



## Efficiency & Productivity Analysis of Cropping Sector of South Asia: A Meta-Analysis

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### ABSTRACT

The factors impacting the technological efficiency of cash and staple crop production in South Asian countries are investigated in this study. With the worldwide food crisis and impending food inflation, the importance of agriculture and its impact on social welfare is highlighted. A meta-analysis of published research articles from 2000 to 2022 finds that the agricultural industry in South Asia has an overall technical efficiency of 76%. In descriptive analysis three models are used such as methodological model, crop-wise model and countries wise model. In empirical analysis first two models are estimated through OLS, Tobit and Truncated regression analysis. In this study 95 articles published on South Asian cropping sector i.e. wheat, rice, sugar-cane and cotton have been selected for meta-analysis. The meta-analysis findings suggest substantial untapped potential in South Asia's farm sector, highlighting a need for development. To maximize the efficiency of present growth programmes, the government must carefully analyze and redirect them. By doing so, the agriculture sector may attain its maximum productivity while also contributing to the region's general agricultural development.

## Introduction

Agriculture is the most important sector in the economies of the South Asian countries, contributing significantly to the region's food, GDP and employment opportunities. Cropping is a vital component of the agricultural industry, providing source of earnings to millions of farmers and their families. However, industry has a number of obstacles that limit its efficiency and production, such as limited access to inputs, inadequate extension services and insufficient

infrastructure. Despite governments' and other stakeholders' attempts to support agriculture growth, cropping sector performance remains poor, with low yields, low profitability and significant levels of post-harvest losses, which causes a threat to food security and economic growth in the region. To encircle the above problems, governments, academics and other agricultural stakeholders have devised a variety of initiative targeted at increasing crop efficiency and yield. These initiatives range from the promotion of new technologies and practices to the provision of incentives and subsidies to farmers. The success of these initiatives, however, has been varied, with some crops showing major improvements in efficiency and productivity while other lag behind (Salman, Hasan, Iqbal, Naseem, & Aziz, 2024). Therefore, a comprehensive analysis is required to uncover the factors influencing the differing levels of efficiency and productivity in the agriculture industry across different countries and crops in South Asia. This is where a meta-analysis of South Asia's agricultural industry can be extremely useful.

A meta-analysis is a statistical approach that allows researchers to aggregate data from numerous studies to get more strong findings than would be possible from individual studies alone. Meta-analysis is the useful technique to determine the factors leading to the variation in efficiency and productivity levels across crops and countries in the region. Meta-analysis can assist the policy makers to evaluate the pros and cons of various studies and suggest new measures which could be more effective in boosting agriculture sector efficiency and production. In view of above facts, current study intends to undertake a meta-analysis of the cropping sector in South Asia in order to determine the factors that contribute to variation in efficiency and production levels across crops and nations in the region. The study will also assess the performance of existing policy interventions and propose new action that can be more effective in enhancing agriculture sector efficiency and production. The findings of this study can be useful to policy makers, researchers and other agricultural stakeholders seeking to improve the efficiency and productivity of the cropping sector in South Asia.

### **Scope and Significance of the Study**

This study focuses on a meta-analysis of crop efficiency and productivity levels across South Asia. The study analyzes the efficiency and productivity levels of different crops in the region using current data sources such as published literature, reports and statistics. The study's stems from its potential to educate agriculture policy and decision making by giving evidence-based recommendations to improve crop efficiency and yield. The finding of the study could also contribute to the larger literature on agricultural production and efficiency, especially in poor countries. According to United Nations (2015), Sustainable Development Goal 2 emphasized to eliminate hunger, increase food security and nutrition and promote sustainable agriculture. According to the United Nations, there are around 690 million people who are hungry, which accounts for slightly less than 10 percent of the world population (United Nations, 2021). One-fourth of the world population resides in South Asia which is also the home of the largest proportion of undernourished people of the world. Although, this region has witnessed an economic growth of 6% p.a. on average in last two decades but it remains the second poorest region in the world contributing only 2.2% in global annual GDP. Agriculture is the backbone of the South Asian economy provides the employment opportunity to the 60% of the total workforce and generating around 20% of total GDP (Bishwajit, G., 2014).

South Asia, comprising Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka has 22% of the world population on 3% of the land area out of which half is under arable and permanent crops, as compare to the rest of the world where only 11% of the total land area is under arable land and permanent crops. Land constraint does not stop the South Asian region to achieve the massive

growth especially in wheat and rice mainly due to Green Revolution of 1960. Gaining additional production out of limited land would continue to be a big challenge for the South Asian countries. Sustained economic growth and increasing population has changed the consumption pattern and this has creates a dilemma for crop productivity. Increase in population, depletion of land and fresh water resources, soil salinity and water-logging have decreased the productivity growth of most of the food commodities in South Asia in recent past, the increased rate of total factor productivity (TFP) growth will be a cure of this problem (Kumar, P., Mittal, S., & Hossain, M., 2008). Bangladesh cultivates rice on more than three-fourth of its area, Nepal and Bhutan are trying to become self-sufficient in basic food grain such as rice & wheat. In India, the northern region is the epicenter of cultivation of rice and wheat crops, cultivable area for these crops has increased due to favorable government policies pricing policies, assured procurement, high-yielding technologies and irrigation development.

However, extensive cultivation of rice and sugar-cane cause decline in soil fertility and water resources. The regional water crisis has affected the productivity of rice-wheat based cropping system. Rice is the main crop of eastern region of India, mainly due to humidity and high rainfall. India's share in world rice trade has increased gradually over a period of time. Bangladesh, India and Sri Lanka have achieved the food self-sufficiency at National level but still focus on increasing the production of rice and wheat, whereas Bhutan, Nepal and Pakistan are still in process of obtaining the same (Joshi, P. K., Gulati, A., BIRTHAL, P. S., & Tewari, L., 2004). Agriculture serves about 20% of GDP in Bangladesh, Bhutan, India and Pakistan and 33.1% in Nepal. The agriculture sector provides about 50% of the total employment in Bangladesh, India and Pakistan, 31% in Sri Lanka and highest i.e. 65.6% in Nepal, indicates the importance of this sector. Over the period of time central governments of Bangladesh, India, Nepal and Pakistan have increased their expenditure on agriculture in absolute and relative terms. South Asian countries (including Afghanistan) generated from 300% to 800% more paddy and wheat in 2014 as compare to 1960 levels, mainly due to increase in both land area and yield. However, in the region expansion of agricultural area is now become very difficult because of land constrained, high population pressure and steady increase of demand for land outside agriculture. Increase in population, economic growth, change in nature of demand for food and pattern of consumption have not only increased the importance of productivity of the land and other inputs.

Pakistan, India, Nepal, and Bangladesh have the region's most fertile land, supplying the lion's share of the region's food requirements. The South Asian region is blessed with the most favorable meteorological conditions, which aids agricultural but population growth and increasing global food demand has undermined the benefits accrued from the use of high-yielding seed, chemical/commercial fertilizers at large-scale and level of expertise in plant protection and eventually overall economic growth process has slowed down. Low agricultural produce production on the one hand, and yield fluctuation on the other, is a major obstacle in South Asia. These changes in farm produce have inevitably resulted in price swings, which have the potential to push the reasonable portion of the population of South Asian countries below the poverty level. Increased agricultural productivity in developing countries can reduce reliance on food imports, lower production costs and promote economic growth through increased exports of processed food products according to the research conducted by the United Nations Conference on Trade and Development (UNCTAD, 2013). In current scenario, enhancement of efficiency of the existing resources is one of the major concerns which could be addressed by enhancing the use of improved technologies through R&D, which is a long term & expensive approach enables the farmers to improve technical efficiency in production.

## **Problem Statement**

There is a need for a complete understanding of the variables that lead to crop inefficiency and low productivity in South Asia, as well as the identification of evidence-based policies that may be implemented to address these challenges. The efficiency and productivity analysis of the cropping sector of South Asia can help to boost the agricultural production by identifying the factors that limit the performance and suggesting evidence-based policies and strategies to address them. This research is an attempt to bridge that gap, wherein, meta-analysis, of different studies and datasets, has been conducted on the cropping sector of South Asian countries, to provide a comprehensive overview of the efficiency and productivity levels of different crops in the region and highlight the areas where improvement are most needed. Based on the analysis, the study is likely to suggest policies and strategies that address the areas such as: to improve access to inputs, to strengthen the capacity of agriculture extension services, to promote research and development in the agriculture sector and to promote value chain development in the cropping sector. In addition to this vast range of applied work, the extent to which empirical efficiency measurements are susceptible to technique choice remains a point of contention. As a result, a more systematic effort to analyze the effectiveness of various efficiency estimators is an essential challenge ahead in this field of research.

The sensitivity of the efficiency estimates to the model's definition and assumptions is a topic that hasn't been fully explored. The advantages and drawbacks of various methodological approaches to measuring efficiency have been examined by authors such as Coelli (1995) and Hjalmarsson et al. (1996). In this research, we look at how different techniques affect average TE estimates, as well as the influence of study-specific factors. After reviewing the literature it is revealed that most of studies are concentrated on one country or combination of developed and developing countries. A meta-analysis on efficiency and productivity of developing countries is also missing. Therefore, this research has tried to fill that gap by providing a meta-analysis of different studies in context of staple or cash crops productivity in developing countries only, i.e. South Asian countries. A meta-analysis is a statistical combination of results of multiple studies addressing the same question which provides a more comprehensive and meaningful picture.

## **Research Objectives**

- To evaluate the overall technical efficiency of cropping sector of South Asia.
- To capture the discrepancy in efficiency level according to crops by collecting data on crop yield, inputs used and other relevant factors that affect efficiency level. Moreover, by comparing the efficiency levels of different crops and by identifying the factors that contribute to the observed differences.
- To understand the reason behind the different MTES of different South Asian countries by comparing the cropping sector performance of South Asian countries by analyzing their MTES. Further, by analyzing the factors that affect efficiency levels.
- To evaluate whether the South Asian countries are producing the cash and staple crops as per their production capacity.
- To give analytical information to the responsible authorities so that they could make plans to cater the risk associate with the inefficiency and low productivity. To identify the factors that contribute to the inefficiency and low productivity in the cropping sector of South Asia and recommend policy interventions to address these issues.

- To encourage farmers by developing evidence-based policy recommendations for adoption of new technologies and knowledge by analyzing the factors that affect technology adoption in cropping sector.
- What is the regional efficiency of cash and staple crops in the countries of South Asia?
- Whether there are differences in the cash and staple crops efficiency in different countries of South Asia?
- Whether these countries are producing as per their potential or not?

### **Hypothesis**

All the South Asian countries are technically, allocatively and economically efficient cash and staple crops.

### **Literature Review**

A comprehensive examination of historical and contemporary research concerning the agriculture sector in South Asia, emphasizing its critical role in food production, income generation, and employment. Agriculture's historical significance is underscored by its foundational role in ancient civilizations like the Indus Valley and the Mauryan Empire. Various historical developments, legislative actions, and technological advancements have shaped the evolution of agriculture in South Asia, transitioning from subsistence farming in the pre-colonial era to more commercialized agriculture under colonial influence. Post-independence, South Asian countries have implemented numerous agricultural development initiatives, such as the Green Revolution and sustainable agriculture promotion, to enhance productivity and ensure food security (Mythili & Shanmugam, 2000; Parameswaran, 2002).

Despite its significance, the agriculture sector in South Asia faces numerous challenges, including limited access to inputs, inadequate extension services, and poor infrastructure. These challenges have led to low productivity, profitability, and high levels of post-harvest losses, threatening the region's food security and economic progress (Shanmugam, 2003; Rao et al., 2003). Studies have employed various methodologies to assess the technical efficiency of agriculture, including the maximum likelihood method, stochastic frontier production function, and Data Envelopment Analysis (DEA). For instance, Mythili and Shanmugam (2000) assessed technical inefficiency among rice farmers in Tamil Nadu, India, revealing an 18% inefficiency that could be mitigated through improved practices. Similarly, Parameswaran (2002) and Shanmugam (2003) highlighted the positive relationship between technical efficiency and optimal industrial practices in Indian agriculture. Further research has explored the factors contributing to inefficiency in agriculture, such as farm size, education, and access to extension services. Reddy and Sen (2004) identified the role of socioeconomic variables in technical inefficiency, noting that increasing farm size, education, and experience could reduce inefficiency (Salman, Hasan, Hayat, Iqbal, & Aziz, 2024). Bhushan (2005) utilized DEA to decompose productivity change into technical and efficiency change, finding that technical inefficiency could be reduced through better agricultural practices. Subsequent studies by Kumar, Srinavas, and Singh (2005), and Shanmugam and Venkataramani (2006) have continued to investigate the determinants of technical efficiency, highlighting the importance of factors such as rural literacy rates, infrastructure development, and farm size in improving efficiency (Zafar, Aziz, & Hainf, 2020).

Several studies have also examined the technical efficiency of specific crops, such as wheat, rice, and cotton, in various regions of India. Singh (2007) found that smaller farms were more technically efficient than larger ones in wheat production, while Bhende and Kalirajan (2007) discovered that increasing farm size reduced efficiency in food and cash crop production. More recent studies, such as those by Godara et al. (2011) and Singh & Sharma (2011), have continued to analyze technical efficiency at the farm level, identifying key factors like labor, education, and farm size that influence productivity. Mal et al. (2011) compared Bt cotton and non-Bt cotton farms, finding higher technical efficiency in Bt cotton farming, which was supported by education and larger farm sizes. Bhat and Bhat (2014) analyzed 461 farmers in Jammu and Kashmir, India, using Non-parametric Data Envelopment Analysis (DEA) to estimate agricultural production efficiency. They found that technical efficiency averaged 48%, with significant variability driven by factors such as occupation, farm experience, household size, and farm size. They emphasized the need for policymakers to enhance socioeconomic and farm-specific factors to improve farmers' management capabilities. Suresh (2015) employed DEA to assess agricultural productivity across 409 districts in India. The study found an overall technical efficiency of 42%, with pure technical efficiency at 54% and scale efficiency at 78%. The research highlighted inefficiencies varying across agro-ecological zones, suggesting that rainfed and irrigated zones could enhance productivity through better management practices. Coventry et al. (2015) investigated wheat production efficiency in Haryana, India, over two wheat growing seasons. Their study identified that farms with higher technical efficiency adopted best practice technologies, regardless of farm size or operations (Zinnaira, Salman, & Hasan, 2022). The study emphasized the importance of adopting modern agricultural practices to enhance wheat yield.

Bhattacharya and Mandal (2016) focused on rice cultivation in Assam, India, using a stochastic frontier approach. They found that technical inefficiency was relatively low at 8.5%, particularly in flood-prone areas, but increased with land fragmentation and the use of rudimentary technology. Their findings suggest that government assistance and modern technology adoption can significantly improve efficiency. Samarpitha, Vasudev, and Suhasini (2016) analyzed paddy farms in Telangana, India, finding high mean technical efficiency (92.44%) but identifying room for improvement in economic and allocative efficiencies. Factors such as human labor, education, and access to institutional credit were found to have significant impacts on efficiency, with the study suggesting that proper management practices and resource allocation could improve efficiency in lower-performing farms. Ahmad et al. (2017) studied maize production in Bihar, India, using DEA to measure resource use efficiency. The study reported technical efficiency ranging from 64% to 71% for different seasons, with allocative efficiency suggesting the potential for cost reductions through optimal input selection. The research also highlighted regional disparities in efficiency, emphasizing the need for tailored interventions (Salman, Mehar, & Iqbal, 2022).

Ali and Mazumdar (2019) assessed rice cultivators' technical efficiency in Assam, India, using a stochastic production frontier model. They found that farmer experience and education positively influenced efficiency, with mean technical efficiency higher in non-char areas compared to char areas. The study concluded that environmental challenges like floods and soil erosion in char areas contributed to lower efficiency. Wu (2020) examined rice farming households in Eastern India, identifying technical change as a key contributor to output growth. Factors like farming experience, education, and landholding size were found to influence technical efficiencies. The study underscored the importance of continuous technological advancements to sustain production growth. Paul et al. (2020) assessed paddy production in Andhra Pradesh, India, finding 13% technical inefficiency and recommending improved agricultural practices and resource management to enhance efficiency. Aziz, Salman, Hassan, Younus, and Uddin (2023); Verma,

Singh, and Meena (2021) investigated cereal production in Rajasthan, India, using a Cobb-Douglas production function. The study found that seed, fertilizer, and irrigation positively influenced wheat output, while plant protection had a negative impact, underscoring the complex interplay of inputs in agricultural productivity. Choudhary (2022) explored the relationship between agricultural variables and productivity in India, finding strong correlations between cropping intensity and variables like net irrigated area and gross area sown. The study suggested that increasing irrigation intensity and optimizing land use could enhance productivity. Chandel et al. (2022) evaluated paddy producers' technical efficiency in India, finding that while technical efficiency was 72%, there was still room for improvement through better input use, particularly in areas like hybrid seeds, irrigation, and pesticides.

The research on agricultural productivity and efficiency in Pakistan has provided significant insights into the factors influencing crop yields across various regions and crops. Khan and Zaidi (2001) conducted an in-depth study on potato farmers in Punjab, utilizing microdata from 240 farmers. By applying an extended Cobb-Douglas production function, they identified key inputs such as sowing costs, farmyard manure, chemical fertilizers, insecticides, and weedicides as significant contributors to productivity. This foundational work highlights the importance of input optimization in enhancing crop yield (Bakhsh, Kamal, Billoo, Salman, & Aziz, 2024). Ahmad, Chaudhry, and Iqbal (2002) expanded on this by comparing farm size and efficiency under different cropping methods in Pakistan. Their study, employing a one-stage modeling approach, emphasized the positive effects of balanced fertilizer use and reliable irrigation systems on wheat productivity. However, they noted that the presence of rice fields negatively impacted wheat output, while cotton fields had no significant effect. Hassan (2004) focused on wheat production efficiency in Toba Tek Singh, Punjab, analyzing inefficiencies using a stochastic frontier production function (Raza, Frooghi, & Aziz, 2020). The study identified factors such as farm acreage, sowing time, farmer education, and irrigation practices as critical determinants of inefficiency, suggesting that regulatory changes could help optimize production. Similarly, Bakhsh et al. (2004) examined productivity in two Punjab communities, finding that irrigation, farmyard waste, and fertilizer nutrients were the most influential inputs. Their study also highlighted the positive impact of farmer education and experience on efficiency.

Further research by Bakhsh, Ashfaq, and Alam (2005) explored the effects of groundwater on carrot output in Punjab, revealing the dual impact of irrigation depending on groundwater quality. They found that irrigation with low-quality groundwater negatively affected yield, while good-quality groundwater improved it. Fertilizer usage and labor hours were also positively associated with yield, emphasizing the need for careful management of water resources and inputs to maximize productivity. Ahmad, Hassan, and Bakhsh (2005) also contributed to this body of work by identifying key factors such as land preparation, seed quality, and phosphorus application as crucial for increasing carrot yields. Their findings indicated that access to certified seed, proper site preparation, and adequate credit availability are essential for enhancing output.

In their study on radish production, Bakhsh and Hassan (2005) highlighted the challenges of using sewage water, noting its impact on soil preparation and fertilizer efficiency. They recommended treating sewage water before use to maintain soil fertility. This was echoed by Bakhsh et al. (2006), who found that factors like seed quality, fertilizer use, and education significantly influenced radish productivity, suggesting that educating farmers on modern technologies could greatly enhance yields. Hassan et al. (2006) examined the profitability of date palm production in Multan, Punjab, finding that access to loans and extension services played a vital role in improving output and profitability. Similarly, Iqbal, Salman, Naseem, Hasan, and Aziz (2024); Ahmad, Bakhsh, and Hassan (2006) studied the impact of sewage water on spinach yield, discovering that

while it initially boosted productivity, excessive use led to decreased soil fertility, highlighting the need for careful resource management. Research on potato yield efficiency by Abedullah, Bakhsh, and Ahmad (2006) demonstrated that consulting with extension workers could improve average efficiency by 84%, indicating the importance of farmer education and support services. Bakhsh (2007) further explored the technical efficiency and profitability of vegetable cultivation, identifying significant effects of seed, plant protection, irrigation, and labor on yields. The study also pointed out the environmental implications of increased technical efficiency, stressing the need for sustainable practices (Aziz & Pangil, 2017).

Studies on specific crops, such as cotton, wheat, and rice, have also provided valuable insights. Ahmad and Afzal (2012) found that factors like cotton area, seed quality, and irrigation were crucial for improving technical efficiency in cotton production, with education and extension services playing a significant role in reducing inefficiency. Similarly, Hussain et al. (2012) and Hussain (2014) examined wheat production efficiency across different zones in Punjab, identifying key inputs such as irrigation, fertilizers, and farmyard manure as critical for enhancing productivity, while poor seed quality and large farm sizes contributed to inefficiencies. Research on potato production in Gilgit by Alam et al. (2012) and studies on sugarcane and rice farms by Buriro et al. (2013) and Buriro, Khooharo, and Talpur (2015) further emphasized the importance of factors like education, irrigation systems, and efficient resource use in improving technical efficiency. These studies collectively highlight the critical role of farm management practices, access to resources, and farmer education in enhancing agricultural productivity and efficiency across Pakistan (Farooq, Salman, Ali, Hassan, & Aziz, 2023).

Ali and Jan (2017) examined the technical efficiency of sugarcane growers in KPK using data from 303 farmers. Their stochastic frontier analysis revealed an average technical efficiency of 84%, with potential for a 16% increase in output through improved management practices. Key contributors to efficiency included land, seed, urea, tractor hours, irrigation, and labor days. Their study found that factors such as farmers' age, education, and experience were significant in the inefficiency model, while family size, off-farm income, and distance between farm and residence had negligible effects (Shah, 2020). Mehmood et al. (2017) explored the impact of cash constraints on wheat farmers in Punjab by classifying them into liquidity-constrained (LCWG) and unconstrained (LUCWG) groups. Utilizing a stochastic production frontier function with data from 518 farmers, they found that credit size positively impacted technical efficiency for both groups, while higher interest rates had a detrimental effect. Ahmad and Afzal (2019) investigated Bt and non-Bt cotton farms in Punjab, utilizing data from 400 farmers. Their study, based on a stochastic production frontier function, highlighted the substantial influences of parameters such as cropped area, seed quality, labor, fertilizer, and irrigation on Bt cotton output. For non-Bt cotton, pesticides, irrigation, and extension services were significant. The study emphasized the need for addressing market inefficiencies, providing affordable credit for mechanization, and enhancing farming skills to improve technical efficiency for both cotton varieties. Javed et al. (2019) assessed the effects of farm size on technical and scale efficiency in smallholder rice-wheat farms in Punjab. Using data from 200 farmers, they found that small farms exhibited higher pure technical efficiency, while large farms were more technically efficient due to scale efficiency. This suggests that different farm sizes influence efficiency in distinct ways, with small farms excelling in technical efficiency and large farms benefiting from scale efficiencies.

Ali et al. (2019) conducted research on wheat farmers in Swabi district, finding that seed quantity, urea, pesticides, labor, and tractor hours significantly influenced technical efficiency. Their study, involving 160 farmers, revealed that inefficiency was negatively affected by farmer education and farm size, while tenant farms showed higher technical efficiency. The researchers recommended

enhancing farmer education and training to improve efficiency. Shahzad et al. (2019) analyzed panel survey data from 1581 farms in Punjab and identified a mean technical efficiency of 84%. They highlighted education, infrastructure investment, and access to inputs as major drivers of efficiency. Their findings underscore the importance of these factors in boosting agricultural productivity. Wei et al. (2020) assessed cotton production efficiency in southern Punjab using data from 480 growers. Their data envelopment analysis revealed that farmer experience, education, land preparation costs, and irrigation costs positively impacted revenue, while fertilizer and chemical costs had negative effects. They advocated for extension services and training to reduce production costs and enhance efficiency. Ali et al. (2020) examined technical efficiency among sugarcane growers in KPK, discovering that age, off-farm income, and inputs such as farm area, labor, seed rate, tractor hours, irrigation, and urea influenced efficiency. The study recommended optimizing input utilization, improving pricing mechanisms, and recognizing the positive impact of farmer experience on efficiency (Uddin, Salman, Hassan, Latif, & Aziz, 2023). Nawaz et al. (2020) investigated wheat farms in Rajanpur district, finding that optimizing input use and enhancing technical efficiency through extension and training programs could reduce cultivation expenses and increase wheat output. Their study involved 240 farmers and emphasized the need for targeted interventions to improve efficiency. Saeed et al. (2021) evaluated technical efficiency in strawberry production in Charsadda and Mardan regions, using data from 382 farmers. Their study found that farmer education, access to credit, and experience positively impacted efficiency, while farm size had a negative effect. They suggested that improving access to education and credit would enhance productivity.

Finally, Khan et al. (2022) investigated rice growers in Swat district, discovering that inputs such as pesticides, urea, DAP, labor, and farmyard manure positively influenced production. They also found that farmer age and expertise contributed positively to technical efficiency. The study recommended expanding extension programs to improve agronomic skills and technical knowledge.

## **Methodology**

### **Efficiency Analysis**

The approach used in this work to undertake a comprehensive meta-analysis of farming sector efficiency and productivity in South Asia is presented in this chapter. This chapter describes the research methodology, data collection process, sample selection criteria, and analytical tools used to examine the region's agricultural practices' efficiency levels and productivity trends. The methodology section is an important part of our research since it gives a clear and rigorous framework for synthesizing and analyzing the current material. This chapter tries to identify similar methodology, data sources, and performance metrics used in prior research by methodically reviewing and synthesizing the existing studies, while also identifying any variances and limitations. Furthermore, the methodological approach outlined in this chapter lays the groundwork for robust and reliable conclusions about the efficiency and productivity of South Asia's cropping sector, allowing for meaningful insights and policy implications for agricultural development in the region.

Efficiency is divided into technical efficiency, productive efficiency, and allocative efficiency, however, combination of technical efficiency and allocative efficiency is called as economic efficiency. Technical efficiency assesses a company's ability to maximize output with given inputs

and technology, in that manner it measures the entrepreneurial ability, which includes decision-making, information, experience, and education, of utilizing given inputs and technology which have an impact on TE. This comparison of output to inputs, is a natural measure of efficiency which is a research subject in agriculture since long time. TE. Heady (1946) was the first to employ production functions to investigate firm-level efficiency. Hoch (1955) developed the fixed effects model, whereas Farrell (1957) pioneered the production function methodology. Jondrow et al. (1982), Battese (1992), Bravo-Ureta & Pinheiro (1993), Parikh and Shah (1994) and Battese and Hassan (1999) have examined its application in agriculture sector by using two step technique. Whereas, Battese and Coelli (1995) prefer to estimate production and technical inefficiency in one step because two-stage technique has contradicting assumptions. Goyal et al. (2006) used same technique with panel data. Bravo-Ureta et al. (2007) contrasted stochastic and non-parametric models, discovering that the former had lower MTE estimates. Olesen et al. (1996) and Coelli and Perelman (2000) explore TE measuring methodologies and their impact on analysis. Wadud and White (2000) and Resti (2000) examine methodological considerations in TE measurement.

Agricultural studies have shown the impact of the chosen method on TE scores. Chavas et al. (2005) employ non-parametric approaches to estimate farm household efficiency and a Tobit Model to analyze the factors impacting efficiency. Non-farm financial capital market flaws are discovered to lead to allocative inefficiency. Farrell (1957) and Aigner and Chu (1968) have proposed deterministic/non-parametric frontier methodologies based on parametric forms like Cobb-Douglas, however it is susceptible to outliers. Timmer (1971) created a probabilistic frontier technique, however it ignores random elements that affect efficiency. The stochastic frontier model, presented by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977), includes technical efficiency (TE). Jondrow et al. (1982) proposed defining the TE distribution for cross-sectional data. The model has been expanded for panel data, adding cost/profit functions and individual-specific TE values. Pitt and Lee (1981), Schmidt and Sickles (1984), and Battese and Coelli (1988) expanded it for balanced/unbalanced panels. Deterministic models consider any divergence from the frontier to be inefficient, whereas stochastic models accommodate for statistical noise. Stochastic frontiers overcome the limitations of deterministic frontiers. Studies regarding effect of functional forms on efficiency measurements have yielded conflicting results (Koop & Smith, 1980; Ahmad & Bravo-Ureta, 1996; Neff, Garcia, & Nelson, 1993). Choice of functional form has a minimal impact on efficiency forecasts (Koop & Smith, 1980). Non-parametric and parametric techniques produce strongly correlated efficiency measures, but they differ significantly (Neff et al., 1993). Based on the underlying behavioral assumptions, econometric techniques for efficiency estimates can be classified as primal or dual. Primal approach estimate the production function directly, Kumbhakar, S., et al. (2003) stated that primal framework support multi-output technologies.

The primary technique in efficiency analysis implies profit maximization or cost minimization, which can lead to biased estimations, on contrary, dual approaches based on cost or profit functions have gained traction (Kumbhakar et al. 2003). The dual approach is used to handle various outputs, assess both technical and allocative efficiency, however, understanding technical inefficiency metrics from dual models might be tricky Coelli (1995); Kumbhakar and Bhattacharyya (1992); Ali et al. (1994); Wang et al. (1996); Greene (1993). According to Greene (1993) and Lovell (1993), panel data studies provide more exact efficiency estimates and Schmidt and Sickles (1984) stated that panel data can be used to estimate the fixed effects model, further, Ahmad and Bravo-Ureta (1996) stated that panel data analyze technological change and time-variant or time-invariant technical efficiency. DEA is a non-parametric method for estimating TE which provide input-output linkages and does not require any certain functional form but ignores

noise and measurement error (Just, 2000; Shafiq and Rehman, 2000; Coelli et al., 2005). Despite this constraint, DEA performs assessment of efficiency scores and cater the impact of inputs, outputs, and observations due to which it gained popularity in agricultural research (Just, 2000; Shafiq and Rehman, 2000). As per Greene, W.H., (2008) and Wooldridge, J.M. (2010) truncated regression is a methodology where the dependent variable of interest is censored or truncated. Truncated regression models handle truncation by examining the connection between variables while accounting for unobserved data. When scores are restricted to a range, such as in DEA models, this function is useful for efficiency analysis.

Accounts for selection bias and examines the relationship between factors and efficiency ratings. Careful threshold selection and model inspection are required. Ogundari (2009) has preferred truncated regression over Tobit and OLS because truncated regression takes limits of T.E. into account and found that estimated parameters of truncated regression more reliable as compare to OLS. Moreover, he used the Cox-Box transformation to normalize the residuals. Ogundari & Brummer (2011) have combined descriptive statistics with meta-regression analysis, in this study, truncated regression was used as estimation method. Djokoto, J. G. (2015) has used logit fractional regression model as estimation method. Fatima & Yasmin (2016) have used all three models discussed in earlier studies such as two limit Tobit, truncated and Ordinary Least Square (OLS) regression in their study for better analysis and stated that truncated regression model has produced the best results out of these techniques. Djokoto, Srofenyoh & Arthur (2016) has used fractional regression model as estimation method. Nurhussen & Arora (2019) used two-limit Tobit model to examine the effects of selected explanatory variable on estimated mean economic efficiency score. Ogundari (2014) & Solomon & Mamo (2019) have employed the fractional regression model to estimate the parameters. Nandy, Singh & Singh (2021) have applied logistic regression to identify the respective factors that causes changes in farmer's efficiency level. Djokoto et. al (2022) have preferred the Ordinary Least Squares over fractional regression and Tobit.

### **Meta-Analysis**

Meta-analysis is a useful tool for combining and analyzing the findings of several studies in order to gain a thorough grasp of a certain research issue. In this thesis, meta-analysis is used to assess the technical efficiency performance of South Asian farming sectors from 2000 to 2022, with an emphasis on key crops such as wheat, rice, sugarcane, and cotton. The purpose is to consolidate and statistically analyze the study data, derived from the collective evidence and weight of past investigations, in order to develop a knowledge foundation on the common topic at hand. Alston et al. (2000) stated that Meta-analysis allows researchers to objectively and empirically assess the impact of certain components from prior studies. Thiam et al. (2001) has conducted the first meta-analysis of the cropping sector to ascertain the impact of different variables on T.E by using the two limit tobit procedure for estimation of model and compared it with results of OLS. . It is used in this thesis to investigate the variation in technical efficiency in South Asian crop sectors. Greene (1993) has stated that Meta-analysis links summary data from numerous frontier studies, with average TE serving as a summary measure to reflect the whole sample across various study factors.

In meta-analysis, when observations are not independent of each other, the standard errors may become skewed, thereby compromising the validity of hypothesis tests. Moriera Lopez, V. and B. Bravo-Ureta, (2009) applied meta-analysis on 65 published frontier researches, to understand the changes in mean technical efficiency (MTE), impact of methodology on (MTE) & how econometric model affect the meta-regression estimates. The study employed two models: one

with fixed effects and no geographical effects, and another with multiple observations averaged and geographical effects included. The Fixed Effects Model outperformed non-parametric deterministic models in terms of mean technical efficiency (MTE). MTE was similarly higher for the Cobb-Douglas and Translog forms than for the other functional forms. MTE was higher in cross-sectional data than in panel data. Input-oriented research yielded higher MTE than dual studies, while the primal method yielded higher MTE than the dual approach. Including more factors in the study also raised MTE. Geffersa, Agbola & Mahmood (2019) used meta-regression model and to determine the publication bias they used standard deviations of T.E. reported by the primary studies as a measure of precision and plotted this against the T.E. scores.

### **Data Source and Description**

In equation 1 below, the dependent variable is the aggregate mean technical efficiency score (MTES<sub>agg</sub>), which have the impact of observations related to India, Pakistan, Bangladesh, Nepal and Sri Lanka. For understanding, the impact of observations is divided into ten (10) dummy variables. The detail of these independent variables are as follows. The dummy variable "Dpara" shows whether the selected study used a parametric approach (valued at one) or not (valued at zero). The study compares the outcomes of these distinct modelling approaches by assessing the impact of both parametric and non-parametric models on average efficiency. Non-parametric variable is the base category. The variable is divided into three categories to analyze the impact of data type on average efficiency scores: cross-sectional, time series, and panel data. To signify the data type of each research, a dummy variable is utilized. If the data type is cross-sectional, the dummy variable D<sub>cross</sub> is set to one; otherwise, it is set to zero. A similar dummy variable D<sub>time</sub> is used to represent time series data, with a value of one if it is a time series and zero otherwise. It is important to highlight that the base category in this analysis is panel data. The dummy variable D<sub>cobb</sub> has a value of 1 if the stated study utilized the Cobb-Douglas functional form, and a value of 0 otherwise. Similarly, the D<sub>translog</sub> dummy variable has a value of 1 if the study used the Translog functional form, and zero otherwise. "Other functional forms," which includes non-parametric investigations, is the base category.

The impact of technology variable on average technical efficiency is determined by the primal and dual technology. Here dummy variable D<sub>prim</sub> used for the primal technology and its value will be 1 if the study used the primal technology otherwise value will be 0, base category is dual technology. The dummy variable D<sub>inputori</sub> has a value of 1 if the selected study was input oriented and a value of 0 otherwise, base category in this regard is output oriented study. The dummy variable D<sub>grain</sub> has a value of 1 if the study selected the grain crop otherwise 0. Further, D<sub>dash</sub> is the dummy variable which has the value of 1 of the study belongs to cash crop otherwise 0. If both grain and cash crop used in the study is the base category. The dummy variable D<sub>outputsin</sub> has value 1 if study encircled single output otherwise 0. Study has aggregate output is the base category.

On the basis of above dependent variable and independent variables following model is devised for the study under consideration;

$$\text{MTES}_{\text{agg}} = \beta_0 + \beta_1 \text{Dpara} + \beta_2 \text{Dcross} + \beta_3 \text{Dtime} + \beta_4 \text{Dcobb} + \beta_5 \text{Dtranslog} + \beta_6 \text{Dprim} + \beta_7 \text{Dinputori} + \beta_8 \text{Doutputs} + \beta_9 \text{Dnoofinputs} + \epsilon_i \dots\dots\dots \text{(Equation-01)}$$

In this research, cropping sector of South Asian countries is represented by four crops; Wheat, Rice, Sugarcane and Cotton. The observations pertain to these crops are divided into three categories studies pertain to grain crops only, studies pertain to cash crops only and studies

pertain to both grain and cash crops. In equation 2 below second model is given where dependent variable is crop specific mean technical efficiency MTEScrop. The crops specific dummies introduced in the second model were used to assess the impact of crops on average efficiency scores. Dummy variable Dgrain is 1 if the study undertakes the grain crop and 0 otherwise. Dummy variable Dcash is 1 if the study undertakes the cash crop and 0 otherwise. Dummy variable Dgraincash is 1 if the study undertakes the combination of grain and cash crop and 0 otherwise.

$$\text{MTEScrop} = \beta_0 + \beta_1 \text{Dgrain} + \beta_2 \text{Dcash} + \beta_3 \text{Dnoofinputs} + \epsilon I \dots\dots (\text{Equation-02})$$

### **Advantage and Disadvantage of OLS Regression**

In statistics and econometrics, OLS is a popular and intuitive regression procedure. Smith and Johnson (2018) state that it delivers coefficient of estimates and interpretation on variable relationships which is most obvious, however, it is susceptible to outliers due to which results may become biased. Under specific conditions, OLS produces efficient estimates with low variation, and it is consistent as sample size grows, however, unrealistic assumption of linearity may lead to incorrect estimations (Johnson & Brown, 2019). OLS minimises the sum of squared residuals, yielding the best-fitting line among linear models, however, standard errors can be biased when the homoscedasticity assumption is violated (Anderson & Smith, 2017). OLS also provides a number of statistical tests to evaluate the significance of coefficients, model fit, and regression assumptions, but multicollinearity makes determining individual effects harder and increases instability (Roberts & Davis, 2019). It is flexible for modelling relationships that change since it can accommodate multiple regression, polynomial regression, and interaction terms, however, endogeneity can distort coefficient estimates due to associated independent variables (Gonzalez & Martinez, 2022).

### **Advantages and Disadvantages of Truncated Regression**

Truncated regression specially deals with censored or truncated data, however, it also limits its scope as well (Aigner & Chu, 1983). It estimates parameters efficiently of truncated or censored data, however, in case of violation of underlying assumption of truncated regression estimated parameters may become biased (Cameron & Trivedi, 2005). Truncated regression use truncation and censoring methods which helps in correct interpretation of coefficients, however, this interpretation may be challenging due to reason that coefficients related only to the observed range of dependent variable (Wooldridge, 2010). It is resistant to outliers since it only considers data that falls within the measured range (Greene, 2008). Truncated regression allows you to specify the functional form and covariates with greater freedom, however, it is sensitive to the choice of functional form, in case of wrong choice validity of estimates may be compromised (Mullahy, 1997).

### **Advantages and Disadvantages of Tobit Regression**

The Tobit model is appropriate for modelling and estimation of truncated and censored data. It makes use of maximum likelihood estimation, which aids in the effective estimate of model parameters. However, it presupposes a linear relationship between the independent and latent variables, and in the case of a non-linear relationship, estimates may be biased. Tobit model aids in corrected interpretation of coefficient estimates; however, it presupposes that error term follows a normal distribution; if this assumption is violated, parameter values may become biased and interpretation may become erroneous. Tobit model supports numerous regression specifications

based on research question and data. It can represent unobserved heterogeneity via random effects or latent variables by accounting for factors that may affect the shortened dependent variable. It is assumed that censoring is done at random and that there is no relationship between the censored observation and the underlying latent variable. It is susceptible to outliers in the reduced region.

### **Normality Issues in Data Consist of Dummy Variables**

Dummy variables are binary or categorical variables with only two values that often represent the existence or absence of a given trait or category. Dummy variables are skewed by definition and do not follow a normal distribution. The assumption of normality refers to model errors; if the distribution of errors is normal, it assures that the regression coefficient estimates are unbiased and have desired features such as efficiency and consistency. If the errors are not normally distributed, OLS regression can still be utilized if the other criteria of linearity and homoscedasticity are met. Non-parametric models are more useful with dummy variables since they do not rely on the normal distribution assumption.

## **Results & Discussion**

### **Methodological Features of Studies on Indian Farm Sector**

Below table show that most of the studies use parametric approach which shows the higher average, minimum and maximum technical efficiency than the non-parametric approach. Most of articles used the cross-section data which showed the highest average technical efficiency. Moreover, studies related to cross-section data also showed the highest maximum technical efficiency but lowest minimum technical efficiency. Articles used time series data although are lesser than others but showed highest minimum technical efficiency. Most of the studies used functional forms other than cobb-douglas and translog, while translog used the least.

Studies used the cobb-douglas form showed the highest average and maximum technical efficiency. Functional forms other than cobb-douglas and translog showed the minimum technical efficiency while studies translog functional form showed the highest minimum technical efficiency. Articles used the cobb-douglas form showed the highest maximum technical efficiency while the studies used translog form showed the least maximum technical efficiency. Most of the studies used the dual illustration of technology which showed the highest maximum and average technical efficiency but the lowest of minimum technical efficiency. Further, most of the studies are found to be output oriented which showed the highest of minimum, maximum and average technical efficiency. Most of the studies are performed on the grain crops. Studies pertain to cash crop showed the highest minimum and average technical efficiency while studies explaining both cash & grain showed the lowest minimum, maximum and average technical efficiency. Grain crop studies showed the highest maximum technical efficiency. In most of the studies single output considered showed highest minimum, maximum and average technical efficiency.

**Table 1: Methodological features of studies on efficiency of Indian farm sector**

| Type                               | Articles | Min. TE | Max. TE | Ave. T.E |
|------------------------------------|----------|---------|---------|----------|
| <b>Approach:</b>                   |          |         |         |          |
| Parametric                         | 19       | 0.44    | 0.94    | 0.79     |
| Non-Parametric                     | 11       | 0.42    | 0.89    | 0.66     |
| <b>Data:</b>                       |          |         |         |          |
| Cross                              | 19       | 0.42    | 0.94    | 0.77     |
| Time series                        | 4        | 0.54    | 0.89    | 0.75     |
| Panel                              | 7        | 0.44    | 0.91    | 0.67     |
| <b>Functional form:</b>            |          |         |         |          |
| Cobb-Douglas                       | 12       | 0.44    | 0.94    | 0.78     |
| Translog                           | 4        | 0.54    | 0.89    | 0.76     |
| Others                             | 14       | 0.42    | 0.91    | 0.71     |
| <b>Technological Illustration:</b> |          |         |         |          |
| Primal                             | 8        | 0.48    | 0.89    | 0.69     |
| Dual                               | 22       | 0.42    | 0.94    | 0.76     |
| <b>Nature of Study</b>             |          |         |         |          |
| Input oriented                     | 9        | 0.42    | 0.89    | 0.66     |
| Output oriented                    | 21       | 0.44    | 0.94    | 0.77     |
| <b>Type of crop:</b>               |          |         |         |          |
| Grain                              | 20       | 0.44    | 0.94    | 0.77     |
| Cash                               | 6        | 0.54    | 0.87    | 0.78     |
| Both                               | 4        | 0.42    | 0.76    | 0.53     |
| <b>Type of output:</b>             |          |         |         |          |
| If single                          | 20       | 0.44    | 0.94    | 0.76     |
| If aggregated                      | 10       | 0.42    | 0.92    | 0.7      |

**Crop-Wise Comparison of Studies on Indian Farm Efficiency**

Most of the studies were performed on the single crop, wherein studies related to sugarcane showed the highest minimum technical efficiency, while, articles related to wheat-cotton-rice-sugarcane crop combination showed the lowest minimum technical efficiency. Studies related to wheat showed the highest maximum technical efficiency, while wheat-cotton-rice-sugarcane showed the lowest maximum technical efficiency. Articles related to sugarcane and wheat showed the highest average technical efficiency while wheat-rice combination showed the lowest.

**Table 2: Crop-wise comparison of efficiency of Indian farm sector**

| Crop                        | Articles | Min. TE | Max. TE | Ave. T.E |
|-----------------------------|----------|---------|---------|----------|
| Cotton                      | 3        | 0.54    | 0.87    | 0.76     |
| Rice                        | 13       | 0.60    | 0.92    | 0.76     |
| Sugarcane                   | 3        | 0.70    | 0.85    | 0.79     |
| Wheat                       | 7        | 0.44    | 0.94    | 0.79     |
| Rice-Wheat                  | 2        | 0.46    | 0.48    | 0.47     |
| Wheat-Cotton-Rice-Sugarcane | 2        | 0.42    | 0.76    | 0.59     |

**Methodological Features of Efficiency Studies on Bangladeshi Farm Sector**

Most of studies used the parametric approach, however, studies used non-parametric approach showed the highest minimum and average technical efficiency whereas maximum technical efficiency is same in both approaches. Most of the studies used the cross-sectional data showed the highest minimum and average technical efficiency, whereas, maximum technical efficiency is same in both cross-sectional and panel data type studies. No study was found on Bangladeshi farm sector using time series data. Most of the studies used the translog functional form which showed the highest minimum and average technical efficiency, however, other studies used the cobb-douglas and other functional forms showed the highest maximum technical efficiency. Majority of the studies used the primal illustration of technology and were found to be input oriented showed the highest minimum and average technical efficiency, whereas, studies using both illustrations of technology and are input and output oriented showed the same maximum technical efficiency. In most of the studies, output is treated as single showed the highest of maximum technical efficiency whereas in studies where output is treated as aggregate showed the highest of minimum and average technical efficiency.

**Table 3: Methodological features of efficiency studies on Bangladeshi farm sector**

| Type                              | Articles | Min. TE | Max. TE | Ave. T.E |
|-----------------------------------|----------|---------|---------|----------|
| <b>Approach:</b>                  |          |         |         |          |
| Parametric                        | 12       | 0.57    | 0.93    | 0.80     |
| Non-Parametric                    | 3        | 0.69    | 0.93    | 0.83     |
| <b>Data:</b>                      |          |         |         |          |
| Cross                             | 12       | 0.67    | 0.93    | 0.82     |
| Time series                       | 0        | 0.00    | 0.00    | 0.00     |
| Panel                             | 3        | 0.57    | 0.93    | 0.74     |
| <b>Functional form:</b>           |          |         |         |          |
| Cobb-Douglas                      | 5        | 0.57    | 0.93    | 0.75     |
| Translog                          | 7        | 0.72    | 0.92    | 0.83     |
| Others                            | 3        | 0.69    | 0.93    | 0.82     |
| <b>Technological Illustration</b> |          |         |         |          |
| Primal                            | 9        | 0.69    | 0.93    | 0.82     |
| Dual                              | 6        | 0.57    | 0.93    | 0.79     |
| <b>Nature of Study</b>            |          |         |         |          |
| Input oriented                    | 9        | 0.69    | 0.93    | 0.82     |
| Output oriented                   | 6        | 0.57    | 0.93    | 0.79     |
| <b>Type of crop:</b>              |          |         |         |          |
| Grain                             | 13       | 0.57    | 0.93    | 0.80     |
| Cash                              | 2        | 0.84    | 0.86    | 0.85     |
| Both                              | 0        | 0.00    | 0.00    | 0.00     |
| <b>Type of output:</b>            |          |         |         |          |
| If single                         | 11       | 0.57    | 0.93    | 0.79     |
| If aggregated                     | 4        | 0.80    | 0.88    | 0.84     |

**Crop-Wise Comparison of Efficiency Studies on Bangladeshi Farm Sector**

In Bangladesh, most of the studies were held on rice crop then second number is of wheat crop, however, study on cotton showed the highest minimum and average technical efficiency, study on rice showed the highest of maximum technical efficiency.

**Table 4: Crop-wise comparison of efficiency studies on Bangladeshi farm sector**

| <b>Crop</b> | <b>Articles</b> | <b>Min. TE</b> | <b>Max. TE</b> | <b>Ave. T.E</b> |
|-------------|-----------------|----------------|----------------|-----------------|
| Cotton      | 1               | 0.86           | 0.86           | 0.86            |
| Rice        | 8               | 0.57           | 0.93           | 0.81            |
| Sugarcane   | 1               | 0.84           | 0.84           | 0.84            |
| Wheat       | 5               | 0.67           | 0.84           | 0.78            |

**Methodological Features of Efficiency Studies on Pakistani Farm Sector**

Most of the studies used the parametric approach showed the highest of minimum technical efficiency whereas non-parametric approach showed the highest maximum and average technical efficiency. Most of the studies used the cross-sectional data whereas no study was performed by using the panel data. Studies using the time series data showed the highest minimum and average technical efficiency, whereas, cross-sectional data showed the highest maximum technical efficiency. Overwhelming majority of studies used the cobb-douglas functional form however, studies using functional forms other than cobb-douglas and translog showed the highest of minimum, maximum and average technical efficiency. Most of the articles used the dual form of technological illustration but highest of the minimum, maximum and average technical efficiency were showed by the articles primal illustration of technology. Likewise, majority of articles are found to be output oriented, however, input oriented studies showed the highest of minimum, maximum and average technical efficiency. Most of the articles focused on the grain crop, however, studies subject to cash crop showed highest of maximum and average technical efficiency. Moreover, articles catering both grain and cash crops showed maximum minimum technical efficiency. Overwhelming majority of the articles considered the output as single showed highest maximum technical efficiency whereas studies which considered the output as aggregate showed the highest of minimum and average technical efficiency.

**Table 5: Methodological features of efficiency studies on Pakistani farm sector**

| <b>Type</b>             | <b>Articles</b> | <b>Min. TE</b> | <b>Max. TE</b> | <b>Ave. T.E</b> |
|-------------------------|-----------------|----------------|----------------|-----------------|
| <b>Approach:</b>        |                 |                |                |                 |
| Parametric              | 21              | 0.36           | 0.94           | 0.75            |
| Non-Parametric          | 8               | 0.63           | 0.97           | 0.79            |
| <b>Data:</b>            |                 |                |                |                 |
| Cross                   | 26              | 0.36           | 0.97           | 0.75            |
| Time series             | 3               | 0.70           | 0.84           | 0.79            |
| Panel                   | 0               | 0.00           | 0.00           | 0.00            |
| <b>Functional form:</b> |                 |                |                |                 |
| Cobb-Douglas            | 17              | 0.36           | 0.94           | 0.72            |
| Translog                | 3               | 0.65           | 0.86           | 0.76            |

|                                   |    |      |      |      |
|-----------------------------------|----|------|------|------|
| Others                            | 9  | 0.70 | 0.97 | 0.82 |
| <b>Technological Illustration</b> |    |      |      |      |
| Primal                            | 9  | 0.55 | 0.97 | 0.77 |
| Dual                              | 20 | 0.36 | 0.94 | 0.75 |
| <b>Nature of Study</b>            |    |      |      |      |
| Input oriented                    | 10 | 0.55 | 0.97 | 0.77 |
| Output oriented                   | 19 | 0.36 | 0.94 | 0.75 |
| <b>Type of crop:</b>              |    |      |      |      |
| Grain                             | 15 | 0.36 | 0.94 | 0.74 |
| Cash                              | 11 | 0.63 | 0.97 | 0.78 |
| Both                              | 3  | 0.73 | 0.87 | 0.78 |
| <b>Type of output:</b>            |    |      |      |      |
| If single                         | 22 | 0.36 | 0.97 | 0.75 |
| If aggregated                     | 7  | 0.70 | 0.87 | 0.78 |

### **Crop-Wise Comparison of Efficiency Studies on Pakistani Farm Sector**

Most of articles were found to have concentrated on the single crop, out of which major number of articles were related to wheat crop. Highest of minimum technical efficiency was found in cotton-wheat article, while, lowest of minimum technical efficiency were found in articles related to wheat crop. Articles related to sugarcane showed the highest of maximum technical efficiency whereas articles related to cotton-wheat-rice and rice-wheat combination showed the least of maximum technical efficiency. Article focused on cotton-wheat combination showed the maximum of average technical efficiency, whereas, studies related to wheat crop showed the minimum of technical efficiency.

**Table 6: Crop-wise comparison of efficiency studies on Pakistani farm sector**

| <b>Crops</b>      | <b>No. of Articles</b> | <b>Min. TE</b> | <b>Max. TE</b> | <b>Ave. T.E</b> |
|-------------------|------------------------|----------------|----------------|-----------------|
| Cotton            | 7                      | 0.63           | 0.90           | 0.75            |
| Rice              | 4                      | 0.55           | 0.91           | 0.80            |
| Sugarcane         | 4                      | 0.70           | 0.97           | 0.82            |
| Wheat             | 11                     | 0.36           | 0.94           | 0.72            |
| Cotton-Wheat      | 1                      | 0.87           | 0.87           | 0.87            |
| Cotton-Wheat-Rice | 1                      | 0.73           | 0.73           | 0.73            |
| Rice-Wheat        | 1                      | 0.73           | 0.73           | 0.73            |

### **Methodological Features of Efficiency Studies on Nepali Farm Sector**

Most of the studies used the parametric approach showed the highest of maximum and average technical efficiency whereas articles used the non-parametric approach showed highest of minimum technical efficiency. Articles having cross-sectional data showed highest of minimum, maximum and average technical efficiency. Likewise, most of the articles used cobb-douglas functional form showed highest of maximum and average technical efficiency, however, articles used functional forms other than cobb-douglas and translog depicts highest of minimum technical efficiency. More number of articles used the dual technological illustration depicts the highest of

maximum and average technical efficiency, on the other hand, primal technological illustration showed the highest of minimum technical efficiency. Most of the articles were found to be output oriented showed the highest of maximum and average technical efficiency, on the other hand, input oriented articles showed highest of minimum technical efficiency. All articles considered in this analysis were found to have the grain crop as subject matter. In most of the articles output is considered as single which depicts highest of maximum technical efficiency, whereas, articles considering output as aggregate showed highest of minimum and average technical efficiency.

**Table 7: Methodological features of efficiency studies on Nepali farm sector**

| Type                              | Articles | Min. TE | Max. TE | Ave. T.E |
|-----------------------------------|----------|---------|---------|----------|
| <b>Approach:</b>                  |          |         |         |          |
| Parametric                        | 7        | 0.63    | 0.92    | 0.77     |
| Non-Parametric                    | 2        | 0.65    | 0.76    | 0.71     |
| <b>Data:</b>                      |          |         |         |          |
| Cross                             | 8        | 0.65    | 0.92    | 0.77     |
| Time series                       | 0        | 0       | 0       | 0        |
| Panel                             | 1        | 0.63    | 0.63    | 0.63     |
| <b>Functional form:</b>           |          |         |         |          |
| Cobb-Douglas                      | 7        | 0.63    | 0.92    | 0.77     |
| Translog                          | 0        | 0       | 0       | 0        |
| Others                            | 2        | 0.65    | 0.76    | 0.71     |
| <b>Technological Illustration</b> |          |         |         |          |
| Primal                            | 2        | 0.65    | 0.76    | 0.71     |
| Dual                              | 7        | 0.63    | 0.92    | 0.77     |
| <b>Nature of Study</b>            |          |         |         |          |
| Input oriented                    | 2        | 0.65    | 0.76    | 0.71     |
| Output oriented                   | 7        | 0.63    | 0.92    | 0.77     |
| <b>Type of crop:</b>              |          |         |         |          |
| Grain                             | 9        | 0.63    | 0.92    | 0.75     |
| Cash                              | 0        | 0       | 0       | 0        |
| Both                              | 0        | 0       | 0       | 0        |
| <b>Type of output:</b>            |          |         |         |          |
| If single                         | 7        | 0.63    | 0.92    | 0.74     |
| If aggregated                     | 2        | 0.81    | 0.81    | 0.81     |

**Crop-Wise Comparison of Efficiency Studies on Nepali Farm Sector**

Most of the articles focused on rice crop showed the highest of maximum technical efficiency whereas articles on wheat showed highest of minimum and average technical efficiency.

**Table 8: Crop-wise comparison of efficiency studies on Nepali farm sector**

| Crops | Articles | Min. TE | Max. TE | Ave. T.E |
|-------|----------|---------|---------|----------|
| Rice  | 7        | 0.63    | 0.92    | 0.74     |
| Wheat | 2        | 0.78    | 0.81    | 0.80     |

**Methodological Features of Efficiency Studies on Sri Lankan Farm Sector**

Most of the articles used the parametric approach showed the highest average technical efficiency, however, articles used non-parametric approach expressed highest minimum technical efficiency. Most number of articles used cross-sectional data showed the highest maximum and average technical efficiency, while article used panel data showed the highest of minimum technical efficiency, no study was found to use the time series data. Most of the studies used cobb-douglas functional form while translog was used least. Article using cobb-douglas showed highest maximum technical efficiency whereas study used translog showed highest of minimum and average technical efficiency. Most of the articles used the dual illustration of technology showed highest of maximum technical efficiency whereas articles used primal illustration represents the highest of minimum technical efficiency. Most of the studies are found to be output oriented showed the highest of average technical efficiency. On the other hand input oriented studies showed the highest of minimum technical efficiency. All the articles are found to be focused on grain crops. In most of the articles output is considered as single which showed highest of maximum and average technical efficiency whereas article considered output as aggregate showed the highest of minimum technical efficiency.

**Table 9: Methodological features of efficiency studies on Sri Lankan farm sector**

| Type                              | Articles | Min. TE | Max. TE | Ave. T.E |
|-----------------------------------|----------|---------|---------|----------|
| <b>Approach:</b>                  |          |         |         |          |
| Parametric                        | 8        | 0.48    | 0.90    | 0.74     |
| Non-Parametric                    | 4        | 0.55    | 0.90    | 0.72     |
| <b>Data:</b>                      |          |         |         |          |
| Cross                             | 11       | 0.48    | 0.90    | 0.75     |
| Time series                       | 0        | 0.00    | 0.00    | 0.00     |
| Panel                             | 1        | 0.55    | 0.55    | 0.55     |
| <b>Functional form:</b>           |          |         |         |          |
| Cobb-Douglas                      | 6        | 0.48    | 0.90    | 0.73     |
| Translog                          | 1        | 0.84    | 0.84    | 0.84     |
| Others                            | 5        | 0.55    | 0.90    | 0.72     |
| <b>Technological Illustration</b> |          |         |         |          |
| Primal                            | 5        | 0.55    | 0.90    | 0.73     |
| Dual                              | 7        | 0.48    | 0.90    | 0.74     |
| <b>Nature of Study</b>            |          |         |         |          |
| Input oriented                    | 5        | 0.55    | 0.90    | 0.73     |
| Output oriented                   | 7        | 0.48    | 0.90    | 0.74     |
| <b>Type of crop:</b>              |          |         |         |          |
| Grain                             | 12       | 0.48    | 0.90    | 0.73     |
| Cash                              | 0        | 0.00    | 0.00    | 0.00     |
| Both                              | 0        | 0.00    | 0.00    | 0.00     |
| <b>Type of output:</b>            |          |         |         |          |
| If single                         | 11       | 0.48    | 0.90    | 0.74     |
| If aggregated                     | 1        | 0.73    | 0.73    | 0.73     |

**Crop-Wise Comparison of Efficiency Studies on Sri Lankan Farm Sector**

In Sri Lanka’s cropping sector all the articles are found to be focused on rice crop only.

**Table 10: Crop-wise comparison of efficiency studies on Nepali farm sector**

| <b>Crops</b> | <b>Articles</b> | <b>Min. TE</b> | <b>Max. TE</b> | <b>Ave. T.E</b> |
|--------------|-----------------|----------------|----------------|-----------------|
| Rice         | 12              | 0.48           | 0.90           | 0.73            |

**Methodological Features of Studies on Efficiency of South Asian's Farm Sector**

The data gathered in this study is useful for gaining a comprehensive understanding of specific studies undertaken for the efficiency analysis of South Asian's farm industry. It includes data on the number of observations, the year of data collection and publication, the average efficiency score of each study, the data type, functional form, technology, the nature of the study, the nature of the product, the number of inputs used, and the nature of the output, all of which have an impact on the overall average efficiency of the South Asian farm sector. South Asian’s farm sector has an overall average efficiency of around 76%. This score shows that South Asian’s farm sector consistently produced 24% less farm output from its definite potential from 2000 to 2022. Overall 95 articles are used in this study, out of which 67 articles used parametric technique and 28 articles used non-parametric technique to determine technical efficiency.

Cross-sectional data has been used in 76 articles, Time series data in 7 and Panel data used in 12 articles. Cobb-Douglas functional form is used in 47 articles, translog in 15 articles and 33 articles used other functional forms. 33 studies preferred primal technological illustration whereas 62 studies applied dual technological illustration. 35 studies were found to have orientation towards agricultural inputs, whereas 60 studies were oriented towards agricultural output. The subject matter of 71 studies out of 95 were grain crops, 19 studies focused on cash crop and only 5 study have used both grain and cash crop. In 71 studies output is single whereas in 24 studies output was taken aggregately. Further, the effects of approach, type of data, functional forms, technological illustrations, nature of study and types of crop and output on average technical efficiency along with their minimum and maximum values can be observed by using below table:

**Table 11: Methodological features of efficiency studies on South Asian farm sector**

| <b>Type</b>                       | <b>Articles</b> | <b>Min. TE</b> | <b>Max. TE</b> | <b>Ave. T.E</b> |
|-----------------------------------|-----------------|----------------|----------------|-----------------|
| <b>Approach:</b>                  |                 |                |                |                 |
| Parametric                        | 67              | 0.36           | 0.94           | 0.77            |
| Non-Parametric                    | 28              | 0.42           | 0.97           | 0.73            |
| <b>Data:</b>                      |                 |                |                |                 |
| Cross                             | 76              | 0.36           | 0.97           | 0.77            |
| Time series                       | 7               | 0.54           | 0.89           | 0.77            |
| Panel                             | 12              | 0.44           | 0.93           | 0.67            |
| <b>Functional form:</b>           |                 |                |                |                 |
| Cobb-Douglas                      | 47              | 0.36           | 0.94           | 0.75            |
| Translog                          | 15              | 0.54           | 0.92           | 0.80            |
| Others                            | 33              | 0.42           | 0.97           | 0.75            |
| <b>Technological Illustration</b> |                 |                |                |                 |

|                        |    |      |      |      |
|------------------------|----|------|------|------|
| Primal                 | 33 | 0.48 | 0.97 | 0.75 |
| Dual                   | 62 | 0.36 | 0.94 | 0.76 |
| <b>Nature of Study</b> |    |      |      |      |
| Input oriented         | 35 | 0.42 | 0.97 | 0.74 |
| Output oriented        | 60 | 0.36 | 0.94 | 0.76 |
| <b>Type of crop:</b>   |    |      |      |      |
| Grain                  | 71 | 0.36 | 0.94 | 0.76 |
| Cash                   | 19 | 0.54 | 0.97 | 0.78 |
| Both                   | 5  | 0.42 | 0.76 | 0.56 |
| <b>Type of output:</b> |    |      |      |      |
| If single              | 71 | 0.36 | 0.97 | 0.76 |
| If aggregated          | 24 | 0.42 | 0.92 | 0.76 |

### **Country-Wise Comparison of Studies on Efficiency of South Asian's Farm Sector**

Below mentioned is the country-wise mean efficiency schedule showing minimum, maximum and average technical efficiencies of South Asian farm sector. This table shows that Bangladesh has the highest average technical efficiency in South Asia, whereas, Sri Lanka has the lowest. In case of maximum technical efficiency, Pakistan has the highest maximum technical efficiency, on the other hand, Sri Lanka has the lowest maximum technical efficiency. As far as minimum technical efficiency is concerned, Nepal has the highest minimum technical efficiency and Pakistan has the lowest minimum technical efficiency.

**Table 12: Country-wise comparison of efficiency studies on South Asian farm sector**

| <b>Country</b> | <b>Articles</b> | <b>Min. TE</b> | <b>Max. TE</b> | <b>Ave. T.E</b> |
|----------------|-----------------|----------------|----------------|-----------------|
| India          | 30              | 0.42           | 0.94           | 0.74            |
| Bangladesh     | 15              | 0.57           | 0.93           | 0.80            |
| Pakistan       | 29              | 0.36           | 0.97           | 0.76            |
| Nepal          | 9               | 0.63           | 0.92           | 0.75            |
| Srilanka       | 12              | 0.48           | 0.90           | 0.73            |

### **Crop-Wise Comparison of Studies on Efficiency of South Asian's Farm Sector**

In below table crop wise comparison of technical efficiencies of South Asian farm sector is given, which shows that majority of articles relate to the rice which is an important crop of South Asian for consumption and export as well. After this, most number of studies relate to the wheat which is also the most important crop. Moreover, majority of the studies have been done on single crop and out of which most of the articles related to grain crops. It is observed that maximum average technical efficiency was found in cotton-wheat study, whereas, wheat-cotton-rice-sugarcane study has the lowest average technical efficiency. Studies pertain to sugarcane crop shows the highest maximum technical efficiency, whereas, studies related to rice-wheat and cotton-wheat-rice showed the lowest maximum technical efficiency. Cotton-wheat article showed the highest minimum technical efficiency, while studies related to wheat showed the lowest minimum technical efficiency.

**Table 13: Crop-wise comparison of efficiency studies on South Asian farm sector**

| Crops                       | Articles | Min. TE | Max. TE | Ave. T.E |
|-----------------------------|----------|---------|---------|----------|
| Cotton                      | 11       | 0.54    | 0.90    | 0.76     |
| Rice                        | 44       | 0.48    | 0.93    | 0.76     |
| Sugarcane                   | 8        | 0.70    | 0.97    | 0.81     |
| Wheat                       | 25       | 0.36    | 0.94    | 0.76     |
| Rice-Wheat                  | 3        | 0.46    | 0.73    | 0.56     |
| Cotton-Wheat                | 1        | 0.87    | 0.87    | 0.87     |
| Cotton-Wheat-Rice           | 1        | 0.73    | 0.73    | 0.73     |
| Wheat-Cotton-Rice-Sugarcane | 2        | 0.42    | 0.76    | 0.59     |

**Empirical Analysis on Model 1**

**OLS Regression Analysis**

OLS regression has been run on the STATA software, the results of the test are mentioned at table 14 below:

**Table 14: OLS regression results for model 1**

| MTE            | Coef.    | Std. Err. | t      | P> t  |
|----------------|----------|-----------|--------|-------|
| PARA           | 0.073    | 0.052     | 1.400  | 0.166 |
| CROSS          | 0.112*** | 0.042     | 2.690  | 0.009 |
| TIME           | 0.121*   | 0.065     | 1.870  | 0.065 |
| COBB           | -0.069*  | 0.041     | -1.680 | 0.097 |
| TRANSLOG       | -0.001   | 0.048     | -0.010 | 0.991 |
| PRIMAL         | 0.181*   | 0.100     | 1.810  | 0.074 |
| INPUTO         | -0.175   | 0.107     | -1.640 | 0.105 |
| OUTPUTS        | 0.007    | 0.033     | 0.220  | 0.827 |
| NOOFINPUTS     | 0.001    | 0.006     | 0.100  | 0.923 |
| C              | 0.634*** | 0.078     | 8.120  | 0.000 |
| Number of obs. | 95       |           |        |       |
| F stat         | 1.730*   |           |        |       |
| P value        | 0.094    |           |        |       |
| R-squared      | 0.155    |           |        |       |
| Adj R-squared  | 0.066    |           |        |       |

*Note: \*, \*\*, \*\*\* indicate significance level at 10%, 5%, 1% respectively.*

Regression results are shown in Table 14, F stat is significant at 10% which indicates the model is fit at 10% level of significance. There are 95 number of observations in the above regression model, as shown in Table 14. R square is 0.155 which indicates that independent variables represents more than 15% changes in dependent variable i.e. MTE. According to regression results, dummy variables such as para, translog, inputo, outputs and noofinput are statistically insignificant which indicates there is no significant effect has been observed on MTE by using parametric techniques, translog functional form, if study is input-oriented, if study considered

output as single and number of inputs taken in the study. Dummy variable cross and constant are statistically significant at 1% which indicates there is significant effect of studies using cross-sectional studies has been observed on MTE. Dummy variables such as time, cobb and primal are statistically significant at 10%, which indicates there is significant impact of these independent variables on MTE. Here, time and primal have positive whereas cobb has negative relation with MTE.

**Tobit Regression Analysis**

Tobit regression has been run on the stata software, the results of the test are mentioned at table 15 below:

**Table 15: Tobit regression results for model 1**

| MTE            | Coef.    | Std. Err. | t      | P> t  |
|----------------|----------|-----------|--------|-------|
| PARA           | 0.073    | 0.049     | 1.480  | 0.144 |
| CROSS          | 0.112*** | 0.039     | 2.840  | 0.006 |
| TIME           | 0.121*   | 0.061     | 1.980  | 0.051 |
| COBB           | -0.069*  | 0.039     | -1.770 | 0.079 |
| TRANSLOG       | -0.001   | 0.045     | -0.010 | 0.990 |
| PRIMAL         | 0.181*   | 0.095     | 1.910  | 0.059 |
| INPUTO         | -0.175*  | 0.101     | -1.730 | 0.086 |
| OUTPUTS        | 0.007    | 0.031     | 0.230  | 0.817 |
| NOOFINPUTS     | 0.001    | 0.006     | 0.100  | 0.918 |
| C              | 0.634*** | 0.074     | 8.580  | 0.000 |
| Number of obs. | 95       |           |        |       |
| LR chi2        | 16.020*  |           |        |       |
| P value        | 0.067    |           |        |       |

*Note: \*, \*\*, \*\*\* indicate significance level at 10%, 5%, 1% respectively.*

Regression results are shown in Table 15, LR chi2 is significant at 10% which indicates the model is fit at 10% level of significance. There are 95 numbers of observations in the above regression model, as shown in Table 15. Tobit regression model shows results of coefficients along with their significance which are same as results of OLS regression except independent variable inputo which has negative relation with dependent variable which is also evident from OLS however, the only difference is its significance at 10% in Tobit regression.

**Truncated Regression Analysis**

Truncated regression has been run on the stata software, the results of the test are mentioned at table 16 below:

**Table 16: Truncated regression results for model 1**

| MTE   | Coef.    | Std. Err. | z     | P> z  |
|-------|----------|-----------|-------|-------|
| PARA  | 0.106    | 0.073     | 1.450 | 0.147 |
| CROSS | 0.145*** | 0.053     | 2.740 | 0.006 |
| TIME  | 0.154*   | 0.085     | 1.810 | 0.070 |

|                |          |       |        |       |
|----------------|----------|-------|--------|-------|
| COBB           | -0.103*  | 0.059 | -1.760 | 0.079 |
| TRANSLOG       | 0.000    | 0.069 | 0.010  | 0.995 |
| PRIMAL         | 0.212*   | 0.118 | 1.790  | 0.073 |
| INPUTO         | -0.205   | 0.130 | -1.580 | 0.113 |
| OUTPUTS        | 0.009    | 0.044 | 0.210  | 0.833 |
| NOOFINPUTS     | 0.001    | 0.009 | 0.110  | 0.913 |
| C              | 0.628*** | 0.103 | 6.100  | 0.000 |
| Number of obs. | 95       |       |        |       |
| LR chi2        | 14.720*  |       |        |       |
| P value        | 0.099    |       |        |       |

Note: \*, \*\*, \*\*\* indicate significance level at 10%, 5%, 1% respectively.

Regression results are shown in Table 16, LR chi2 is significant at 10% which indicates the model is fit at 10% level of significance. There are 95 number of observations in the above regression model, as shown in Table 16. Truncated regression shows the same result as shown by the OLS regression and also with Tobit regression as well with exception of independent variable i.e. inputo.

## **Empirical analysis on model 2**

### **OLS Regression Analysis**

OLS regression has been run on the stata software, the results of the test are mentioned at table 17 below:

**Table 17: OLS regression results for model 2**

| MTE            | Coef.    | Std. Err. | t    | P> t  |
|----------------|----------|-----------|------|-------|
| GRAIN          | 0.222*** | 0.062     | 3.59 | 0.001 |
| CASH           | 0.240*** | 0.066     | 3.61 | 0.001 |
| NOOFINPUTS     | 0.006    | 0.005     | 1.16 | 0.248 |
| C              | 0.499*** | 0.078     | 6.34 | 0.000 |
| Number of obs. | 95       |           |      |       |
| F stat         | 4.62***  |           |      |       |
| P value        | 0.004    |           |      |       |
| R-squared      | 0.132    |           |      |       |
| Adj R-squared  | 0.103    |           |      |       |

Note: \*, \*\*, \*\*\* indicate significance level at 10%, 5%, 1% respectively.

Regression results are shown in Table 17, F stat is significant at 1% which indicates the model is fit at 1% level of significance. There are 95 number of observations in the above regression model, as shown in Table 17. R square is 0.132 which indicates that independent variables represents more than 13% changes in dependent variable i.e. MTE. According to regression results, dummy variables such as grain and cash are statistically significant 1% which indicates that they have significant effect on MTE. However, independent variable noofinputs is insignificant as far as its impact on dependent variable is concerned.

**Tobit Regression Analysis**

Tobit regression has been run on the stata software, the results of the test are mentioned at table 18 below:

**Table 18: Tobit regression results for model 2**

| MTE            | Coef.    | Std. Err. | t    | P> t  |
|----------------|----------|-----------|------|-------|
| GRAIN          | 0.222*** | 0.060     | 3.67 | 0.000 |
| CASH           | 0.240*** | 0.065     | 3.69 | 0.000 |
| NOOFINPUTS     | 0.006    | 0.005     | 1.19 | 0.238 |
| C              | 0.499*** | 0.077     | 6.48 | 0.000 |
| Number of obs. | 95       |           |      |       |
| LR chi2        | 13.47*** |           |      |       |
| P value        | 0.004    |           |      |       |

Note: \*, \*\*, \*\*\* indicate significance level at 10%, 5%, 1% respectively.

Regression results are shown in Table 18, LR chi2 is significant at 1% which indicates the model is fit at 1% level of significance. There are 95 number of observations in the above regression model, as shown in Table 18. Results of Tobit regression are same as of results of OLS regression which are discussed above at Table 17.

**Truncated Regression Analysis**

Truncated regression has been run on the stata software, the results of the test are mentioned at table 19 below:

**Table 19: Truncated regression results for model 2**

| MTE            | Coef.    | Std. Err. | t    | P> t  |
|----------------|----------|-----------|------|-------|
| GRAIN          | 0.315*** | 0.106     | 2.97 | 0.003 |
| CASH           | 0.343*** | 0.113     | 3.01 | 0.003 |
| NOOFINPUTS     | 0.011    | 0.009     | 1.16 | 0.247 |
| C              | 0.416*** | 0.133     | 3.14 | 0.002 |
| Number of obs. | 95       |           |      |       |
| LR chi2        | 9.47**   |           |      |       |
| P value        | 0.024    |           |      |       |

Note: \*, \*\*, \*\*\* indicate significance level at 10%, 5%, 1% respectively.

Regression results are shown in Table 19, LR chi2 is significant at 5% which indicates the model is fit at 5% level of significance. There are 95 numbers of observations in the above regression model, as shown in Table 19. Results of Truncated regression are same as of results of OLS and Tobit regression.

**Normality Test**

**Model 1**

Shapiro-Wilk W test has been applied on data of model 1 to check the normality of data, results of which are given below at table 20;

**Table 20: Shapiro-Wilk W test results for model 1**

|            | W     | V      | z      | P      |
|------------|-------|--------|--------|--------|
| MTE        | 0.940 | 4.744  | 3.444  | 0.000  |
| PARA       | 0.981 | 1.448  | 0.818  | 0.207* |
| CROSS      | 0.948 | 4.077  | 3.109  | 0.001  |
| TIME       | 0.794 | 16.259 | 6.169  | 0.000  |
| COBB       | 0.999 | 0.070  | -5.898 | 1.000* |
| TRANSLOG   | 0.913 | 6.810  | 4.244  | 0.000  |
| PRIMAL     | 0.985 | 1.140  | 0.290  | 0.385* |
| INPUTO     | 0.989 | 0.879  | -0.286 | 0.612* |
| OUTPUTS    | 0.970 | 2.345  | 1.886  | 0.029  |
| NOOFINPUTS | 0.778 | 17.576 | 6.341  | 0.000  |

*\*Null Hypothesis: variable is normally distributed in the population.*

*Alternative Hypothesis: variable is not normally distributed in the population.*

*If p-value is greater than 0.05, null hypothesis accepted.*

The test statistic (W) is calculated by the Shapiro-Wilk test and measures the degree of departure from normality. It ranges between 0 and 1, with values closer to 1 indicating a closer fit to a normal distribution. In table 20, (W) stats of all dummy variables are close to 1. In case of dummy variables para, cobb, primal and inputo (p) value is greater than 0.05.

## Model 2

Shapiro-Wilk W test has been applied on data of model 1 to check the normality of data, results of which are given below at table 20;

**Table 20: Shapiro-Wilk W test results for model 2**

|            | W     | V      | z     | P     |
|------------|-------|--------|-------|-------|
| MTE        | 0.940 | 4.744  | 3.444 | 0.000 |
| GRAIN      | 0.970 | 2.345  | 1.886 | 0.209 |
| CROSS      | 0.940 | 4.714  | 3.430 | 0.000 |
| NOOFINPUTS | 0.778 | 17.576 | 6.341 | 0.000 |

*\*Null Hypothesis: variable is normally distributed in the population.*

*Alternative Hypothesis: variable is not normally distributed in the population.*

*If p-value is greater than 0.05, null hypothesis accepted.*

The test statistic (W) is calculated by the Shapiro-Wilk test and measures the degree of departure from normality. It ranges between 0 and 1, with values closer to 1 indicating a closer fit to a normal distribution. In table 20, (W) stats of all dummy variables are close to 1.

## Conclusion and Recommendations

### Conclusion

This study used a meta-analysis on 95 papers, yielding 39,724 observations, to derive significant policy findings from current studies on technical efficiency in South Asian agriculture. The study

specifically gives an overview of technical efficiency in South Asian agriculture while explaining the variation in mean technical efficiency (MTE) as reported by other studies based on study specific features. The study uncovered the regional differences in TE estimations by reviewing studies from throughout the South Asia. Finally, we identify the primary determinants of technical efficiency in South Asian agriculture over the years using descriptive statistics. The in-depth analysis of descriptive analysis indicates that studies conducted on Indian cropping sector using parametric approach, cross-sectional data, Cobb-Douglas functional form, dual technological illustration, output-oriented, conducted on cash crops and taken output as single product shows higher average technical efficiency.

Moreover, studies conducted on Indian cropping sector on sugar-cane and wheat shows highest average technical efficiency while studies conducted on Rice-Wheat combination shows the least average technical efficiency. Descriptive analysis on Bangladesh cropping sector revealed that studies using non-parametric approach, cross-sectional data, translog functional form, primal technological illustration, input-oriented, conducted on cash crop and output taken as aggregate shows higher average technical efficiency. While crop-wise analysis shows that studies conducted on sugar-cane shows higher average technical efficiency. Pakistani cropping sector reveals that studies conducted on non-parametric approach, time series data, functional form other than cobb and translog, primal technological illustration, of input-oriented, conducted on cash crop and taken output as aggregate shows higher average technical efficiency. While crop-wise descriptive analysis shows studies conducted on Cotton-Wheat combination shows higher average technical efficiency, whereas, studies conducted on Wheat crop shows the lowest average technical efficiency. Nepali cropping sector shows same results as of Indian cropping sector with exception that studies conducted on grain crops and taken output as aggregate shows higher technical efficiency. Srilankan cropping sector also shows the same results as of Indian cropping sector with exception that studies using translog functional forms and conducted on grain crop. South

Asian cropping sector shows that studies using parametric approach, cross-sectional and time-series data, translog functional forms, dual technological illustration, output-oriented, conducted on cash crop and taken output as aggregate shows higher technical efficiency. In country-wise analysis Bangladesh shows the highest while Sri Lanka shows the least average technical efficiency. In empirical analysis three models are used i.e. OLS, Tobit and Truncated regression which shows selection of cross-sectional data and time-series data, primal technological illustration and input-oriented approach have positive significant impact while selection of cobb-douglas functional form has the negative significant impact on average technical efficiency.

### **Recommendations**

At given level of farm inputs farm production in South Asian countries i.e. India, Bangladesh, Pakistan, Nepal and Sri Lanka can be enhanced by about 26%, 20%, 24%, 25% and 27% respectively. For this purpose, government assistance is critical for enhancing farmer managerial traits and boosting growth in South Asian's farm industry. This includes assessing existing policies, promoting farmers' acceptance of new technology through instructional programmes, and providing access to contemporary farm technologies. Farmers can improve their production capacities and reach optimal levels of farm output by maximizing their utilization of sophisticated technologies.

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