital; technical change was found to be the major contributor to positive growth in less-developed countries. Bravo-Ortega and Lederman (2004) used data for 1961-2000 and applied a Translog production function to estimate TFP growth in Latin America and the Caribbean and broader panels. Results indicated heterogeneous patterns of income groups and regions. Electricity generating capacity was found to have a highly significant positive effect, while roads and illiteracy had negative effects on TFP. Results indicated that there is a rising gap in productivity between developed and developing countries due to heterogeneity at the international level. Fuglie et al. (2007) used data for 1948-2004 and applied the Translog production function to estimate TFP in US agriculture. Results indicated that US agriculture experienced 1.8% average annual TFP growth. Results indicated that high levels of TFP reduced labor share; agricultural labor force decreased at 3.2% per annum. On the other hand, high levels of TFP increased labor productivity by 4.9% perannum through labor-saving technologies and more use of non-labor inputs like fertilizers, seeds, and machinery. These freed resources for use in other sectors of the economy. Bata (2011) used data for 1976-2006 and applied parametric (Translog with OLS) and non-parametric (Malmquist index) methods to estimate TFP in Latin America and the Caribbean. Results indicated that conventional inputs like Burja (2012) has studied the performance of the agricultural sector in Romanian regions during 2007 and 2008, applying the DEA method with variable returns to scale, with the results expressed in terms of the net value added of the farms and the labor and capital of the farms, respectively, for the Romanian regions, such as the North-East, the South-East, and others. The results indicated efficiency ranging from 21.7 to 41.1%, with an average efficiency of 48.0% when labor input was included, with significant variations in the North-East and the South-Muntenia regions, with the average variation ranging between 2.8 and 71.7%, and the average variation in the country being 11.9%.The above studies highlight the role of TFP as an important factor in the long-term measurement of technological progress and efficiency in the agricultural sector, which depends on factors such as infrastructure and human capital.

Studies related to African Countries

The technical efficiency in the agricultural sector of 33 African countries over the period 1966-2001 was studied by Mugera and Ojede (2011) using the DEA method, which produced the results in the form of standard and bootstrap bias-corrected technical efficiency scores. The results indicated the inefficiencies, and no catch-up in efficiency over the years was observed. Bootstrap bias-corrected technical efficiency scores indicated the decline in mean technical efficiency and provided a more accurate measure of technical efficiency. The main factors for inefficiency included the lack of access to certain inputs, such as credit, planting materials, veterinary medicine, and fertilizers, and the availability of effective extension services. The productivity and technical efficiency in maize production with conservation and conventional farming systems in 15 districts of Zimbabwe were studied by Mazvimavi et al. (2012) with the help of SFA with the translog production function, and the data included panel data from smallholder farmers over three years. The results indicated the positive output elasticity of labor, seeds, and fertilizers in both conservation and conventional farming systems, while land and draft animals had negative output elasticity in conservation farming. Conservation farming resulted in 39% more production than conventional farming. The technical efficiency scores ranged Mekonnen et al. (2012) studied determinants of technical inefficiency in developing agriculture using SFA on a panel data set of 29 Asian and African countries during 1994-2000. The authors extended input variables such as fertilizers, arable land, labor, and livestock into translog and cobb-douglas production functions, where translog is more appropriate. Technical efficiency is related to innovation system indicators such as expenditures on R&D, education/knowledge, institutional quality, infrastructure (roads and telephone), governance (corruption and press freedom), and foreign direct investment. The average efficiency scores are around 86-86.5%. The least developing countries have high efficiency scores because of their high potential for improving resource allocation. Conversely, countries with high development assistance and FDI have lower efficiency scores. Technical efficiency increases by 15-20% in countries such as Bangladesh, Ethiopia, Malawi, Mozambique, Nigeria, Senegal, and Tanzania. For Southern African countries in 2000, efficiency scores vary significantly; e.g., Zambia had an efficiency of 24%, Mozambique 52%, Zimbabwe 76%, and Botswana 81%. For Asian countries, Pakistan loses 20% efficiency, and Vietnam has an efficiency of 61%.'Technical inefficiency is still high in African and Asian agriculture, and this is mainly due to input availability constraints, infrastructure, and innovation system constraints.

The Role of infrastructure in Agriculture Productivity

The literature review of the role of infrastructure in affecting agricultural productivity, which distinguishes between physical and social infrastructure, such as transport, roads, railways, electricity, irrigation, telecommunications, ports, housing, and water supply, and social infrastructure, which covers education, health, nutrition, sanitation, banking, recreation, etc. The role of infrastructure is seen to facilitate the flow of services from capital stock over time, which isfurther divided into preceding (anticipatory of growth), chain-reaction (simultaneous with demand), and delayed (lagging behind industrialization) types of infrastructure. Ehrlich and Szilagyi (1980), developed point systems of infrastructure variables such as transportation, housing, health, communication, and education/culture for several countries. Others grouped infrastructure according to developmental timing and investment shares. Antle (1982, 1983) initiated farm-level and cross-country studies of the relationships between infrastructure variables (extension services, schooling, irrigation, transport, communication, etc.) and productivity using variable coefficient and Cobb-Douglas production functions. The results for India and for 47 less-developed and 19 developed countries showed significant positive effects of infrastructure variables, which confirmed Hayami and Ruttan's hypothesis. The indirect contribution of infrastructure to productivity is seen in terms of resource availability and adoption of technology. Other studies further confirmed these results using different methodologies and cases. In the Philippines, Evenson (1986), using duality profit functions, proved that public investments (roads, electrification, research, and extension services) positively affected output supply and input demand. In Pakistan, Looney and Winterford (1992) proved the passive but positive role of infrastructure on GDP growth using Granger causality tests on proxies for public investments. Binswanger and Khandakar (1993), working on the Indian case, proved the interactive effects of government investments, banks, and aggro-climatic conditions on output supply, with high elasticities for roads and irrigation. Other studies, such as Feltenstein and Ha (1995), working on the Mexican case using Translog cost functions, reported mixed results on infrastructure's effects on costs (electricity and communication reducing costs and transport increasing costs), while Wylie (1996), working on the Canadian case, reported high output elasticity's for infrastructure (0.407-0.517) using Translog and Cobb-Douglas functions. Indian-specific studies focused on regional and rural characteristics. Ghosh and De (1998) and Bhatia (1999) employed principal component analysis to create infrastructure indices, which showed high positive relationships to economic growth and food grain productivity (e.g., 10 percent improvement in infrastructure could increase yields by around 470 kg/ha). Fan et al. (2000) employed a system of simultaneous equations to demonstrate that government spending on roads, research, irrigation, and education is significant in reducing rural poverty and increasing TFP, with roads having the highest poverty-reducing impact. Lall (1999) and Picci (1999) analyzed the contribution of public capital to underdeveloped regions and Italian regions, respectively, to confirm that core infrastructure (roads, electricity, etc.) is a productivity driver with both direct and incentive effects. Later studies further developed these findings. Felloni et al. (2001) and Narayanmoorthy and Hanjra (2006) found roads, electricity, and irrigation to be important factors in their cross-country and district-level analyses, respectively. Ashok (2006) in the case of Tamil Nadu found the impact of irrigation, roads, markets, and literacy on TFP and diversification. Li and Liu (2009) in China, applying DEA and Tobit models, found roads to be important factors in efficiency. Majumdar (2005) and others focused on the issue of regional disparities and the variable role of infrastructure, such as the role of power infrastructure in the development of agriculture and roads in the development of industry. Recent studies, such as Bojnec et al. (2012), Zhou and Hi-Peng (2013), and Baba et al. (2014), applying DEA and Malmquist models, confirmed the positive impact of infrastructure on efficiency, with some infrastructure, such as railways, having negative or mixed results.The section is concluded with the research gap: Although various studies have extensively established the link between infrastructure and productivity using different methods (Cobb-Douglas, DEA), the current study makes its contribution by taking into account basic variables (arable land, gross capital formation, agricultural labor), a particular period of time (until 2012), and employing an underutilized approach of two-stage DEA and truncated regression for more efficient analysis.

Research Gap

This paper contributes to the existing literature on agricultural productivity with the incorporation of significant variables such as arable lands, gross capital formation, and agricultural labor force, as suggested in earlier literature, and novelty with regard to the extended period up to 2025 and the application of a two-stage approach using DEA and truncated regression, which has not yet been applied in earlier literature.

DATA AND RESEARCH METHODOLOGY

Panel Data 2017-2025 has been obtained from World Development Indicators, OECD stats and United Nation Stats of 25 OECD countries.

Table 1. Summary of Variables

Variables	Unit of Measurement	Data Source
Output Variable		
Agriculture Value added	Current US $	World Development Indicators
Input Variables		
Arable Land	Hectors	World Development Indicators

Gross Capital Formation	Current US $	World Development Indicators
Agriculture Labor Force	in Thousands	World Development Indicators
Exogenous Variables		
Investment on Roads	Current US $	OECD Stats
Investment on Rail	Current US $	OECD Stats
Electricity Consumption	kWh per capita	World Development Indicators
Mobile Subscription	per 100 people	World Development Indicators
Internet Subscription	per 100 people	World Development Indicators
Human Development Index		United Nations Stats

Output Variable

Value Added Agriculture World Development Indicators in Current US $.Li and Liu (2009) has taken the output variable as agriculture value added.

Input Variables

Arable Land in Hecters from World Development Indicators Ashok and Balasubramanian (2006), Felloni (2001), Li and Liu (2009). Gross Capital Formation in Current US $ from World Development Indicators. Salinas-Jimenes (2004) has employed the capital as proxy for agriculture capital use. Agriculture Labor Forcein Thousands from World Development Indicators.Ashok and Balasubramanian (2006), Felloni (2001), Li and Liu (2009) these studies has employed the labor force participation in agriculture sector as very important variable.

Exogenous Variables

Investment on Roads Current US$ from OECD Stats. Felloni (2001),Ashok and Balasubramanian (2006), Narayanamoorthy (2006), Segun et al (2008), Li and Liu (2009), Bojnec et al (2012) has worked on the investigation of the road influence on the agriculture sector and has found this as significant variable. Investment on Rails Current US $ from OECD Stats Bojnec et al (2012).Electricity Power Consumption kWh per capita from World Development Indicators Felloni (2001),Narayanamoorthy (2006), Segun et al (2008), Li and Liu (2009), Bojnec et al (2012). Mobile Subscription and Internet Subscription per 100 people from World Development Indicators Segun et al (2008), Li and Liu (2009), Bojnec et al (2012).Human Development Index United Nation Stats. Dummy Variable 1will be applied, if the country is European and 0 other wise,Li and Liu (2009) .

Table 2. OECD Countries List

European Countries			Non-European Countries		
Countries	HDI	GDP	Countries	HDI	GDP
Austria	0.930	421809268656.554	Australia	0.958	1672078242948.22
Czech REP	0.915	222958017484.654	Canada	0.939	1833766996134.79
Denmark	0.962	363238912546.89	Japan	0.925	4606002855955.13
Finland	0.948	254323653957.12	Korea REP	0.898	1917295522781.86
France	0.920	2720362347819.81	Mexico	0.789	1350022500028.81
Germany	0.959	3677048776153.86	Norway	0.970	443929688973.891
Greece	0.908	223655084018.924	UK	0.946	443929688973.891
Hungary	0.870	157952280644.587			
Italy	0.915	2033588532657.24			
Luxembourg	0.922	70508886559.2138			
Poland	0.906	658084600079.586			
Portugal	0.890	242206495918.36			
Slovenia	0.931	55598805913.7619			
Slovak REP	0.880	107227789781.413			
Spain	0.918	1428595035672.37			
Switzerland	0.970	811109937475.131			
Turkey	0.853	1316562171166.78			
US	0.938	22568462768174.3			

Source: OECD Stats

Note: GDP Gross domestic product in million US dollars 2015; Human Development Index UNDP 2025

Methodology

Two methodologies are specified for the efficiency analysis.

i. Non-parametric approach
ii. Parametric approach

Data Envelopment Analysis DEA

A non Parametric approach DEA by Farrel (1957) of measuring efficiency without incorporating stochastic term and does not require specification of the model.

Charnes, Cooper and Rohds (CCR) 1978 developed to conduct mathematical programming that provides frontier analysis and central tendencies.

$\max h_o(u,v)=\frac{\sum_r u_r y_{ro}}{\sum_i v_i x_{io}}$.............. (a)

h= the function to be maximize
m=number of inputs consumed
s=the number of outputs generated
x_{ij}=the amount of input i consumed by DMU_j
y_{rj}=the amount of output r produced byDMU_j
j=number of DMU
o=index of DMU being examined
u,v=weights to be calculated

If max h_o=1 this implies that efficiency has been achieved. In other words, DMU has reached the frontier. Maxh_o≤1 means DMU are not efficient.

Input oriented model

$\max z=\sum_{r=1}^{s} u_r y_{ro}$.................. (b)

subject to

$\sum_{r=1}^{s} u_r y_{rj}-\sum_{i=1}^{m} v_i x_{ij}\leq 0$

$$\sum_{i=1}^{m} v_i x_{ij}=1$$

$u_r v_i \geq 0$

Output oriented model

$\min q=\sum_{i=1}^{m} v_i x_{io}$................ (c)

subject to

$$\sum_{i=1}^{m} v_i x_{io}-\sum_{r=1}^{s} u_r y_{rj}\geq 0$$

$$\sum_{r=1}^{s} u_r y_{ro}=1$$

.$u_r v_i \geq 0$

Banker, Charnes and Cooper (BCC) 1984

$\sum_{j=1}^{n} \lambda_j=1$based on VRS and output oriented.

The CCR model yields same results in both the input oriented and output oriented technique. If CCR model is adopted the interpretation would be possible both for output and inputs. For BCC separate estimation has to be made for output and input interpretation.

Truncated Regression

The data collection of the variable depends on the dependent variable usually in many studies denoted by Z. So we can say collection of the observation depends on Z. Suppose we collect the score of the test in which the number of students who scored greater than 50% marks.

$Z_i = \alpha X_i + e_i$................................... (d)

Where: $e_{i\sim}$ N (0, σ)If the sample selected has some condition like at least 50% minimum marks score the application of the OLS would yield the results that are biased. So Truncated Regression model is applied. With the Maximum Likelihood estimation, the unbiased problem can be solved.

https://doi.org/10.55627/jhd.004.01.1862

Results and Discussions

Table 3. DEA Technology under Constant Returns to Scale

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Austria	0.579	0.534	0.575	0.641	0.654	0.566	0.584	0.666	0.583
Australia	1.000	1.000	1.000	0.896	1.000	0.916	0.893	0.970	0.991
Canada	0.704	0.753	0.757	0.758	0.900	0.755	0.704	0.676	0.683
Czech REP	0.532	0.585	0.610	0.550	0.609	0.524	0.464	0.675	0.695
Denmark	0.893	0.682	0.662	0.682	0.554	0.584	0.807	0.831	0.952
Finland	0.969	1.000	0.908	1.000	1.000	1.000	1.000	1.000	1.000
France	0.855	0.851	0.731	0.807	0.882	0.766	0.825	0.842	0.814
Germany	0.557	0.443	0.437	0.465	0.576	0.525	0.438	0.515	0.499
Greece	1.000	1.000	0.948	0.949	0.970	1.000	0.960	1.000	1.000
Hungary	1.000	0.963	1.000	1.000	1.000	0.982	1.000	1.000	1.000
Italy	1.000	1.000	0.944	0.966	1.000	1.000	0.907	1.000	1.000
Japan	1.000	0.875	0.729	0.673	0.818	0.955	0.911	0.941	1.000
Korea REP	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Luxembourg	0.854	0.527	0.498	0.618	0.611	0.551	0.483	0.456	0.620
Mexico	0.506	0.453	0.515	0.515	0.486	0.424	0.429	0.458	0.464
Norway	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Poland	0.401	0.364	0.418	0.493	0.453	0.418	0.455	0.533	0.493
Portugal	0.736	0.707	0.854	0.852	0.851	0.804	0.748	0.823	0.832
Slovenia	0.681	0.708	0.670	0.656	0.638	0.729	0.740	0.969	0.854
Slovak REP	0.850	0.777	0.929	1.000	1.000	1.000	0.825	0.965	1.000
Spain	0.918	0.900	0.795	0.832	0.848	0.831	0.867	0.910	0.873
Switzerland	0.785	0.688	0.598	0.605	0.759	0.759	0.657	0.786	0.714
Turkey	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
UK	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
US	0.412	0.314	0.316	0.344	0.418	0.357	0.381	0.398	0.367

Source: Author's Calculations

Table 3 shows Korea, Norway, and Turkey remained on the CRS efficiency frontier throughout all nine years with 100% efficiency. Finland & Greece were on the CRS frontier 7 times, Italy 6 times, and Australia/Slovak Republic 4 times. Efficiency peaks for other countries varied from a minimum of 31% (US in 2018) to a high of 97% (Slovenia in 2024), 92% (Spain in 2017), and 95% (Denmark in 2025).

Table 4. Descriptive Statistics under Constant Returns to Scale

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Mean Efficiency	0.817	0.774	0.765	0.781	0.809	0.786	0.772	0.824	0.824
Standard Deviation	0.206	0.228	0.217	0.208	0.205	0.222	0.217	0.206	0.209
Minimum	0.401	0.314	0.316	0.344	0.418	0.357	0.381	0.398	0.367
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
No. of times at Frontier	10.000	9.000	6.000	8.000	10.000	9.000	7.000	9.000	11.000

Source: Author's calculations

Table 4 Under CRS the mean efficiency was 82 percent in 2024 and 2025 that was the highest efficiency score. The lowest mean efficiency was 77 percent in 2018. The deviation was 21 percent in 2021 the lowest deviation.

Table 5. Summary Statistics under Constant Returns to Scale

	Mean Efficiency	Maximum value	Minimum value	Standard Deviation	No. of Times at Frontier
Austria	0.598	0.666	0.534	0.045	0.000
Australia	0.963	1.000	0.893	0.047	4.000
Canada	0.743	0.900	0.676	0.068	0.000
Czech REP	0.583	0.695	0.464	0.074	0.000

Denmark	0.738	0.952	0.554	0.138	0.000
Finland	0.986	1.000	0.908	0.031	7.000
France	0.819	0.882	0.731	0.047	0.000
Germany	0.495	0.576	0.437	0.052	0.000
Greece	0.981	1.000	0.948	0.024	5.000
Hungary	0.994	1.000	0.963	0.013	7.000
Italy	0.980	1.000	0.907	0.034	6.000
Japan	0.878	1.000	0.673	0.117	2.000
Korea REP	1.000	1.000	1.000	0.000	9.000
Luxembourg	0.580	0.854	0.456	0.119	0.000
Mexico	0.472	0.515	0.424	0.035	0.000
Norway	1.000	1.000	1.000	0.000	9.000
Poland	0.448	0.533	0.364	0.053	0.000
Portugal	0.801	0.854	0.707	0.056	0.000
Slovenia	0.738	0.969	0.638	0.108	0.000
Slovak REP	0.927	1.000	0.777	0.088	4.000
Spain	0.864	0.918	0.795	0.041	0.000
Switzerland	0.706	0.786	0.598	0.073	0.000
Turkey	1.000	1.000	1.000	0.000	9.000
UK	1.000	1.000	1.000	0.000	9.000
US	0.367	0.418	0.314	0.038	0.000

Source: Author's calculations

Table 5 indicates the mean efficiencies with deviations. Those countries with low deviations represents more reliability.

Table 6. Stem and Leaf under Constant Returns to Scale

Efficiency Scores	2017	2018	2019	2020	2021	2022	2023	2024	2025
1.00	10	9	6	8	10	9	7	9	11
0.90-0.99	2	2	4	2	2	3	3	5	2
0.80-0.89	4	2	1	4	4	2	5	3	4
0.70-0.79	3	4	4	1	1	4	3	1	1
0.60-0.69	1	1	3	6	4	0	1	3	3
0.50-0.59	4	3	3	1	2	5	1	2	1
0.40-0.49	2	2	3	2	3	2	5	2	3
0.30-0.39	0	2	1	1	0	1	1	1	1

Source: Author's calculations

Table 6 represents the number of countries efficiency score over the time span of 2017 to 2015.Efficiency score 1 is scored by 10 countries in 2017. Similarly, breakdown of different efficiency score range and number of countries is presented in the table.

Table 7. DEA Efficiency Analysis under Variable Returns to Scale

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Austria	0.625	0.569	0.614	0.672	0.692	0.612	0.623	0.705	0.628
Australia	1.000	1.000	1.000	0.959	1.000	0.986	1.000	1.000	1.000
Canada	0.706	0.756	0.764	0.806	0.905	0.809	0.772	0.701	0.691
Czech REP	0.587	0.635	0.647	0.557	0.614	0.538	0.518	0.683	0.705
Denmark	0.935	0.721	0.696	0.712	0.605	0.621	0.844	0.865	0.976
Finland	1.000	1.000	0.961	1.000	1.000	1.000	1.000	1.000	1.000
France	0.855	0.899	0.847	0.916	0.922	0.794	0.960	0.884	0.858
Germany	0.593	0.458	0.481	0.525	0.682	0.576	0.536	0.624	0.582
Greece	1.000	1.000	0.975	0.968	0.996	1.000	0.996	1.000	1.000
Hungary	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Italy	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Japan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Korea REP	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Luxembourg	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mexico	0.521	0.471	0.516	0.516	0.488	0.425	0.431	0.458	0.464
Norway	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Poland	0.433	0.419	0.436	0.494	0.457	0.423	0.465	0.543	0.517
Portugal	0.768	0.743	0.907	0.918	0.919	0.845	0.787	0.829	0.857
Slovenia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Slovak REP	1.000	0.910	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Spain	0.934	0.906	0.843	0.910	0.874	0.913	1.000	1.000	0.954
Switzerland	0.856	0.766	0.683	0.687	0.848	0.847	0.751	0.864	0.797
Turkey	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
UK	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
US	0.414	0.314	0.316	0.345	0.419	0.357	0.382	0.398	0.367

Source: Author's calculations

In VRS, ten countries (Hungary, Italy, Japan, Korea, Luxembourg, Norway, Slovenia, Slovakia, Turkey, and UK) maintained full efficiency (1.0) for the entire nine years compared to just three countries (Norway, Turkey, and UK) in CRS. Australia also achieved full efficiency 7 times in VRS compared to just 4 times in CRS. The remaining countries also achieved higher efficiency compared to CRS. The peak efficiency was up to 1.0 (Spain 2023-24), 0.9762 (Denmark 2025), and 0.9217 (France 2021), while the lowest was 0.3139 (US 2018).

Table 8. Descriptive Statistics under Variable Returns to Scale

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Mean Efficiency	0.855	0.829	0.834	0.846	0.862	0.836	0.849	0.867	0.861
Standard Deviation	0.201	0.222	0.215	0.207	0.196	0.219	0.217	0.190	0.200
Minimum	0.414	0.314	0.316	0.345	0.419	0.357	0.382	0.398	0.367
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
No. of times at Frontier	14.00	13.00	12.00	12.00	13.00	13.00	14.00	15.00	13.00

Source: Author's calculations

Table 8 The descriptive statistics represent the year wise analysis of the efficiencies of the countries under Variable Returns to Scale.The 2024 was the year in which the overall higher level of efficiency was achieved by 15 countries under variable returns to scale.

Table 9. Summary Statistics under Variable Returns to Scale

	Mean	Maximum value	Minimum value	Standard Deviation	No. of times at Frontier
Austria	0.638	0.705	0.569	0.043	0.000
Australia	0.994	1.000	0.959	0.014	7.000
Canada	0.768	0.905	0.691	0.067	0.000
Czech REP	0.609	0.705	0.518	0.065	0.000
Denmark	0.775	0.976	0.605	0.135	0.000
Finland	0.996	1.000	0.961	0.013	8.000
France	0.882	0.960	0.794	0.049	0.000
Germany	0.562	0.682	0.458	0.070	0.000
Greece	0.993	1.000	0.968	0.012	5.000
Hungary	1.000	1.000	1.000	0.000	9.000
Italy	1.000	1.000	1.000	0.000	9.000
Japan	1.000	1.000	1.000	0.000	9.000
Korea REP	1.000	1.000	1.000	0.000	9.000
Luxembourg	1.000	1.000	1.000	0.000	9.000
Mexico	0.477	0.521	0.425	0.036	0.000
Norway	1.000	1.000	1.000	0.000	9.000

Poland	0.465	0.543	0.419	0.044	0.000
Portugal	0.841	0.919	0.743	0.066	0.000
Slovenia	1.000	1.000	1.000	0.000	9.000
Slovak REP	0.990	1.000	0.910	0.030	8.000
Spain	0.926	1.000	0.843	0.053	2.000
Switzerland	0.789	0.864	0.683	0.071	0.000
Turkey	1.000	1.000	1.000	0.000	9.000
UK	1.000	1.000	1.000	0.000	9.000
US	0.368	0.419	0.314	0.039	0.000

Source: Author's calculations

Table 9 is country-wise breakdown of mean efficiency scores with deviations under VRS.

Table 10: Stem and Leaf under Variable Returns to Scale

Efficiency Scores	2017	2018	2019	2020	2021	2022	2023	2024	2025
1.00	14	13	12	12	13	13	14	15	13
0.90-0.99	2	2	3	5	4	2	2	0	2
0.80-0.89	2	1	2	1	2	3	1	4	2
0.70-0.79	2	4	1	1	0	1	3	2	2
0.60-0.69	1	1	4	2	4	1	1	2	2
0.50-0.59	3	1	1	3	0	2	2	1	2
0.40-0.49	2	3	2	1	3	2	2	1	1
0.30-0.39	0	1	1	1	0	1	1	1	1

Source: Author's calculations

Table 10 indicates the efficiency score breakdown over the time span 2017-2025 under VRS. Thus 2024 is the year 15 countries scored 1.

Table 11. DEA Technical Efficiency under Scale Efficiency

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Austria	0.925	0.938	0.937	0.954	0.946	0.925	0.937	0.944	0.929
Australia	1.000	1.000	1.000	0.935	1.000	0.929	0.893	0.970	0.991
Canada	0.997	0.996	0.991	0.940	0.995	0.933	0.912	0.965	0.988
Czech REP	0.907	0.921	0.942	0.987	0.992	0.974	0.897	0.988	0.985
Denmark	0.955	0.946	0.950	0.959	0.916	0.941	0.957	0.961	0.975
Finland	0.969	1.000	0.945	1.000	1.000	1.000	1.000	1.000	1.000
France	1.000	0.946	0.864	0.881	0.957	0.964	0.859	0.952	0.948
Germany	0.939	0.967	0.909	0.885	0.844	0.910	0.818	0.826	0.857
Greece	1.000	1.000	0.972	0.980	0.974	1.000	0.964	1.000	1.000
Hungary	1.000	0.963	1.000	1.000	1.000	0.982	1.000	1.000	1.000
Italy	1.000	1.000	0.944	0.966	1.000	1.000	0.907	1.000	1.000
Japan	1.000	0.875	0.729	0.673	0.818	0.955	0.911	0.941	1.000
Korea REP	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Luxembourg	0.854	0.527	0.498	0.618	0.611	0.551	0.483	0.456	0.620
Mexico	0.971	0.961	0.998	0.997	0.996	0.997	0.997	0.999	0.999
Norway	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Poland	0.927	0.869	0.959	0.997	0.990	0.989	0.979	0.980	0.953
Portugal	0.958	0.952	0.941	0.929	0.926	0.952	0.950	0.994	0.971
Slovenia	0.681	0.708	0.670	0.656	0.638	0.729	0.740	0.969	0.854
Slovak REP	0.850	0.854	0.929	1.000	1.000	1.000	0.825	0.965	1.000
Spain	0.983	0.993	0.943	0.915	0.971	0.910	0.867	0.910	0.916
Switzerland	0.917	0.899	0.876	0.880	0.895	0.896	0.876	0.910	0.896
Turkey	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
UK	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
US	0.996	1.000	1.000	0.997	0.998	1.000	0.998	1.000	1.000

Source: Author's calculations

Keeping optimal size of the economy the efficiency score represents that the respective countries scored optimally embodied in Table 11.Scale efficiency scores signifies the improvement of the efficiency score of the countries over the nine years according to its optimal size.

Table 12. Descriptive Statistics under Scale Efficiency

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Mean Efficiency	0.855	0.829	0.834	0.846	0.862	0.836	0.849	0.867	0.861
Standard Deviation	0.201	0.222	0.215	0.207	0.196	0.219	0.217	0.190	0.200
Minimum	0.414	0.314	0.316	0.345	0.419	0.357	0.382	0.398	0.367
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
No. of times at Frontier	10.00	9.00	7.00	8.00	10.00	9.00	7.00	9.00	11.00

Source: Author's calculations

Table 12 The descriptive statistics represent the standard deviation was lowest one in 2024 that determined there was low variability in the efficiency scores of the countries in that year.As we compare descriptive statistics table under CRS,VRS and SE, it is seen that CRS and SE show the higher efficiencies.In 2025 the highest number of countries at highest frontier.

Table 13. Summary Statistics under Scale Efficiency

	Mean	Maximum value	Minimum Value	Standard Deviation	No. of times at Frontier
Austria	0.937	0.954	0.925	0.010	0.000
Australia	0.969	1.000	0.893	0.040	4.000
Canada	0.969	0.997	0.912	0.032	0.000
Czech REP	0.955	0.992	0.897	0.038	0.000
Denmark	0.951	0.975	0.916	0.017	0.000
Finland	0.990	1.000	0.945	0.020	7.000
France	0.930	1.000	0.859	0.050	0.000
Germany	0.884	0.967	0.818	0.052	0.000
Greece	0.988	1.000	0.964	0.015	5.000
Hungary	0.994	1.000	0.963	0.013	7.000
Italy	0.980	1.000	0.907	0.034	6.000
Japan	0.878	1.000	0.673	0.117	2.000
Korea REP	1.000	1.000	1.000	0.000	9.000
Luxembourg	0.580	0.854	0.456	0.119	0.000
Mexico	0.991	0.999	0.961	0.014	0.000
Norway	1.000	1.000	1.000	0.000	9.000
Poland	0.960	0.997	0.869	0.041	0.000
Portugal	0.953	0.994	0.926	0.021	0.000
Slovenia	0.738	0.969	0.638	0.108	0.000
Slovak REP	0.936	1.000	0.825	0.074	4.000
Spain	0.934	0.993	0.867	0.041	0.000
Switzerland	0.894	0.917	0.876	0.015	0.000
Turkey	1.000	1.000	1.000	0.000	9.000
UK	1.000	1.000	1.000	0.000	9.000
US	0.999	1.000	0.996	0.002	0.000

Source: Author's calculations

Table13The scale efficiency summary statistics describe the countries optimal efficiency, the minimum and maximum value describing the range of the efficiency, the standard deviation embodying the variation of the efficiency and the number of times the efficiency has been scored 100%.

Table 14. Stem and Leaf under Scale Efficiency

Efficiency Scores	2017	2018	2019	2020	2021	2022	2023	2024	2025
1.00	10	9	7	8	10	9	7	9	11
0.90-0.99	13	11	14	12	11	14	10	15	11
0.80-0.89	2	4	2	3	3	1	7	1	3
0.70-0.79	0	1	1	0	0	1	1	0	0
0.60-0.69	1	0	1	3	2	0	0	0	1
0.50-0.59	0	1	0	0	0	1	0	0	0
0.40-0.49	0	0	1	0	0	0	1	1	0
0.30-0.39	0	0	0	0	0	0	0	0	0

Source: Author's calculations

Table 14 the distribution of efficiency range of the countries over the years. 100% scale efficiency was seen in 2025 as 11 countries attained optimal efficiency score at highest.

Table 15. Comparison of Mean Efficiencies

	CRS	VRS	SE
Austria	0.5980	0.6379	0.9372
Australia	0.9631	0.9939	0.9688
Canada	0.7433	0.7677	0.9685
Czech REP	0.5826	0.6093	0.9547
Denmark	0.7385	0.7748	0.9511
Finland	0.9864	0.9957	0.9905
France	0.8192	0.8818	0.9301
Germany	0.4950	0.5621	0.8839
Greece	0.9807	0.9928	0.9877
Hungary	0.9938	1.0000	0.9938
Italy	0.9797	1.0000	0.9797
Japan	0.8780	1.0000	0.8780
Korea REP	1.0000	1.0000	1.0000
Luxembourg	0.5800	1.0000	0.5800
Mexico	0.4720	0.4766	0.9906
Norway	1.0000	1.0000	1.0000
Poland	0.4475	0.4653	0.9604
Portugal	0.8008	0.8413	0.9526
Slovenia	0.7383	1.0000	0.7383
Slovak REP	0.9274	0.9900	0.9360
Spain	0.8641	0.9260	0.9344
Switzerland	0.7058	0.7887	0.8940
Turkey	1.0000	1.0000	1.0000
UK	1.0000	1.0000	1.0000
US	0.3674	0.3679	0.9987

Source: Author's Calculation; Note: CRS stands for Constant Returns to Scale, VRS stands for Variable Returns to Scale, SE stands for Scale Efficiency

Table 15 is a comparison of mean efficiencies under CRS,VRS and SE across the countries. United Kingdom, Turkey, Norway and Korean Republic has embodied 100% efficiency with CRS, VRS and SE.

Table 16. Truncated Regression

Efficiency	Coefficient	Standard Error	z test	P>|z|
Rail Investment	4.97E-11	9.30E-12	*5.34E+00	0.00E+00
Road investment	-1.11E-11	1.71E-12	**-6.49E+00	0.00E+00
Power Cons	5.96E-06	5.61E-06	1.06E+00	2.88E-01

Internet	1.49E-03	1.30E-03	1.15E+00	2.52E-01
Mobile Sub	-1.82E-03	9.81E-04	-1.85E+00	6.40E-02
HDI	3.88E-04	3.31E-04	1.18E+00	2.40E-01
Location	-2.20E-02	5.59E-02	-3.90E-01	6.94E-01
Constant	7.55E-01	8.02E-02	9.41E+00	0.00E+00
Sigma	1.77E-01	1.41E-02	1.25E+01	0.00E+00

Source: Author's calculations

Note: *5.34 significant at 95 % confidence interval. **-6.49 significant at 95 % confidence interval.

The parameter estimates of the Truncated Regression Model have been presented in Table 16 support the significant impact of the infrastructural variables on the agriculture productivity. The coefficient estimate of investment on Railways indicates positive sign with Z stats 5.34 at 95 % confidence interval, highly significant.The investment on Roads shows negative sign, Z value -6.49E+00 at 95 % significance level, highly significant but exerts negative impact on agricultural productivity,supported by Bravo-Ortriga and Lederman (2004) and Li and Lui (2009). The electricity,internet subscription and HDI embodied positive impact on agriculture productivity.Mobile subscription is significant but negatively related to agriculture productivity.

CONCLUSION

The study investigated theimpacts of infrastructure on agriculture sector through efficiency analysis by employing DEA. The technical efficiency has been computed by employing the CCR model under the assumption of constant returns to scale. In order to measure the scale efficiency, the technical efficiency under variable returns to scale has to calculate Li and Lui (2009).The descriptive statistics presented the summary of the calculation of efficiency. Stem and leaf tables described the distribution of the efficiencies over the time period annually.By The Truncated Regression On the infrastructure technical efficiency under constant returns to scale was regressed.The infrastructure variables emerged as significant variables like roads and railways. Investment on roads infrastructure resulted in negative sign, implying that investment on roads would lead to negative or reverse impact. Railways are highly significant and would contribute positively in this case. The estimated results of electricity confirm that electricity is significant variable and exerts positive influence in boosting agriculture productivity. The significance of internet users can be seen through z value on the table. All variables of infrastructure are significant and these results give strong evidence that infrastructure can significantly help to raise agriculture productivity.

REFERENCES

Ahmad. M (2003) "Agriculture Productivity, Efficiency and Rural Poverty in Irrigated Pakistan: A Stochastic Production Frontier Analysis" *The Pakistan Development Review, 42 (3*), 219-248

Ali, H. (2019). Parity Pricing as an Approach to Price Support Programme in Agriculture Sector of Pakistan: Policy Analysis. *European Online Journal of Natural and Social Sciences*, *8*(2), 253-268.

Ali, H.,& Tahir, H. (2017). Pricing of Agricultural Capital Input in Pakistan: An Analysis of Bound Testing Approach. *Review of Economics and Development Studies*, *3*(2), 101-110.

Ali. S (2004) "Total Factor Productivity Growth in Pakistan's Agriculture: 1960-1996*" The Pakistan Development Review, 43 (4),* 493-513

Antle. J.M (1982) "Human Capital, Infrastructure and the Productivity of Indian Rice Farmers" *Journal of Development Economics, 14,* 163-181

Antle. J.M (1983) "Infrastructure and Aggregate Agricultural Productivity: International Evidence" *Economic Development and Cultural Change, 31(3),* 609-619

Ashok. K.R and Balasubramanian. R (2006) "Role of Infrastructure in Productivity and Diversification of Agriculture" Tamil Nadu Agriculture University, India

Ashrafi. A, Jaafar. A.B and Lee. L.S (2010) "Two stage Data Envelopment Analysis: An enhanced Russel model" *International Conference on Business and Economics Research, vol.1 (2011) © (2011) IACSIT Press, Kuala Lumpur, Malaysia*

Baba. S.H, Mir. S.A, Khan. A.A, Bazaz. N.H and Manzoor .M (2014) "Rural Infrastructure and Agricultural Growth Linkages in Jammu and Kashmir" *Economic Affairs*, 60 (1), 143-150, DOI: 10.5958/0976-4666.2015.00020.0

Ball. E.V, Bureau. C.J, Nehring. R and Somwaru. A (1997) "Agricultural Productivity Revisited" *American Journal of Agricultural Economics, 79 (4),* 1045-1063

Banker.R. D, Charnes. A and Cooper. W.W (1984) "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis." Management Science, 30(9), 1078-1092.

Bashir. Z and Ahmad. M (2000) "The Role of Agricultural Growth in South Asian Countries and Affordability of Food: An Intercountry Analysis" *The Pakistan Development Review, 39 (4),* 751-767

Bhatia. M.S (1999) "Rural Infrastructure and Growth in Agriculture*" Economic and Political Weekly, 34 (13),* A43-A48
Binswanger. H.P, Khandker. S.R and Rosenzweig. M.R (1993) "How infrastructure and Financial Institution Affect Agriculture Output and Investment in India" *Journal of Development Economics, 41 (1993),* 337-366
Bojnec. S, Ferto. I, Jambor. A and Toth. J (2012) "Determinants of Technical Efficiency in Agriculture in New EU Member States from Central and Eastern Europe" Acta Oeconomica, 64 (2), 197-217
Bravo-Ortega. C and Lederman. D (2004) "Agricultural Productivity and Determinants: Revisiting International Experiences"*Estudios de Economia, 31 (2*), 133-163
Camelia. B (2012) "Determinants of the Agriculture Productivity Growth among Romanian Regions" *Annales Universitatis Apulensis Series Oeconomica, 14 (1)*
Chao-de. Y and Hong-an. X (2011) "Analysis of Factors Influencing Comprehensive Productivity of Agriculture in Henan Province on the Basis of Grey Correlation*" Asian Agriculture Research, 3 (10),* 6-10
Charnes. A, Cooper.W.W, and Rhodes.E .(1978) "Measuring the Efficiency of Decision Making Units" *European Journal of Operational Research 2,* 429-444
Chaudhry. G.M, Chaudhry. M.G and Qasim. A.M (1996) "Growth of Output and Productivity in Pakistan's Agriculture: Trends, Sources and Policy Implications" *The Pakistan Development Review, 35 (4),* 527-536
Daraio, C., & Simar, L. (2007) "Advanced robust and nonparametric methods in efficiency analysis: Methodology and applications" (2nd ed.). New York: Springer.
Desai. B.M and Namboodiri. N.V (1998) "Determinants of Total Factor Productivity in Indian Agriculture*" Economic and Political Weekly, 32 (52*), A165-A171
Dholakia. H.R and Dholakia. H.B (1993) "Growth of Total Factor Productivity in Indian Agriculture*" Indian Economic Review, 28(1),* 25-40
Ebata. A (2011) "Agricultural Productivity Growth in Central America and the Caribbean" *Dissertation and Thesis in Agriculture Economics. Paper 8.*http://digitalcommons.unl.edu/agecondiss/8.
efficiency of the Italian health system" Paper no.39126, June 13, 2012 http://mpra.ub.uni-muenchen.de/39126/
Evenson. R.E (1986) "Infrastructure, Output Supply and Input Demand in Philippine Agriculture: Provisional Estimates" *Journal of Philippine Development, 13 (23),* 62-76
Fakayode. B.S, Omotesho. O.A, Tsoho. A.B and Ajayi. P.D (2008) "An Economic Survey Of Rural Infrastructure and Agricultural Productivity Profiles in Nigeria" European Journal of Social Sciences, 7(2), 158-171
Fan. S, Hazell. P and Thorat. S (2000) "Government Spending, Growth and Poverty in Rural India" *American Journal of Agriculture Economics, 82 (4),* 1038-1051
Farell.M.J (1957)"The Measurement of Productive Efficiency*" Journal of Royal Statistical Society. Series A (General)* 120 (3), 253-290.
Farhadi. M (2015) "Transport Infrastructure and Long-run Economic Growth in OECD countries" *Transportation Research Paper A, 74 (2015),* 73-90
Faruq. H.A and Telaroli. P.J (2011) "Factors Affecting Manufacturing and Agriculture Productivity Trends among Asian Countries*" ASEAN Economic Bulletin, 28 (1),* 45-60
Felloni. F, Wahl. T, Wandschneider. P and Gilbert. J (2001) "Infrastructure and Agricultural Production: Cross-Country Evidence and Implications for China*" Working Paper 103, Washington State University*
Feltenstien. A and Ha. J (1995) "The Role of Infrastructure in Mexican Economic Reform" *The World Bank Economic Review, 9 (2),* 287-304
Forsund. R. F and Hjalmarsson. L .(1974) "On the Measurement of Productive Efficiency" *The Swedish Journal of Economics* 76 (2), 141-154
Fuglie. K.O, MacDonald. J.M and Ball. E (2007) "United State Department of Agriculture" *Economic Research Centre*
Ghosh. B and De. P (1998) "Role of Infrastructure in Regional Development: A Study over the Plan Period" *Economic and Political Weekly, 33 (47,48*), 3039-3043, 3045-3048
Hamid. A and Ahmad. H.K (2009) "Growth and Productivity in Purview of Transitional Dynamics in Pakistan Agriculture Sector" *Pakistan Economic and Social Review, 47 (1),* 49-78
Hawkins. L.C (1950) "Measurements of Eficiency*" Oxford Economic Papers, New Series, 2 (1),30-50*
Hawkins. L.C .(1950) "Measurements of Efficiency" *Oxford Economic Papers, New Series 2 (1),* 30-50
Hirschman. A.O (1958) "The strategy of Economic Development" New Heaven, Yale University, 13-217
Hu. F and Antle. J.M (1993) "Agricultural Policy and Productivity: International Evidence" *Review of Agriculture Economics, 5 (3),* 495-505
Kokkinou.A .(2010) "A Note on Theory of Productive Efficiency and Stochastic Frontier Models"*European Research Studies,* 13 (4), 109-118
Kopp. J.R .(1981) "The Measurement of Productive Efficiency: A Reconsideration" *The Quarterly Journal of Economics* 96 (3), 477-503
Lall. S.V (1999) "The Role of Public Infrastructure Investment in Regional Development: Experience of Indian States" *Economic and Political Weekly, 34 (12),* 717-725
Lewis. W.A (1955) "The Theory of Economic Growth" London. Allen &Unwin.

Li. Z and Liu. X (2009) "The Effects of Rural Infrastructure Development of Agricultural Production Technical Efficiency: Evidence from The Data of Second National Agricultural Census of China" *International Association of Agriculture Economists Conference*, August 16-22, China

Looney. R.E and Winterford. D (1992) "The Role of Infrastructure in Pakistan's Economic Development" *Pakistan Economic and Social Review, 30 (1),* 69-94

Lovell CAK (1993). "Production Frontiers and Productive Efficiency." in Fried HO and SS Schmidt (eds.) the Measurement of Productive Efficiency: Techniques and Applications, Oxford U.K., 3-67.

Majumder. R (2005) "Infrastructure and Regional Development: Interlinkages in India*" Indian Economic Review, New Series, 40 (2),* 167-184

Mathur. A.S, Das. S and Sircar. S (2007) "Status of Agriculture in India: Trends and Prospects" Economic and Political Weekly, 41 (52), 5327-5336

Mazvimavi. K, Ndlovu. P.V, An. H and Murendo. C (2012) "Productivity and Efficiency Analysis of Maize under Conservation Agriculture in Zimbabwe"

Mehta. M. M (1950) "Measurement of Industrial Efficiency" *The Economic Journal* 60 (240), 827-831

Moyo.B (2013) "Power Infrastructure Quality and Manufacturing Productivity in Africa: A firm Level Analysis*" Energy Policy, 61 (2013),* 1063-1070

Mugera. A and Ojede. A (2011) "Agricultural Productivity Growth in Africa: Is Efficiency catching up or Lagging Behind*?" Paper presented at 55th Annual National Conference of Australia Agriculture & Resource Economic Society*, Melbourne, Victoria, February 8-11

Mundlak. Y, Larson. D.F and Butzer. R (2002) "Determinants of Agriculture Growth in Indonesia, the Philippines and Thailand" *Policy Research Working Paper 2803*

Narayanamoorthy. A and Hanjra. M.A (2006) "Rural Infrastructure and Agricultural Output Linkages: A Study of 256 Indian Districts" *Indian Journal of Agriculture Economics, 61 (3),* 444-459

Nicola .A. D , Gitto. S and Mancuso. P .(2011) "A two-stage DEA mo del to evaluate the

Picci. L (1999) "Productivity and Infrastructure in Italian Regions"*GiornaledegliEconomisti e Annali di Economia,Nuova Serie 58 (3, 4),* 329-353

Procelli.F. (2009) "Measurement of Technical Efficiency" A brief Survey of parametric and non-parametric technique.

Prud'homme. R (2004) "Infrastructure and Development" Annual Bank Conference on Development Economics, Washington, May 3-5

Ruttan. V.W (2002) "Productivity Growth in World Agriculture: Sources and Constraints" *Journal of Economic Perspectives, 16 (4),* 161-184

Salinas-Jiménez. M (2004) "Public Infrastructure and Private Productivity in the Spanish Regions" *Journal of Policy Modeling, 26 (2004),* 47-64

Sardar, K., Zinaz, A., Ali, H.(2026). Green Technology, Agribusiness, and Rural Income Level: An Integration of Panel Data Estimation from China. *Journal of Asian Development Studies*. *15(2), 153-171.*

Seitz. D. W .(1970) "The Measurement of Efficiency Relative to a Frontier Production Function" *American Journal of Agricultural Economics* 52 (4), 505-511

Sena, V. (2003) "The frontier Approach to the Measurement of Productivity and Technical Efficiency"*Economic issues*, *8*(2), 71-97.

Simar.L and Wilson.P.W (2007) "Estimation and inference in two-stage, semi-parametric models of production processes"*Journal of Econometrics* 136, 31-64

Simar.L and Wilson.P.W .(2011) "Estimation and Inference in Nonparametric Frontier Models: Recent Developments and Perspectives"*Foundations and Trends in Econometrics,* 5 (3-4), 183-337.

Vlontzos. G, Niavis. S and Manos. B (2014) "A DEA Approach for Estimating the Agriculture Energy and Environmental Efficiency of EU Countries*" Renewable and Sustainable Energy Reviews, 40 (2014),* 91-96

World Bank (2017-2025). World Development Indicators. Washington DC. The World Bank.

World Development Report (1994) "Infrastructure for Development" Oxford University Press

Worthington.A.C. (2004) "Frontier Efficiency Measurement in Healthcare: A Review of Empirical Techniques and Selected Applications" *Medical Care Research and Review* 61(2), 1-36.

Wylie. P.J (1996) "Infrastructure and Canadian Economic Growth 19946-1991" *The Canadian Journal of Economics, 29 (part I)*, S350-S355

Yang.Z (2006) "A two-stage DEA model to evaluate the overall performance of Canadian life and health insurance companies" Mathematical and Computer Modelling 43 910–919

Zhou. L and Hai-Peng. Z (2013) "Productivity Growth in China's Agriculture During 1985-2010*" Journal of Integrative Agriculture, 12 (10),* 1896-1904.