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Farm performance analysis: Technical efficiencies and technology gaps of Nepalese farmers in different agro-ecological regions

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ABSTRACT

This paper employs a stochastic metafrontier framework to examine technical efficiencies and technology gaps of Nepalese farmers in different agro-ecological regions. On average, the technical efficiency level derived from the regional frontier is 81%, from the metafrontier it is 57%, and the technological gap ratio is 70%. There is therefore a clear opportunity to improve the performance of farming households within regions through improving farmer's education, farming experiences, and by adopting climate change adaptation practices. Also indicated is that agricultural policies should be developed to reduce the technology gap between specific regions and the overall agricultural sector. In this context, this study highlights the need to improve farmers' access to agricultural markets, livelihood diversification and strengthening social capital such as farmers' participations in relevant agricultural organizations.

1. Introduction

Traditionally, agriculture has been an important sector of the Nepalese economy. Nevertheless, its contribution to the country's gross domestic product has dropped during recent years from 40% of GDP in 1995–33% in 2015 (MoAD, 2015). Although agriculture has special significance and economic importance, its production and productivity have not been encouraging and its rate of growth unstable – ranging from 5.8% in 2008, 4.5% in 2011, and 1.9% in 2015 (Fig. 1). At these levels agricultural sector productivity is considerably lower than other South Asian countries (Joshi et al., 2012). This low level of development is associated with the poor adoption of agricultural technologies, inefficient use of resources such as land and fertilizer, and lack of research (Adhikari and Bjorndal 2012; Bhattarai et al., 2015).

Thus, on the one hand the performance of the agriculture sector is poor, and on the other hand, there is increasing population pressure on the limited cultivable land. Moreover, as Nepal is a mountainous country, only a small proportion (20%) of the land is cultivated. Thus, the prospect of expanding agricultural land is virtually nonexistent. To meet the demand of the growing population therefore, it is necessary to increase food production through improvements in agricultural production efficiency. For these reasons, it is essential to examine and understand the causes of the inefficient use of resources in the agricultural sector. Increasing efficiency and productivity of this sector is likely to enhance subsistence farmers' opportunities to produce more and diversify farming which in turn would improve their food security and income levels (Ogundari, 2014).

Nepal is divided into three distinct agro-ecological regions (Terai, Hill, and Mountain), which differ in terms of altitude, soil types, landscapes, and climatic conditions which vary from subtropical in the lower elevations to the alpine in the higher elevations. As a consequence, there exists a marked variation in farming systems, and socio-economic conditions.[1] The aforementioned factors have led to wide heterogeneity in the available production technology set for the farming households in different ecological regions. It is important to note that the technical efficiency (TE) of farming households operating under different technologies is not comparable under the same production frontier. This is because households make choices among different sets of input-output combinations (O'Donnell et al., 2008). Therefore, an analysis of agricultural production efficiency in Nepal needs to take into account that farming households operate in different production environments which cannot be assessed under the same production frontier. One option could be to estimate different production frontiers for each region. However, the limitation of employing this approach is that TE measures cannot be compared between the regions because these TE scores are estimated relative to different production frontiers (Melo-Becerra and Orozco-Gallo, 2015). The literature on

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[1] The geographical and climatic variations lead to different level of resource endowment and production potentials which causes further variations in farming systems and socio-economic conditions. The three regions have wide variations with respect to market access as well as diversity in people's ethnicity and culture (MoF, 2015).

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Fig. 1. Economic growth rate in Nepal.

production efficiency in the agricultural sector is limited and focused on the analysis of specific crops such as rice (Piya et al., 2012), maize (Paudel and Matsuoka, 2009), and coffee (Poudel et al., 2015). It is also focused on a particular ecological region. The purpose of this study is, then, to evaluate and compare the production efficiency of farming households in the three different regions of Nepal.

The empirical analysis is carried out employing a metafrontier production function based on a stochastic frontier framework. The metafrontier approach assumes that there is some underlying common technology that makes it possible to estimate a pooled frontier. However, due to heterogeneity it is reasonable to divide farming households in to distinct groups. This is justified by the geographical variations across the agro-ecological regions in Nepal and the differences among the farming households in terms of resources and knowledge. In addition, there exist various similarities across the regions that makes it possible to estimate a pooled frontier. For instance, most farmers in all the three regions are smallholders and grow crops such as maize, wheat, buckwheat, legumes, and oilseeds. In this context, the application of a metafrontier allows the TE of farming households to be compared within each ecological region and between regions in relation to the agricultural sector as a whole. The purpose of this paper is to examine what factors are common across regions and what are region-specific. More specifically, we examine by how much the agricultural output can be improved by using the available inputs and technology within the particular regions and further by adopting the technological condition across the regions. In this context, policy makers can use the information to better guide resource allocation and enhance overall efficiency in resource use and economic well-being.

This paper is organized into five sections, in addition to the introduction. In the second section, we briefly review the literature on the metafrontier approach. The third section describes the study area, data, and methodology used in the analysis. The fourth section presents and discusses the results. The last section concludes.

2. A brief literature review of the metafrontier approach

The metafrontier production function was first purposed by Hayami (1969) and Hayami and Ruttan (1970). This function is based on the idea that all producers in the various production groups have potential access to a set of production technologies. Depending on the specific circumstances such as those relating to production environments, government regulations, production resources, and relative input prices, each producer may choose to adopt a particular technology (Huang et al., 2014). The practical applications of the metafrontier approach have existed since late 1980′s and early 1990′s (See e.g. Charnes et al., 1981; Grosskopf and Valdmanis 1987; Månsson, 1996). Battese and Rao (2002) introduced an application of the metafrontier which allows for the estimation and comparison of TEs among different groups. Battese et al. (2004) and O'Donnell et al. (2008) further developed the empirical application of this approach by employing a two-step procedure for estimating the metafrontier. In the first step, stochastic frontier techniques are used to estimate the group-specific frontier. In the second step, they employ mathematical programming techniques to estimate the metafrontier.

A number of empirical studies have employed the above approach. Examples include that of Moreira and Bravo-Ureta (2010) who estimate and compare the technical efficiency and metatechnology ratios for dairy farms from Argentina, Chile and Uruguay. Villano and Boshrabadi (2010) compare the performance of different Pistachio tree varieties in Iran. Villano et al. (2015) estimate and compare the technical efficiency of rice farmers in the Philippines between those who adopt certified seeds with those who don't. The difficulty with the two-step mixed approach developed by Battese and Rao (2002), Battese et al. (2004) and O'Donnell et al. (2008) is that, due to the deterministic nature of mathematical programming (linear or quadratic) in the second step, the metafrontier estimators are void of statistical properties (Chang et al., 2015).

Huang et al. (2014) propose a two-step stochastic frontier approach to estimate the group-specific frontiers and the metafrontier respectively, and advocate decomposing the efficiency scores of various groups into TE and technology gaps. The main difference with previous approaches lies in the second step. This method uses stochastic frontier techniques, ensuring statistical properties of stochastic frontier analysis in the estimation are retained. Also, this method directly estimates technology gaps and allows for the identification of the sources of variation among groups. Recently, a number of studies have employed the approach developed by Huang et al. (2014). They include Melo-Becerra and Orozco-Gallo (2015) who estimate and compare the technical efficiency for smallholder crop and livestock farmers in different production systems in Colombia. Chang et al. (2015) compare the technical efficiency of accounting firms between the US, China, and Taiwan.

3. Methodology

3.1. Analytical strategy

The metafrontier production function model for the farming households of different ecological regions is estimated by the two-step procedure suggested by Huang et al. (2014). Technical efficiency is derived by estimating a stochastic production frontier from each ecological region and for the metafrontier comprising the entire agricultural sector of Nepal, using the approach by Battese and Coelli (1995). For the jth region, the stochastic frontier of the ith farming household is modeled as,

$$Y_{ji} = f^{j}(X_{ji})e^{V_{ji}-U_{ji}}, \quad \text{where } U_{ji} \sim N \ [\delta_j Z_{ji}, \sigma^2] \tag{1}$$

where $j = 1,2,\ldots,J$; $i = 1,2, \ldots,N$ and where Y_{ji} and X_{ji} respectively denote the output and input vector of the ith farming household in the jth region. Following standard stochastic frontier modeling, V_{ji} is a normally distributed random variable with zero mean and variance σ^2 and which represents statistical noise. The non-negative random errors U_{ji} represent technical inefficiency and δ_j ($j = 1,2,\ldots,J$) is the region specific parameter vector to be estimated.[2] U_{ji}, follows a truncated normal distribution and is assumed to be independent of V_{ji}. Z_{ji} is the exogenous vector of variables determining inefficiency specific to each farming household within each region. A farming household's technical efficiency is then defined as:

$$TE_i^{j} = \frac{Y_{ji}}{f^{j}(X_{ji})e^{V_{ji}}} = e^{-U_{ji}} \tag{2}$$

The common metafrontier production function for all regions is defined as $f^M(X_{ji})$, where the function is the same for all regions. This metafrontier envelops all individual region's frontiers $f^j(X_{ji})$, which is expressed by the following relationship:

$$f^{j}(X_{ji}) = f^{M}(X_{ji})e^{-U_{ji}^{M}}, \ \forall \ j, \ i \tag{3}$$

where $U_{ji}^M \geq 0$. Hence $f^M(.) \geq f^j(.)$ and the ratio of the jth region's production frontier to the metafrontier is defined as the technology gap

[2] See Battese and Coelli (1995) for detailed specification and interpretation of parameters.