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Abstract

Using expenditures as indicator of household production, we identify the determinants of efficiency among Bhutanese households. With data from the Bhutan Living Standard Survey (BLSS) conducted by National Statistical Bureau (Bhutan), this study used a stochastic frontier model with sparse spatial autoregression estimated through the backfitting algorithm to estimate the technical efficiency of the households. There is an empirical evidence on the link between household inefficiency and poverty.

Accessibility of infrastructure facilities and services are instrumental for the households to achieve efficiency. The average technical efficiency of the households is estimated at 92.37% implying that there is still a considerable residual balance to increase production in Bhutan given the infrastructure and basic welfare services present during the survey. The technical efficiency of the urban households is higher than the rural households while among the regions, the west is more efficient than the other two regions in the country. The households

headed by educated persons achieve higher efficiency than those headed by uneducated. The agriculture sector is the most inefficient sector in Bhutan.

Keywords: stochastic frontier model, household efficiency, backfitting, infrastructure

1. Introduction

Bhutan embarked on its first development initiative with the inception of the first five-year plan in 1961. Prior to this, a vast majority of Bhutanese lived rugged lives of isolation. However, Bhutan has undergone major transformation and there has been remarkable improvement in all aspects of living conditions. The Gross Domestic Product (GDP) of the country grew with an average rate of 6.6% over the years and the GDP per capita has been recorded at US$ 1,300 (World Bank 2005 estimate). There is no abject poverty, but poverty does exist as is shown by the poverty analysis report in 2004 based on consumption expenditure. This paper analyzes the effect of factors of production on output indicated by household expenditure. The different determinants of poverty are also considered in the understanding of the phenomena. The technical efficiency/inefficiency of the households will also be estimated and some policy recommendations will be formulated.

Accessibility or isolation of the community is one major determinant of rural poverty. Many households in rural areas are characterized by underdevelopment because of the absence of infrastructure that will facilitate their access to basic welfare services, economic support and

other empowering services, see (Barrios, 2008) for more details. This study will assess the efficiency patterns among Bhutanese households in relation to some efficiency-enhancing infrastructure and welfare services.

The ability of the household to spend is dependent on their disposable income. We used expenditure as a proximate indicator of the production capability of the households. Expenditure is treated as an output measure and the factors of production are broadly categorized into: labor, which will be measured in terms of headcounts and profile of household members and; capital, including human resources, land ownership and material possession of the households. In the typical production function setting, the household as a producer may not be able to produce at the frontier level if there are some obstacles on to their production activities. Accounting for the factors of production, the residual difference between the predicted and actual output may contain information on the distance of the households away from the production frontier. In this case, the residuals can be decomposed further into pure error and inefficiency. The inefficiency part is postulated to be affected by the distance of the household to various economic and welfare services including transportation and communication services.

A stochastic frontier model with sparse spatial autoregression, as postulated by Barrios (2007), will be used to estimate the technical efficiency/inefficiency of the households with expenditure as output indicator. Estimation will use a backfitting algorithm similar to Landagan and Barrios (2007). Backfitting has advantage over the maximum likelihood estimation (MLE) in estimating a stochastic frontier model because MLE is often confronted

with the problem of convergence when the likelihood function is not concave because of over parameterization. The advantages of the backfitting will be evaluated in terms of the ease of empirical calculation as well as its facilitation of the decomposition of the error term into the pure error and inefficiency/efficiency component.

The study aims to understand the causes of shortfall in household output from the frontier, thereby causing poverty as well as the technical efficiency/inefficiency. The study can generate information that could help the policy-makers to focus the allocation of the limited resources to the vulnerable groups. The result on the influence of factors of production and determinants of efficiency/inefficiency should provide policy makers the means to assess the likely impact of development interventions on the incidence of poverty in Bhutan. Thus, specific government policies aimed at improving the welfare of the population through the provision of efficiency-enhancing infrastructure can be considered.

2. Poverty and Living Conditions in Bhutan

Poverty is defined as the lack of opportunities, powerlessness and vulnerability. A poor household earns income or consume at the level that will acquire goods and services that is less than the essential for a minimum standard of living. A poverty line is established at a level of consumption that assures basic needs are met. As (Ravallion, 1998) noted, a credible measure of poverty can be a powerful instrument for focusing the attention of policy makers on the living condition of the poor.

Bhutan's poverty line was estimated at Nu. 740.36 (1 US$=45.17 Nu, as of 2006) per capita per month based on the data from the Bhutan Living Standard Survey. Based on this poverty line, it is estimated that 31.7% of the population of the country is poor. Of this, only 4.2% are from the urban population against 38.3% of the rural population (Bhutan, 2004).

Endemic regional level characteristics are usually associated with poverty. Poverty is high in areas characterized by geographical isolation, a low resource base, low rainfall and other unfavorable geographic and climatic conditions. The extreme north of Bhutan is characterized by a cold climate throughout the year and very few people inhabit the area. The pastoral people herding yaks and sheeps roam these remote places migrating with their herds in search of fresh grazing grounds, with less access from modern amenities like hospitals and schools. The rest of Bhutan which is divided into three regions, namely west, central and east also have differences with regard to the state of roads, employment opportunities, and the level of development. Although the government targets a balanced development throughout the country, physical barriers such as the rugged landscape in some regions (implying very high cost infrastructure like roads, schools and hospitals), resulted to faster development in some areas compared to the others. Therefore, the regional location of a household is an important factor in their poverty status.

At the community level, infrastructure is a major determinant of poverty. The main indicator of infrastructure development is access to feeder road or tarred road, since availability of road makes it easier to establish other facilities like electricity, markets, schools and medical clinics in the area. (Barrios, 2008) also emphasized the role of rural roads in terms of

multiplier effects on the provision of other support and welfare services for the vulnerable segment of the population.

The development of roads is a prerequisite for the attainment of development objectives in almost every area. Road impacts the lives of individuals and communities, it integrates different parts of the nation; it links the nation with the outside world. Because of its manifold impacts and the often long gestation periods, policies related to roads must necessarily be long term in orientation and be derived from priorities established for the nation's future economic and social transformation (Bhutan, 1999). The demand for roads is very high as highlighted by the response of about 12.50% of rural households who had road infrastructure as their top welfare priority which is comparable to that for electrification (12.15%) or schooling facilities (9.98%) as per the results of the 2003 Bhutan Living Standard Survey. Feeder roads are essential for bringing remote communities out of their isolation, expanding their access to essential services and markets, enlarging their opportunities and choices, and creating conditions required to promote rural development.

The first highway "Phuentsholing -Thimphu" in Bhutan was constructed in 1960 and since then, the road network has expanded to a total of 4544 Kilometers. The road network in Bhutan is divided into 6 categories: national highways with 1556 km(34%); district roads with 510.95 km (11%); feeder roads with 1246.91 km (27%); urban roads with 130.22 km (3%); farm roads with 25.85 km (12%) and; forest roads with 574.8 km (13%), see Figure 1.

[Figure 1 Here]

The Population and Housing Census of Bhutan in 2005 observed that out of the country's 126,115 total households, 79,484 accounting for 63% are within half an hour of walking distance from the nearest motor road while 18,392 (14.5%) are located more than four hours of walking distance. Out of a total of 87,804 rural households, 41,347 accounting for 47.1% live within half an hour of walking distance from the nearest motor road while 18,308 (20.8%) are located more than four hours of walking distance (National statistical Bureau, Population and Housing Census Results, 2005).

Another important determinant of poverty at the community level is land distribution among the households in the community. Farmers will be free to choose a resource allocation scheme that will optimize production if they own the land. If the land on which they work is owned by someone else, then the landlord will be the one to decide despite lacking direct knowledge of the farming system. Landlords may decide how resources should be allocated only on the basis of their instincts to protect their interests, so their decisions may not necessarily yield optimum production. There is thus inefficiency when the farmer does not own the land. If the farmer owns the land, then he would opt to plant high value crops and exert proportional efforts to enhance productivity (Bandiera, 2002). Almost all farming households in Bhutan own land. The land act of Bhutan, 1979 article KA 3.4- Ceiling on land belonging to a family, states that a family cannot possess more than 25 acres of land consisting of wet land, dry land, shifting cultivation land, excluding house construction plot, grazing land and cash-crop gardens. The enforcement of this act implies that a family cannot own vast areas of land and so the land distribution is equitable and the land owned by families varies but are always below or equal to this ceiling.

There are several indicators to determine household employment. Within this array of indicators, economists focus on the rate of participation in the labor force, the rate of unemployment, the rate of underemployment and job changes. There has been a steady increase in unemployment rates during the last 6 years in Bhutan. In 1998, the unemployment rate was just 1.4% and by 2003 it was 1.8%. The Labor and Humane Resources Ministry reported that by 2006, the unemployment rate was 3.1%. The main reason for the rising unemployment rate, especially among the youth is cited to be the mismatch between the jobs available in the market and the skills of the job seekers. Also, most youth seem to be looking for a government or a corporate job and reluctant to take private jobs where they feel there is less job security and lesser perks.

The structure of household consumption expenditures can be used to characterize households by describing the make-up of food and non-food spending. It is of interest to measure the relative weight of the goods and services consumed by the household in relation to their poverty level. This measurement gives some indication as to the probable impact of price variation on household purchasing power. We can expect basic products, especially food, to represent a more significant part of total spending by the poor. In Bhutan the mean per capita monthly spending by the poor on food is 54.1% while the corresponding figure for non poor is 40.45%.

In the BLSS, the ownership of important household appliances like refrigerator, microwave oven, washing machine etc. were asked and could be used as a determinant for the dichotomy

of the poor or non poor. Similarly, data on land, livestock, and poultry ownership may further indicate household assets.

3. Analytical Framework

A stochastic frontier model with sparse spatial autoregression component used to model production efficiency of Bhutanese households using the 2003 Bhutan Living Standard Survey(BLSS).

3.1. Bhutan Living Standard Survey

Bhutan Living Standard Survey (BLSS) is a nationwide survey of households undertaken by the National Statistical Bureau following the Living Standard Measurement Survey (LSMS) methodology developed by the World Bank. The methodology is customized for Bhutanese population and collected information through an integrated household questionnaire covering demographic characteristics, housing, education, health, employment, assets ownership and consumption. A community questionnaire aimed at collecting information on services and prices of the common commodities was also included. The sample size of 4200 households was distributed to urban and rural areas. The sampling design divided the country into 40 strata based on their geographic and administrative location. There were twenty urban strata (urban areas of the twenty districts) and twenty rural strata (rural areas of the twenty districts).

The urban areas were divided into blocks, each block was formed with a well defined boundary and with number of households ranging from a low of 100 households to a high of 300. Gewogs (a group of villages forms a geog and it is headed by an elected person) in the rural areas and blocks in the urban areas were treated as enumeration areas and thereby the primary sampling units (PSU). The PSUs were selected based on probability proportional to size using the cumulative size method. Within the selected PSUs a total of 20 households and 10 households were selected based on systematic circular sampling scheme for the gewogs and blocks respectively. The map of Bhutan showing the Dzongkhags/districts and geogs/Barangays is given in Figure 2.

[Figure 2 Here]

3.2 Stochastic Frontier Model with Sparse Spatial Autoregression

Barrios(2007) proposed a production stochastic frontier that imbeds a sparse spatial autoregression into the Cobb-Douglas production model. The frontier model and the efficiency equation are as follows:

$$\ln y_i = \ln f(\boldsymbol{x}_i;\boldsymbol{\beta}) + \delta \boldsymbol{D}[\ln y_i - \ln f(\boldsymbol{x}_i;\boldsymbol{\beta})] + v_i - u_i \qquad (1)$$

$$u_i = \frac{1}{1+\exp(-(\boldsymbol{z}_i\boldsymbol{\phi})} + \varepsilon_i \qquad (2)$$

To allow dummy variables among the factors of production (zero values for some producers), an exponential function f can be used. δ is the parameter accounting for spatial externalities common among spatial neighbors, this also accounts for clustering or convergence of efficiency among 'neighboring' producers. $D = [(d_{ij})]$ is the spatial weight matrix where

$$d_{ij} = \begin{cases} 1, & \text{if unit i and unit j are spatially related} \\ 0, & \text{otherwise} \end{cases}$$

We consider the geogs (a group of villages and headed by an elected person) in rural areas and towns in urban areas as spatial units, households within the area are considered 'neighbors'. $\boldsymbol{z}_i$ is a vector of fixed factors hypothesized to affect efficiency of the households and $\varepsilon_i = (\varepsilon_{i1}.....\varepsilon_{in})$ is pure error.

The model described in equations (1) and (2) constitutes an additive model including the components on production function, the effect of spatial externalities, and the logit of efficiency/inefficiency-inducing factors. In an additive model, (Hastie and Tibshirani, 1990), discussed the advantages and optimality of the backfitting algorithm in estimation. Estimation will also use a modified backfitting algorithm similar to (Landagan and Barrios, 2007), as modified by (Barrios, 2007). The estimation algorithm follows:

1. Depending on the link function f, ignore u_i in (1) and estimate $\boldsymbol{\beta}$ using maximum likelihood estimation (MLE) or least squares estimation (LSE). Compute the residuals from (1) as $-\hat{u}_i = \ln y_i - \ln f(\boldsymbol{x}_i; \hat{\boldsymbol{\beta}})$ or $\hat{u}_i = \ln f(\boldsymbol{x}_i; \hat{\boldsymbol{\beta}}) - \ln y_i$, this contain information on $\boldsymbol{\phi}$ and δ.

2. Estimate δ from $\hat{u}_i = \delta \boldsymbol{D}\hat{u}_i + \xi_i$ ignoring $\boldsymbol{z}_i$. Compute the residuals as $\hat{\hat{u}}_i = \hat{u}_i - \hat{\delta}\boldsymbol{D}\hat{u}_i$, this contain information on $\boldsymbol{\phi}$.

3. Estimate $\boldsymbol{\phi}$ from $\hat{\hat{u}}_i = \dfrac{1}{1+\exp(-\boldsymbol{z}_i\boldsymbol{\phi})} + \varepsilon_i$, a logistic regression model where elements of $\boldsymbol{u}$ are taken from the residuals in Step 2.

4. The estimates of technical efficiency is then computed from

$$TE_i = \exp - \left[\frac{1}{1 + [-(\boldsymbol{z}_i \hat{\boldsymbol{\phi}})]} \right]$$

3.3 Variable Definition

The variables that will be used to fit the model in Equations 1 and 2 are describes below.

The output indicator y_i

The output indicator y_i used in the study is the total monthly expenditure of the households. For calculating the total monthly expenditure of the households, the Bhutan Living Standard Survey collected expenditure data on the following;

(1) Expenses on housing and housing related services. In this category of expenses are the monthly rent paid for the dwelling of the households either in actual rent paid or the imputed rent, monthly payment of water, cooking gas, candles, electricity, kerosene and firewood.

(2) Expenses on education and health services. Although education and health services are free in Bhutan, households do incur expenses in terms buying books for school going children, private tutoring, buying some medicines not available in hospitals but private pharmacies etc.

(3) Expenses on food and non food items. There were about 89 food items broken down into categories like cereals, dairy products etc. and detailed expenditure incurred on them were collected. Expenses incurred on food taken away from home were also included. Non-food expenses included expenses incurred on clothing, footwear, transport etc.

The reference period for the survey varied on the question being asked on specific items. For food item expenses, the reference period was last week in a typical month while housing and services expenses were collected on a typical month basis. Educational expenses were collect for the survey period academic year. For non food expenses like clothing and footwear, transport and communications, recreations, furnishing and equipment and miscellaneous expenditure the reference period was expenses incurred last 12 months.

Factors of production x_i

Initially, the following factors of production were considered: household size, percent of children in the household, percent of old (above 64 years) in the household, percent of employed members in the household, percent of literate members in the household, total land owned by the household in acres, total livestock and poultry owned by the households, age of the household head, construction material of the roof and construction material of window of the households. After the initial analysis, some factors are not significant, resulting to the following list of final factors of production indicators:

(a) Labor

1. hhsize=household size
2. pchildren = percent of children (below 15 years) in the household
3. pemployed=percent of employed members in the household

A household with more employed individuals can contribute more to total household income thereby allowing flexibility in expenditure allocation. Larger household size would mean more individuals will consume the goods and services, resulting to higher

expenditures. The children are part of the consuming household members but are not contributing in total income.

(b) Capital

4. pliterate=percent of household members who knows how to read and write
5. lowned=total land owned by household in acres. (land owned to be aggregated. The land owned is composed of orchard, wetland, dryland and other land (grass land etc.)
6. cmroof=construction material of the roof. Households where the roof material is either metal sheets or concrete/cement are coded 1 and other materials are coded 0

Literacy is an important indicator of the quality of humane capital. Being a dominantly agricultural country, land ownership among the Bhutanese household can represent the fixed capital available for production. Roof material indicates capital accumulation behavior among the households.

Determinants of efficiency z_i

In this study, efficiency is hypothesized to be affected by accessibility infrastructure and provision of basic welfare services. There were 25 determinants of efficiency considered for the study. Of that, nine (distance to police, distance to firewood, distance to bank, distance to bus station, distance to school, expenditure on the use of internet by the household in a month, the presence or absence of tractor and rice grinding in a household, presence or absence of modern household utilities and the household being agricultural household or otherwise) were found to have p-values way above 0.05. Therefore they were removed from subsequent modeling. The following determinants were included in the final study.

1. dtroad=time taken by the household to reach the nearest tarred road in minutes

2. dfroad=time taken by household to reach the nearest feeder road in minutes
3. dalcentre= time taken by the household to reach the nearest agriculture/livestock extension centre in minutes
4. ddzongkhag=Time taken by the households to reach the Dzongkhag/District administrative centre in minutes
5. dpost=time taken by household to reach the nearest post office in minutes
6. dhospital=time taken by household to reach nearest hospital or BHU in minutes
7. dtemple=time taken by household to reach nearest temple in minutes
8. dpetrol=time taken by household to reach nearest petrol station in minutes
9. exptland=land transport expenditure(bus,taxi,etc. Expenditure refers to amount spent by the household members for buying tickets, hiring vehicles etc. In-kind expenditure like amount that a household would have spent had there been a transport facility has not been encompassed)
10. exptair=air transport expenditure (amount paid to buy air tickets)
11. expctelephone=expenditure for telephone by household in a month
12. phone= household has telephone inside dwelling or not. (code 1 for yes and 2 for no)
13. swater= safe source of drinking water. (if source of drinking water is from a pipe then 1 else 0)
14. electri=household has electricity or not.(if electricity then 1 else 0)

Accessibility can facilitate the procurement of inputs and the distribution of outputs to their respective markets. It will also facilitate the delivery of basic social services intended to

enhance living conditions of the households. A community that is accessible and with all the basic social services can easily push their productive capability to get closer to frontier level.

4. Results and Discussion

The backfitting algorithm used in the estimation procedure alleviates the convergence problem usually encountered in maximum likelihood estimation with many variables both in the production function and in the efficiency equation. Because of the possible multicollinear behavior of variables, the likelihood function often exhibit non concavity, a bottleneck in the attainment of convergence. The backfitting algorithm will effectively reduce the size of the variables that enter into the estimation scheme, facilitating the convergence of the iterative process. The use of the logit model for efficiency can replace the use of truncated-normal distribution that further implicates into the divergence of the maximum likelihood estimation. The both the stochastic frontier model estimated using maximum likelihood method (MLE) and the backfitting algorithm are presented.

4.1 Output , factors of production, and determinants of efficiency

The summary statistics of the variables pertaining to the 4007 responding households are reported in Table 1. The average expenditure of the households is Ngultrum 8,664.00 per household per month (1US$=40.46 Ngultrum) with a standard deviation of 7,854.816 that indicates a large variability in the expenditure pattern of the households. The average household size is 4.804, the maximum members recorded in a household being 16 members.

Although the Land Act of Bhutan caps the maximum land holdings per household at 25 acres, note that the maximum acreage holding by a household here is 913 acres. This is because in the Land Ceiling Act, grazing for animals and other related categories are not included.

The distance that a household takes to reach a given infrastructure or a welfare facility is recorded in minutes. The shorter the distance of the households from these facilities, the better the households will be in terms of their ability to use and benefit from these efficiency enhancing facilities. Most of these facilities are on average located more than half an hour away from the households. The farthest a household is located from a tarred road is recorded at 2,880 minutes. This means that members of that household would take about 6 days to reach the nearest tarred road if the person were to walk 8 hours a day. Expenditures incurred by the households for travel related facilities are recorded in terms of actual payment for tickets without taking into account in-kind expenses in the sense of time a person spends commuting for work or other related activities. We note that average expenses incurred for travel facilities are quite low showing the non utilization or the absence of these facilities.

[Table 1 Here]

4.2 Ordinary stochastic frontier model

The ordinary stochastic frontier model (SFM) with Cobb-Douglas production function and a truncated-normal distribution of the efficiency error component is estimated using MLE and summarized in Table 2. While the iteration converged, non-concave likelihood function has been noted several times during the iteration, and as a consequence, the technical efficiency

summarized in Table 2 yield very minimal variation. The failure of the model to produce reasonable estimates of technical efficiency is an implication of the non-concave likelihood function and failure to achieve the real optimum. When the model is characterized by several factors (including dummy variables), the likelihood is flooded with parameters to be estimated. This caused ill-conditioning on the Hessian matrix pivotal in the numerical evaluation of the MLE. The backfitting algorithm can somewhat relieve this problem since it estimates the parameters in blocks, reducing the total number of parameters to be estimated at a time, per iteration.

[Table 2 Here]

4.3 Factors of production

Using the SFM embedded with a sparse spatial autoregression, we present the estimates generated through backfitting in this section and the subsequent sections. The estimated regression coefficients and measures of their statistical significance are presented in Table 3. The factors of production can explain 97.88% of the variation in the expenditure pattern of the households. Therefore the degree of association is high between the output indicator (expenditure) and the factors of production used in the model.

[Table 3 Here]

All the coefficients are significant ($p<0.05$) except land owned by a household ($p=0.378$). As expected, household size, percent employed in a household, percent literate in a household, land owned and construction (strong) material of the roof have positive coefficients since

higher values would mean higher consumption. Household size contributes positively since more individuals will consume the goods and services produced by the household. On the other hand, percent literate, land ownership and construction materials of the roof are indicators of household resources that can produce a cap to their total expenditures. Percent of children ($p<0.000$) could be expected to have either a positive or a negative effect on the production of the households. In this case, it has a slight positive effect, since children have special needs that can be more costly, contributing to the total household consumption. Although land owned is not significant($p<0.378$), the variable retained in the model to complete the factors of production that the model ought to capture. The ceiling of 25 acre of land ownership could have resulted to homogenous sizes of landholding, resulting to not significant coefficient.

4.4 Determinants of efficiency

The household efficiency/inefficiency is postulated to be influenced by the presence of infrastructure that will facilitate their access to basic support and welfare services. The spatial dimension in the production frontier was introduced as a sparse autoregressive term. Households coming from the same gewogs (rural areas) or towns (urban areas) are treated as neighbors. Households coming from the same gewogs/towns will have similar access to infrastructure and basic welfare services, leading to homogeneous spatial externality influencing production in the area. The estimates of the coefficients for the determinants of efficiency are summarized in Table 4.

[Table 4 Here]

Distance to tarred road, feeder road, post office, temple and petrol are significantly ($p<0.05$) influencing efficiency in household production. Most of these factors have negative coefficients, implying that as distance of households from these infrastructures increases, efficiency decreases. Presence of these infrastructures in the vicinity of the households will enhance efficiency. Expenses incurred by the household in relation to their utilization of land and air transportation services are also significant and have positive coefficients. The expenses incurred are measured in terms of payment for availing and utilization of these services and the positive coefficients show that the more a household is able to avail of these services the more efficient they are. The presence of electricity ($p<0.05$) in the household with the positive coefficient also shows that households availing these facilities tend to be more efficient.

4.5 Efficiency Profile of the Bhutanese households

Due to the volatile household-level technical efficiency estimates, the average technical efficiency by particular segments were computed using nonparametric bootstrap. The bias-corrected estimates and the Monte Carlo estimates of the standard errors are provided. The average technical efficiency for the sample of 4007 households is 92.37% (Table 5). On the average, the households are able to obtain about 92% output of the maximum feasible from a given mix of production inputs. There is a margin of 8% increment scope that can be considered through better utilization of the efficiency enhancing infrastructure and services present at the time of the survey.

[Table 5 Here]

Efficiency enhancing infrastructures and services are comparatively better and more accessible in urban areas. In Table 5, households in the urban areas are more efficient than households in the rural areas. Note that even when the standard errors are accounted, the urban households still have higher efficiency. Better educated urban residents (literacy rate of urban residents in Bhutan is 75.9% compared to 52.1% for rural residents-PHCB, 2005) are able to seek and make better use of the available infrastructure and services at their disposal. Bhutan is divided into 20 administrative districts that can be aggregated into three broad regions based on location proximity of the districts to each other and also similarity in economic characteristics. The western region is composed of the districts of Thimphu, Paro, Haa, Samtse, Chukha, Punakha and Gasa. Central region is composed of Wangdi Phodrang, Dagana, Tsirang, Sarpang, Zhemgang, Trongsa and Bumtang. The districts of Lhuntse, Mongar, Pema Gatsel, Samdrup Jongkhar, Trashi Gang, and Trashi Yangtse form the eastern region. The average technical efficiency of the Western region is highest, followed by Central, and Eastern region. There are a number of factors that may have contributed to this. All the three regions are bordered to the North by China. However, as the altitude of the territories bordering China is very high, the climate is harsh leaving very few inhabitants, lead to varying levels of efficiency by the households. There is also no formal trade with China so its influence if any is minimum. Bhutan is surrounded by India on the other three sides and India accounts for about 91.3% of Bhutan's imports and 92.70% of its exports. Although trade routes to India exist through the East as well as the Center, these trade routes have been facing intermittent problems due to unrest and violence in the adjoining Indian states. Therefore, the main trade route with India is through Phuntsholing, which is located in the West and traders

from the Central and Eastern parts of the country also congregate at this location to conduct business transactions.

The West has been generally endowed with flatter and fertile river valleys compared to the other regions, thus enabling households to indulge in productive commercial farming. The flatter landscape also lowers the cost for infrastructure development and this has resulted in the construction of more roads, school facilities, hospitals and other efficiency-enhancing infrastructure and service facilities in the Western region of the country. The capital of the country, Thimphu is located in the West and with it comes all the known advantages of having a capital in a region, like location of all the ministries of the government as well as most of the important business and commercial centers of the country. Also, the only international airport of Bhutan, Paro International Airport is located in this region. It brings with it the positive economic effects like availing of tourist and travel related business and services.

The head of household is the person who manages the income earned and expense incurred by the household. Individuals were considered literate if they reported that they were able to read and write at least in any one of the languages (Dzongkha, English, Lhotsham or others). No literacy test was administered to validate the reported literacy levels. Table 6 summarizes the technical efficiency by household heads.

[Table 6 Here]

The technical efficiencies of households headed by literate persons are slightly higher than those headed by illiterate ones. This can be explained by the fact that when a household is

headed by a literate person, the income and hence expenditure of the household will be enhanced, since a literate person is more likely to seek and be employed in a more profitable work. Also a household headed by a literate person is likely to be able to make use and profit more from existing infrastructure and welfare service facilities. There is no noticeable difference in efficiency with regard to gender.

Educational level of a person was determined based on the highest grade successfully completed.. Majority of the heads have had no schooling, while about 27% have had some education basic elementary and high school education. A small percentage have college education or higher. In Table 7, the average technical efficiency of households headed by persons who had no schooling are at the lowest (0.91), while for those households headed by persons with schooling level between primary and higher secondary level the average technical efficiency hovers around 0.94. The highest average technical efficiency (0.98) is achieved by households headed by people who had college or higher education. Technical efficiency generally increases as educational level of the head increases.

[Table 7 Here]

Technical efficiency was averaged by expenditure quintiles (contains 20% of the households). Table 8 clearly shows that efficiency increases as the expenditure quintile increases. This provides an evidence of the linkage between poverty and efficiency. The poor are less efficient than their non-poor counterpart, hence, an efficiency-enhancing intervention targeted towards the more vulnerable sector can somehow help alleviate the poverty situation.

[Table 8 Here]

Household well-being also depends on its source of income. In Table 9, average technical efficiency were computed by the source of income of the household. Agricultural households who are dominant in rural areas are less efficient than those earning income outside agriculture. The farming households are susceptible to fluctuations in weather conditions and state of the environment. This further identifies a vulnerable sector of the Bhutanese population needing the intervention to help them combat poverty.

[Table 9 Here]

In Table 10, the occupation of the household head is classified in accordance to major occupational groups. The skilled agricultural workers, has the least average technical efficiency that further supports the observation on the vulnerability of the agricultural sector. Note that household heads belonging to the armed forces achieve the maximum technical efficiency at 0.98 and is explained by the fact that the government provides the army personnel with subsidized food in the form of rations, free clothing and footwear on top of their usual salaries.

[Table 10 Here]

The occupation of household head are also classified according to the 13 broad groups of industries, Table 11 reflects the technical efficiency in each classification. Efficiency is lowest again for the agriculture industry and highest for the public administration and defense consistent with the efficiency associated with the occupations.

[Table 11 Here]

The extensive health care system which has been established since the early 1960s meets the requirement of both urban and rural Bhutan. The national and regional as well as district hospitals and the BHU's provide free medical services to the people. The numerous outreach clinics and community health workers provide immediate health care needs of the communities. A traditional health care center which provides alternative means of treatment is also available in most hospitals around the country. However, given the rugged and difficult terrain, the government's effort to achieve universal health has proved to be rather very difficult and expensive. Further, conditions such as the remoteness, sparse population and lack of reliable communication facilities has hindered the smooth delivery of health care services ultimately resulting in higher infant mortality rates in those areas where there are no proper communication and transport facilities. Table 12 summarizes the percent of household heads sick four weeks prior to the survey period along with their average technical efficiencies. About 18% of the household heads had some form of ailments four weeks prior to the survey. The technical efficiency is very low for those households whose heads were sick, an evidence that health equity can still be improved in Bhutan through the various health programs.

5. Conclusions

A stochastic frontier model with sparse spatial autoregression has been used to estimate the technical efficiency/inefficiency of the households with expenditure as the output indicator. The presence of infrastructure that will facilitate access to basic support, welfare, and other empowering services enhances household production. The household's ability to avail and make better use these efficiency enhancing infrastructures also contributes.

Accessibility infrastructure indexed by walking distance to roads, post office, petrol station and temple as well as provision of services like electricity and safe water sources are found to be instrumental for the households to achieve efficiency. Since some households are too far from roads (the extreme case being 6 days walk to the nearest roads) the government could concentrate on the expansion of the road network. This will also improve access to other welfare services to uplift the living conditions, especially of the rural populace.

The average technical efficiency of the households had been estimated at 92.37% implying that there is still a possibility to increase household production given the infrastructure and basic welfare services present at the time of the survey. Urban households are more efficient than rural households, the western region is more efficient than the other two regions. Households headed by educated persons are more efficient. The agriculture sector is generally disadvantaged as this is the most inefficient sector. These are some of the characteristics of the inefficient sector where inefficiency here is directly linked to poverty among the households in Bhutan.

The government needs to provide more development funding to the central and eastern regions so that more equitable development can take root in the country. Provision of education should ultimately be the topmost priority of the government as it will be the key to the enhancement of efficiency. There is also a need to slant the interventions to benefit the agriculture sector. The agriculture programs should be strengthened, tailor fitted to the needs of the beneficiaries.

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Table 1. Summary Statistics for the Study Variables.

	Mean	Minimum	Maximum	Standard deviation
Factors of Production				
Expenditure	8664.001	509.830	85784.660	7854.816
hhsize	4.804	1	16	2.318
Child	2.205	0	10	1.226
Literate	2.264	0	13	1.731
employed	2.023	0	11	1.360
lowned	2.602	0	913	19.783
Efficiency determinants				
dtroad	92.614	0	2880	265.330
dfroad)	63.563	0	2880	203.276
dalcentre	58.944	0	1560	101.779
ddzongkhag	136.451	0	2880	291.020
dpost	84.070	0	1800	173.815
dhospital	49.482	0	750	67.725
dtemple	37.355	0	480	54.215
dpetrol	112.944	0	2930	234.776
exptland	113.088	0	16666.67	354.253
exptair	46.823	0	10500	448.809
expctelephone	202.148	0	15000	629.941

Table 2. Estimates of Ordinary Stochastic Frontier Model Using MLE

Stoc. frontier normal/truncated-normal model Number of obs = 4007
Wald chi2(6) = 1515.46
Log likelihood = -3554.1068 Prob > chi2 = 0.0000

Lexpenditure	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lhhsize	.4964093	.0220647	22.50	0.000	.4531632	.5396553
pchild	-.0029332	.0005611	-5.23	0.000	-.004033	-.0018334
pemploye	-.0017187	.0004943	-3.48	0.001	-.0026875	-.00075
pliterat	.0075763	.0004039	18.76	0.000	.0067846	.008368
lowned	.0013488	.0004709	2.86	0.004	.0004259	.0022716
cmroof	.3962779	.0228154	17.37	0.000	.3515606	.4409953
_cons	7.559594	.0925531	81.68	0.000	7.378194	7.740995

Estimates of Technical Efficiency

Variable	Obs	Mean	Std. Dev.	Min	Max
teexpenditure	4007	.9985993	3.28e-06	.9985884	. 9986143

Table 3. Estimates of Regression Coefficients in the Production Function.

lexpenditure	Parameter	Coef.	Std. Err.	P>t
lhhsize	β_1	2.266	0.035	0.000
pchild	β_2	0.020	0.001	0.000
pemploye	β_3	0.044	0.001	0.000
pliterat	β_4	0.032	0.001	0.000
lowned	β_5	0.001	0.001	0.378
cmroof	β_6	1.122	0.047	0.000

Table 4. Estimates of Regression Coefficients of the Determinants of Efficiency/Inefficiency.

u2	Coef.	Std. Err.	P>|t|
dtroad	0.0011	0.0002	0.0000
dfroad	-0.0009	0.0003	0.0010
dalcentr	-0.0005	0.0003	0.0660
ddzongkh	-0.0003	0.0002	0.0550
dpost	-0.0007	0.0002	0.0000
dhospita	0.0007	0.0004	0.0780
dtemple	-0.0013	0.0004	0.0040
dpetrol	0.0003	0.0001	0.0270
exptland	0.0001	0.0001	0.0220
exptair	0.0001	0.0000	0.0330
expctele	0.0001	0.0000	0.0880
phone	-0.1835	0.0553	0.0010
swater	-0.1783	0.0689	0.0100
electric	0.1457	0.0566	0.0100
_cons	0.1616	0.0838	0.0540

Table 5. Average Technical Efficiency (TE) Estimates

	Number of households	**Bias-corrected estimate of TE**	**Std. Error**
Bhutan	4007	0.923712	0.0151891
Urban	2319	0.961534	0.0136754
Rural	1688	0.873699	0.0330749
West	1746	0.963718	0.028012
Central	1184	0.907619	0.0259121
East	1077	0.881505	0.0135598

Table 6. Technical Efficiency by Characteristics of the Household Head.

Head of Household	Number of households	Bias corrected estimate TE	Std.Error
Literate	2150	0.936585	0.01747
Illiterate	1857	0.911571	0.0237982
Male	3067	0.92594	0.0174957
Female	940	0.920017	0.0269454

Table 7. Technical Efficiency by Educational Attainment of Household Heads

Education level	Percent of household Head	Bias corrected estimate of TE	Std.Error
No schooling	68.95	0.914451	0.0194859
Primary	5.32	0.946081	0.0240285
Lower secondary	7.19	0.938546	0.0176429
Middle secondary	10.86	0.951027	0.0589641
Higher secondary	4.32	0.941288	0.0384252
College & above	3.37	0.977036	0.0683747

Table 8. Technical Efficiency by Expenditure Quintiles

Population quintile	Number of households	Bias corrected estimate of TE	Std.Error
Lowest	801	0.866058	0.0313166
Secound lowest	802	0.912716	0.0257155
Middle	801	0.946226	0.0430886
Secound highest	802	0.935426	0.0224927
Highest	801	0.958915	0.0394383

Table 9. Technical Efficiency by Main Source of Income of Household Head

Main source of income of the household	Number of households	Bias corrected estimate of TE	Std.Error
Agriculture	1106	0.891881	0.04008
Others	2901	0.938171	0.0150955

Table 10. Technical Efficiency by Occupation of Household Head

Occupation of household head	Number of households	Bias corrected estimate of TE	Std.Error
Legislators, senior officials and managers.	106	0.945095	0.0466817
Professionals	310	0.936989	0.0236447
Technicians and associate professionals	380	0.929367	0.0222761
Clerks	188	0.943835	0.0245888
Service workers and shop and market sales workers	392	0.95474	0.0208834
Skilled agricultural workers	1294	0.877702	0.0368513
Craft and related workers	172	0.952603	0.0174144
Plant and machine operators and assemblers	222	0.965487	0.0143537
Elementary occupations	156	0.9167	0.0314607
Armed forces	238	0.981349	0.0213953
No occupation	549	0.947788	0.0597018

Table 11. Technical Efficiency by Industry of Household Head

Industrial sector	Number of households	Bias corrected estimate of TE	Std.Error
Agriculture	1273	0.863608	0.0320276
Mining	15	0.951991	0.0382921
Manufacturing	111	0.951324	0.0255193
Electricity, gas and water supply	18	0.927591	0.0359968
Construction	90	0.956574	0.0429577

Wholesale and retail	246	0.94918	0.0311615
Hotels and resturants	66	0.941652	0.063234
Transport, storage & communication	80	0.954418	0.051008
Financial intermediation	3	0.903118	0.0582418
Insurance	5	0.913018	0.0869848
Public administration and defense	1389	0.960128	0.0209502
Education	27	0.916219	0.0394362
Health and social work	16	0.911421	0.0505788
Other	668	0.941587	0.0484388

Table 12. Technical Efficiency by Health Status of the Household Head

Status of household head	Percent	Bias corrected estimate of TE	Std.Error
Sick	17.84	0.920983	0.0492837
Not sick	82.16	0.926494	0.0142956

Figure 1. Road Networks in Bhutan

Figure 2. Map with Boundaries of the Dzongkhags/Districts and the Geogs.