UNIVERSITY of BRADFORD
Faculty of Social Sciences

Bradford Centre for International Development

Development Working Papers Series 3

Working paper No 01/15

Rural Road Quality, Farm Efficiency and Income in Ethiopia

Kifle Asfaw Wondemu

June, 2015

Series Editor: Dr Rashmi Arora

Rural Road Quality, Farm Efficiency and Income in Ethiopia[1]

Kifle Asfaw Wondemu

June, 2015

ISBN: 1 898828 31 8

[1] This paper was prepared while the author was a doctoral student at the University of Bradford. The author is currently working with African Development Bank.

Abstract

Small scale farmers in Ethiopia are already operating on their land frontier and the scope for an increase in production and rural income should come, among others, through improvement in technical and allocative efficiency. Although the stake of efficiency improvement is substantial, a number of empirical studies undertaken to identify the determinants of efficiency however are few. Moreover, although road infrastructure is among key public goods that significantly influences the farm level economic efficiency, empirical studies that have considered its role in farm efficiency analysis is scarce. This research investigated the link between the quality of rural road and farm level allocative and technical efficiency as well as the impact of inefficiency on farm income. The result showed that households that have all weather road access are 16% technically and two times allocatively more efficient. Both allocative and technical inefficiencies reduce income; the adverse impact of technical inefficiency on income however is stronger. Although household specific factors have contributed to the observed inefficiencyin most cases it is exogenously driven, namely, it is a rational response to market imperfection and risks. Interventions that reduce market and production risks will increase crop output and farm income.

JEL classification: D61, Q12, O18

Keywords: Rural, roads, efficiency, income, Ethiopia

1. Introduction

In the face of growing resource constraints, raising farm economic efficiency is considered key in achieving short-run increase in farm output and income (Bravo-Ureta and Pinheiro, 1997). As a result, measuring efficiency and identifying its determinants have attracted a lot of interest both in policy as well as academic circles.

The issue is vital for policy makers because the strategy they pursue to improve the farm sector depends on the view they hold regarding the level of efficiency with which the farm sector is operating (Shapiro, 1983). If farmer are assumed to be reasonably efficient, it means that improving resource allocation at the firm level will not significantly increase farm output; and raising farm output calls for the introduction of new inputs or technology that shift the production frontiers (Sherlund, et al, 2002; Shultz, 1964). On the other hand, if the farm sector is considered operating inefficiently, interventions, such as institutional investment on input delivery, infrastructure and extension services, which encourage farmers to use their existing resources more effectively, would be more appropriate (McPherson, 1986; Shapiro, 1983; Ali and Byerlee, 1991).

In view of its important policy implication, clarifying whether peasant farmers are operating efficiently or not and also identifying the determinants of efficiency have attracted a lot of debate. While Schultz is the first to come up with his “poor but efficient’ hypothesis, subsequent empirical studies however challenged his claim (Shapiro, 1983). The issue although not yet satisfactorily resolved, currently there seems to be a general consensus that although peasant agriculture exhibits sizable inefficiencies, these inefficiencies are mostly traced both to internal as well as external factors (ibid). While the internal factors are mostly related with lack of technical skill and insufficient information on the part of the individual peasant, the external factors are related to market failure and institutional constraints (Ali and Byerlee, 1991). The debate also gave rise to considerable improvements in the methods used to measure efficiency as well as in identifying its determinants (Chavas, et al, 2005; Bravo-Ureta and Pinheiro, 1997).

In the Ethiopian context, the agriculture sector is dominated by peasant farms that are already operating on their land frontier. The scope of future increase in production and income, therefore, should come, among other, from an improvement in total factor productivity, which is expected to mainly come through an improvement in resource allocation and technical efficiency (Croppenstedt and Demeke, 1997). Among the external determinants of farm efficiency, access to road infrastructure is an important one. This is because better road access facilitates access to bigger markets and thus allows fuller utilization of existing production potential. It also improves and stabilize farm gate prices, reduces market risk and enhances the profitability and thus the likelihood of adopting improved commercial inputs, such as fertilizer. Its effect on efficiency through ensuring the timely availability of such inputs is also significant. Although the role of road infrastructure on farm productivity is expected to be significant, close to 70% of the rural population in Ethiopia has to travel about six hours to reach all weather roads. In addition, most of these roads are dry weather roads.

As a result, low road density and poor road quality is expected to be a handicap for agriculture sector growth. However, the number of studies undertaken to assess the impact of road infrastructure on farm efficiency is very limited. This study aims to investigate the link between the quality of rural road infrastructure and the technical and allocative efficiency of Ethiopian farm households. Accordingly, the paper is structured as follows. In section 2 the data will be briefly discussed. Next, after the discussion of the conceptual framework, the inefficiency models will be outlined. After the discussions of the empirical results, the paper concludes.

2. The Data

The paper will be based on data drawn from the longitudinal Ethiopian Rural Household Survey (ERHS) that was conducted by Addis Ababa University jointly with International Food Policy Research Institute (IFPRI) and the University of Oxford. Detailed discussion of the sampled villages and the survey data is made by Dercon and Hoddinott (2004) and here we only briefly discuss the sample and some data aspects of data measurement.

Although the household survey covers both the ox and the hoe-plough agriculture systems, the present study focuses on households that are under grain plough agriculture, on the grounds that their input use and crop choice are more influenced by degree of access to road infrastructure. Although the total number of households that are under ox-plough agriculture is 1200, due to missing data and inconsistency, we only use the data of 841 households. Similarly, although the survey has been undertaken in six rounds, since the required village level data were only available for 1997 and 2004, only the data of the two survey rounds will be used.

The sample villages differ substantially from each other not just in road access, but also in relation to aspects like average size of land holding, soil quality, temperature, rainfall intensity, altitude and use of fertilizer. Any attempt to isolate the impact of road access must control adequately for these differences.

The household surveys collect quantitative information on a set of variables reflecting both household characteristics and geographic characteristics of the village, including average size of land holdings, number of oxen owned, fertilizer input per hectare, average age and years of schooling of household head, number of household members, altitude above sea level, average temperature and distance from the village to the nearest town. In addition qualitative information is sought on respondents' perceptions on the magnitude and reliability of rainfall, the quality of soil in the area and critically of the degree of road access at different times of the year.

For example, in the survey four questions are asked concerning the reliability of rainfall, its magnitude, the time it stopped and whether it was raining at harvest time. An answer to each question that implies a negative impact on production is given a score of 1 and the total for all four is added to give a 'rainfall shock index.' Thus if a household experienced all shocks it will be given a score of 4 and if it experienced none of these shocks, a score of zero will be given. For soil quality, we used three possible values, namely 0 for poor quality, 1 for semi fertile and 2 for top soil.

A key aspect of the study is a measure of the quality of road access. In the survey, the quality of roads of the sampled villages was compiled through a structured community level questionnaire. Respondents (community leaders) were asked to attach a value of 1 to 6 depending on how the road allows accessibility to and from the village during the rainy season. Respondents attached a value of 1 to 6 respectively for a road that allows easy access to any vehicles (1), reasonable access to any vehicles (2), good access to trucks and buses (3), reasonable access to trucks and buses (4), access to carts and animals (5) and finally access only for foot traffic (6). The survey also contains information on how the road is built, namely tarmac/concrete, stones, dirt track and other. Based on this information, we classified the road quality into two groups. The first one is 'good road access,' which has a score of 3 and below and covers roads that allow accessibility from any vehicle to good access to trucks and buses. The second category is 'poor road access', which has a score of 4 and above, which covers roads that allows reasonable access only to trucks and buses and to foot traffic. Similar classification was used by Dercon, et al. (2006). For our purpose, the road quality variable will be given a value of 1 for villages with good road access and 0 otherwise. The average per-capita income of households in villages with good road access is 54% higher than those that have poor access. This paper aims to isolate the impact of road quality on farm level technical and allocative efficiency first and then to assess the significance of efficiency differences for the observed differences in average income.

3. Conceptual Framework

We use a farm household model as our theoretical framework. Although the postulated household model is based on the separability assumption, when we estimate the empirical model we introduce different variables that capture market imperfections.

In light of this, the sampled households are assumed to maximize utility function *(U)* defined over net revenue *(M)* and leisure (*l*). The income of the household comes from crop production and off-farm employment. The level of crop production *(Q)* is a function of fixed inputs *K* (such as land, oxen and farm implements), labour *(L)*, commercial fertilizer (*F*) and other fixed household and geographical characteristics (Z). Each crop requires different levels of transport service for their production and marketing.

Selling crops entails a transport cost (τ) that varies by distance and the quality of road connecting the household with the main market. As a result, the effective (farm gate) price farm households receive for the crops they supply will be $P_f = P_M - \tau_j$ where, P_M is the price of similar crop at the terminal market. Similarly, while fertilizer is the only commercial input imported from town, the effective price a household pay for fertilizer input will be $\alpha = \omega + \tau_j$, where, ω is the market price of fertilizer at the source of supply.

There is no active land market and the size of land the household owns is fixed. Although there is an active labour market, the number of days households members can work off-farm is limited to (*H*) days and from the total *T* labour time available*, L* unit is used on family farm, *N* unit is hired out for off-farm employment and the remaining is consumed as leisure (*l*). Family and hired labour are perfect substitutes. In order to avoid complication, the market wage rate (*w*) is assumed to be unaffected by the level of transport cost. However, the level of off-farm employment opportunities are assumed to be affected by magnitude of transport cost, mainly through the effect of the latter on farm productivity.

Considering the income constraint, the production, technology, time and labor market constraints, the Lagrangian form of the household's maximization problem becomes:

$$\text{Max£} = U[M,l] + \lambda[P_f Af(K,L,F,Z) + wN - \alpha F - M] + \mu_1(T - L - N - l) + \mu_2(H - N) \quad (1)$$

Based on the first order condition and only considering those variables that appear in the net-income function, the equilibrium net-income *(M)* of the household will be:

$$M^* = P_f Af(K,L^*,F^*,Z) + wN^* - \alpha F^* \quad (2)$$

Since our interest here is to determine the factors that shift the net income position of the household in the short run, i.e. assuming that factors such as land size and quality as well as oxen inputs are fixed, equation (2) can be totally differentiated and becomes:

$$dM = f(\bullet)\frac{\partial M}{\partial P_f}dP_f + P_f f(\bullet)\frac{\partial M}{\partial A}dA + (P_f f_F - \alpha)\frac{\partial M}{\partial F}dF - F\frac{\partial M}{\partial \alpha}d\alpha + w\frac{\partial M}{\partial N}dN \quad (3)$$

Where, $f(\bullet) = f(K,L,F,Z) = Q$, $f_F = \frac{\partial f(\bullet)}{\partial F}$

From the above equation, it is clear that in the short run, a growth in the net income of the household would come from a change in the market price of the crops supplied to the market, the change in technical efficiency level, the change in the market price of fertilizer and the level of allocative efficiency in the application of fertilizer input as well as from the change in the number of household members engaged in non-farm employment. Although the net income level of the household could also be influenced by the degree of optimality in cropping pattern, for the purpose of focused discussion, we will disregard that. In addition, we have also assumed that re-allocation of labour will not entail significant change in income as the off-farm employment is rationed.

As our interest here is on the link between the level of technical and allocative inefficiency and net-income of the sample, we will maintain the second and third elements of Equation (3) and disregard the others. We also assume that the level of market prices for input, output and the number of household members engaged in off-farm employment differs under different road access conditions. In villages where there is good road access, lower transport and transaction cost, better market opportunity and relatively competitive market conditions generally, ceteris-paribus, allow farm households to face better off-farm employment opportunities, better market prices for inputs and outputs and hence technically and allocatively more efficient. Assuming the level of transport cost is related to road quality, say 1 for good road quality and 0 otherwise, the growth in net income due to better road quality induced technical and allocative efficiency improvement can be approximated by:

$$dM = \int_0^1 P_f f(\bullet) \frac{\partial M}{\partial A} dA + \int_0^1 \left(P_f f_F - \alpha\right) \frac{\partial M}{\partial F} dF \tag{4}$$

Since technical efficiency entails a neutral shift in production function, the first term measures the net income gap due to differences in the level of technical efficiency under different road conditions. The second term, which is the difference between the marginal value product curve of the fertilizer input and its price, is also expected to differ under different road conditions. Again, after controlling for all the other factors, the gap between the curves can be assumed to capture the impact of transport cost on net income that works through altering the level of allocative efficiency.[1] As our interest is on the average increase in income due to transport cost induced increase in economic efficiency, we take the expected value across different level of transport cost. In order to empirically estimate Equation (4), in the next section, we first estimate the efficiency parameters and then assess the significance of the link between efficiency and income.

4. Empirical Model and Strategy

4.1 Technical Efficiency

In order to measure the level of technical efficiency, we postulate a production frontier, which represents the maximum level of output that can be produced given the state of technology (Morrison 2002; Aigner, et al., 1977). Efficiency is measured in terms of the degree of deviation of the actual output from the frontier. In specifying the frontier, although a flexible production function form, such as translog, is generally preferred, when such functional form is fitted on the data, the model suffers from a serious multicollinearity problem, namely either some of the variables become insignificant or have unexpected sign. This might suggest low degrees of substitutability between the production inputs (Gebreegziabher, et al, 2004). As a result, for our purpose, we estimate a Cob-Douglas type frontier of the following form (Gebreegziabher, et al. 2004).

$$\ln y_{it} = \beta_0 + \sum_{i=1}^{6} \beta_i \ln x_{it} + \varepsilon_{it} \qquad (5)$$

where $\boldsymbol{y_i}$ is the level of total output of household *"i"* at time *t*, β is a vector of parameters to be estimated, $\boldsymbol{x_i}$ is a vector of inputs; and includes land in hectare *(x_1),* labor input in man days *(x_2)*, quantity of fertilizer used in kg *(x_3)*, the index for rain shock *(x_4)*, number of oxen owned *(x_5)*, and the average soil quality of land the household cultivates *(x_6)*, where 0 is for poor quality and 1 for top soil; ε_i is a disturbance term.

Regarding sign, higher land size, more labor and oxen power allow farmers to exploit scale advantages and also enable them to undertake timely farm activities; and as a result these variables are expected to have positive signs (Gebreegziabher, et al. 2004). Fertilizer input, by increasing the productivity of land and labor, enable farmers to produce closer to the frontier and as a result its sign is expected to be positive. Rainfall shock by reducing the factor productivity reduces households' output below the potential and hence will have a negative sign (Seyoum, et al, 1998). Soil quality raises the productivity of variable inputs and thus expected to have a positive sign.

The error component (ε_i) in equation (5) is assumed to consist of two independent elements. The first one is the random error term v, which is independently and identically distributed as $N(0,\sigma_v^2)$, represents random variations in output level that arises due to factors outside the farmer's control. The second term (μ), which is assumed to be half normally, identically and independently distributed as $N(0,\sigma_u^2)$, represents the one-sided error term, which measures technical inefficiency level. If the household is technically efficient μ takes the value of zero, and thus the actual output level will be equal to the maximum possible level.

Generating farm/household specific inefficiency score therefore will require the decomposition of the error term into its distinct components. In decomposing the error term following Jondrow, et al., (1982) and considering the half normal case, the conditional mean of μ given ε is shown to be:[2]

$$E[\mu \mid \varepsilon] = \frac{\sigma_\mu \sigma_v}{\sigma} \left| \frac{f(\varepsilon\lambda/\sigma)}{1-F(\varepsilon\lambda/\sigma)} - \frac{\varepsilon\lambda}{\sigma} \right|, \qquad (6)$$

Where $\lambda = \frac{\sigma_\mu}{\sigma_v}{}_v^2$, and f and F are the standard normal density function and the standard cumulative distribution function, respectively evaluated at $(\varepsilon\lambda / \sigma)$ (Ali, et al, 1996). The parameter λ is an indicator of the relative variability of the two sources of errors. If λ is closer to zero, it means that there is no technical inefficiency and the variation between the maximum attainable level of output and the observed level of output is due to random factors that are outside the control of the producer. On the other hand, if λ is greater than one, it means that the variations in production is more dominated by variability emanating from technical inefficiency. Once point estimates of μi are obtained, a technical inefficiency level of each farm household is given by:

$$TE_i = E(\exp\{-\mu_i\} \mid \varepsilon_i = \left[\frac{1-\Phi(\sigma_* - \mu_{*_i}/\sigma_*)}{1-\Phi(-\mu_{*_i}/\sigma_*)}\right]\exp\{-\mu_{*_i} + \frac{1}{2}\sigma_*^2\} \qquad (7)$$

As the analysis is based on two years panel data, the frontier will be estimated on the basis of time invariant efficiency model and the unit of analysis will be village (Bravo-Ureta and Pinheiro, 1993).[3]

Since our objective is to empirically establish if there is a robust link between technical efficiency of the samples and the quality of the roads they have access to, identifying and controlling the influence of other covariates of technical efficiency will be necessary. Following previous studies, in addition to the road quality, the level of human capital, family size, age and gender of the household head, credit access condition of the household, the number of plots and crops the household cultivates will be introduced as additional covariates of technical efficiency (Kalirajan, 1990; Rahman, 2003; Hallam and Machado, 1996). Finally, since the technical inefficiency score is censored at zero, the Tobit (censored regression) model will be used to estimate the link between technical efficiency and its determinants.

$$\mu_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 \ln Z_2 + \alpha_3 \ln Z_3 + \alpha_4 \ln Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \alpha_7 Z_7 + \alpha_8 Z_8 + \varepsilon_i \qquad (8)$$

Where u_i is the technical inefficiency score of household *"i",* and the *Z's* respectively represent dummy for the road quality of the village that connects the household with the nearest market town (1=good), years of schooling of head of the household, age of the head of the household, family size, gender of head of the household (1=Female), number of plots cultivated, number of crops cultivated and dummy for credit access (yes=1).

For the reasons mentioned before, the road variable is expected to a have a positive sign. The sign of the age of the head cannot be determined a priori, because while higher age through its effect on farming experience positively affects the efficiency level, it could also reduce efficiency if higher age makes the head of the household risk averse in adopting new techniques (Seyouma, et al, 1998). The variable for family size is expected to be positive as large family size allows the household to attain a more effective division of labor and ensures availability of the required labor for farm activities (Ali, et al, 1996; Parikh, et al, 1995).[4] Moreover, in a household with low land-labor ratio, higher family size could motivate the household to adopt productivity enhancing commercial inputs (Haji, 2006).

As ploughing is undertaken by men, female headed households had to rely on relatives, which adversely affects timely implementation of farming activities; and thus the gender dummy is expected to be negative (Gebregzaber et al 2004). Lack of financial resources and relatively poor access to credit could also be the other factors that make female headed households to be technical less efficient (ibid). The number of plots the household cultivates, which measures the degree of land fragmentation, makes the household technically less efficient. This is because higher degree of land fragmentation prevents households from having scale economies, makes supervision and protection of the land difficult, entails long distances travel and loss of working hours (Haji, 2006; Parikh, et al, 1995; Ali, et al, 1996;

Bizimana, et al, 2004). As a result the variable is expected to be positive. The number of crops cultivated, while reflects the degree of food market imperfection, is expected to have a negative impact on technical efficiency (Omamo, 1998; Haji, 2006).

4.2 Allocative Efficiency

In measuring allocative efficiency, we consider fertilizer input only. Assuming that farmers maximize expected profit, allocative efficiency occurs if fertilizer is used at the point where the marginal revenue contribution of fertilizer is equal to its cost (price), which is:

$$p_y \frac{\partial \ln y}{\partial \ln x}\left(\frac{y}{x}\right) = \alpha \tag{9}$$

Where y and P_y respectively represent output level and its unit price; x and α respectively represent the quantity of fertilizer input and its market prices.

After re-arranging the terms, it becomes:

$$\frac{\alpha x}{p_y y} = S_{FR} = \frac{\partial \ln y}{\partial \ln x} \tag{10}$$

The left hand side of Equation (13) is the share of the cost of fertilizer from total revenue; and it implies that for profit to be maximized or cost minimized, fertilizer input should be used up to the point where the share of expenditure on fertilizer from total crops revenue is equal to the elasticity of the crop output to fertilizer input (Lau and Yotopoulos, 1971). The magnitude of the deviation between the actual shares (S_{FR}) and the optimal share, in this case the coefficient of the production frontier $\left(\frac{\partial \ln y}{\partial \ln x}\right)$, thus measures the degree of allocative inefficiency of the input (Carter, 1984; Stifel and Minten, 2004). Household specific allocative efficiency estimates of fertilizer input will therefore be:[5]

$$\mu_i = S_{FRi} - \frac{\partial \ln y}{\partial \ln x_{FR}} \quad (11)$$

In order to determine if road quality of the village indeed influences the allocative efficiency level of farm households, the efficiency estimate will be regressed on the road quality and other determinants of allocative efficiency. In order to identify the other determinants of allocative efficiency, we assume that farmers face uncertainty in goods and factor markets and thus their allocation decisions are also influenced by risk consideration. This suggests that the level of allocative mistake depends on each farmers risk aversion and his/her estimates of the level of risk additional use of fertilizer will entail.

Based on previous studies, among household characteristics, the wealth of the household, which is measured in terms of per-capita land size and the number of livestock owned, the education level and gender of the head of the household, age and access to credit are identified as important determinates of the risk preferences of the farmers (Larson and Plessmann, 2009). The weather shock farmers experience also influences the variance of net income and hence the allocative efficiency of fertilizer. The road quality of the village also influences allocative efficiency through its impact on the profitability and risk of fertilizer use (Ahmed and Hossain, 1990).

Incorporating the above variables and also considering that the inefficiency estimate is censored as most of the households underutilized the input, the following Tobit model will be estimated to determine the link between allocative efficiency and road quality.

$$\mu_i = \alpha + \beta_1 \text{Ldpc} + \beta_2 \text{Lstk} + \beta_3 \text{Sch} + \beta_4 \text{Age} + \beta_5 \text{Rain} + \beta_6 \text{Rd} + \beta_7 \text{Gen} + \beta_8 \text{credit} + \varepsilon_{jt} - (12)$$

Where μ_i is the level of allocative mistake, Ldpc= log per capita land size, Lstk=log number of livestock holding, Sch=log average years of schooling of the adult family members, Age is log of age of the household head (HH), Rain is a dummy whether the household experienced rain shocks, Rd is road quality of the village, Gen and Credit respectively represent dummies for gender of the head of the household and whether the household has access to credit.

In terms of sign, β_1 is expected to be positive because higher per-capita land size increases the risk coping and bearing capacity of the farm household and thus reduced the degree of misallocation. Similarly, β_2 is expected to be negative because ownership of large livestock assets, which serves as a hedge against risk, enhances the willingness of the household to take risk. β_3 is expected to have a negative sign because more years of schooling enhances the ability to acquire and process production related information and hence, not only raises the probability of adopting fertilizer, but also enhances its optimal use (Rahman, 2003).[6] Moreover, greater level of formal education increases the chance of getting off-farm employment and reduces the need to take a risk aversion stance. β_4 is expected to be positive because as the head of the household get older, the probability of adopting fertilizer as well as its level of use tend to decline. For the reasons mentioned earlier, β_5 and β_6 are respectively expected to have positive and negative signs. β_7 is expected to be positive as female headed households tend to use less fertilizer. β_8 is expected to be negative as credit access, by easing cash constraints, tends to increase the willingness of the household to take risk.

5. Results and Discussion

5.1 Technical Efficiency

The summary of the production frontier estimation defined by equation (5) is presented in Table 1. The variables are significant and also have the expected sign. The presence of technical inefficiency is confirmed by the significance of "mu'. In addition, the likelihood ratio (LR) test on the null hypothesis of no inefficiency (i.e., γ=0) is rejected at less than 1%. As γ(gamma) , which measures the extent to which the observed variations in the level of output is due to inefficiency, is significant at less than 1%. The result suggests that 15% of the variation between the actual and the potential output is due to technical inefficiency (Bravo-Ureta and Pinheiro, 1997).[7]

The average technical efficiency level of the entire sample is 49% and ranges from 22% to 90%. This suggests that there are ample rooms to increase farm output. Among the variables the size and quality of land and the number of oxen the household owns as well as the adoption and intensive application of fertilizer are important determinants of farm output. Although significant, the marginal output contribution of labour however is not substantial, which is expected given the presence of underemployed family labour (Rahman, 2003). However, when the production frontier is estimated separately by splitting the sample into villages with good and poor road access, the labour input coefficient while positive and insignificant for villages with poor road access, it is positive and significant for villages with good road access.[8] This may be due to the fact that in the latter villages per-hectare application of fertilizer, which normally raises the productivity of labour, is higher. As expected, the level of rain shock adversely affect crop output. On average, a onetime rainfall shock reduces the potential output level by close to 3.7%.

When the samples are grouped according to the quality of road they have access to, the average technical efficiency of households with good road access was 13% higher than those with poor road access (Table 2). On the basis of the t-test, the null hypothesis of no difference in technical efficiency by type of road access is rejected at less than 1%. The result implies that, on average, for the same level of resources, farm households with good road access generate 13% more output.[9] The gap also ranges from the lowest of 10% to the highest of

25% (Table 2). It means, if road quality improves, the average farmer in villages with poor road access could realize a 23% (=1-0.44/.57) increase in output level. The least efficient ones will also realize a 28.6% growth in output.

In order to substantiate the significance of the association between road quality and technical efficiency, the Tobit model was estimated and the result is reported in Table (3). All the variables included, except family size, are significant at less than 5% and also have the expected sign. This holds in both models. Household specific factors, such as age, average schooling level, gender, family size, and degree of land fragmentation are significant determinants.

The road quality of the village is also a significant determinant of technical efficiency and on average farm households with good road access are 16% technically more efficient. This result differe from 13% reported above, which we found when the average efficiency score is calculated by classifying the sample according to their road access condition. However, the Tobit model result is believed to be more reliable as it controls for other factors that affect efficiency directly as well as indirectly through mediating the link between road condition and efficiency level. A closer look into the result suggests that the main mechanism by which road access raises the technical efficiency appears to work through promoting fertilizer application. More than 62% of households that applied fertilizer are in villages with good road access; and their average per-hectare application was also 52% higher. In order to statistically substantiate that, the Tobit model is re-estimated by introducing the fertilizer application dummy and the interaction of road quality and the for fertilizer use dummy as additional independent variables. The result is reported under Model II. As the result shows, while good road access generally increases average technical efficiency level by 16%, close to 9% of this increase comes through road induced higher fertilizer application. As the dummy for road quality in the second model shows, the remaining 7% of the road induced increase in technical efficiency is expected to come from road induced better market opportunity and improved technical information flows.

In order to determine the magnitude of technical efficiency of fertilizer use, based on Seemingly Unrelated Regression model, the production frontier is fitted simultaneously with the ratio of fertilizer to labour.[10] Considering only farm households that have actually applied fertilizer, the result showed that while the technically efficient combination of fertilizer to labour is 1.76, the actual ratio however was 0.7, suggesting a substantial underutilization of fertilizer and overutilization of labour. By other measure too, that is, comparing the ratio of the output elasticity of fertilizer to labour (2.44) to their market price (0.6), fertilizer input is substantially underutilized and suggests that increased application of fertilizer will increase output at a lower cost.[11]

The average years of schooling, as a priori expected, positively influences the technical efficiency level (Ali and Flinn, 1989). Better human capital, possibly by increasing the probability of adopting better technology and enhancing its effective use, raises the technical efficiency level by as much as 5%. Although technical efficiency is not strongly correlated with family size, the average age of the household head matters and households with older family heads are technically less efficient, suggesting that the adverse effect of age that works through inducing a risk averse behaviour might be more dominant. Compared to male headed, female headed households are 3% technically less efficient.

As a-priori expected, a high degree of land fragmentation, through increasing managerial complexity and preventing economies of scale from occurring, reduces technical efficiency by 1%. This is also consistent with the findings of previous studies on Ethiopia (Mulat 1999). As land fragmentation normally increases with rural population size, one mechanism by which high population growth contributes to rural poverty works through reducing technical efficiency.

The number of crops the household cultivates also matters and an increase in the number of crops cultivated reduces the technical efficiency level by 1%. The coefficient estimate is also expected to measure the output loss farm households could incur by devoting their limited land area to crops that they produce less efficiently (Fafchamps, 1992).[12] This implies that the effort to diversify crops with the objective of minimizing risk is not without cost. The significance of the variable also implies that high transaction costs, product and factor market imperfections have important influence on farm level technical efficiency.

The positive sign and significance of the credit dummy variable suggests that liquidity is a critical constraint. Access to credit, by shifting their budget constraints or reducing the shadow price of commercial inputs (such as fertilizer), allows farmers to make a timely purchase of the inputs and hence achieve a 3-4% higher technical efficiency level.

5.2. Allocative Efficiency

The Tobit model estimation result allocative inefficiency model is reported in Table (4). All the included variables have the expected sign and, except age and gender of the household head, all the other variables are significant at less than 5%. Households that reside in villages with good road access exhibited a 4.2% lower allocative inefficiency. The per-capita land size, number of livestock the household owns and average years of schooling are also significant, suggesting that access to physical, human as well as financial capital significantly influence the efficient application of fertilizer.

Although at 10%, female headed households are 1.4% allocatively less efficient. The age of the head of the household, however, has no significant impact on allocative efficiency. Households that have experienced rain shock are also less efficient. Access to credit matters and those that have access to credit service exhibited a 1.2% lower allocative inefficiency.

The presence of allocative and technical inefficiency suggests that, with the existing resource level and technology, resource reallocation and promoting access to the existing technology could boost farm productivity and income.[13] In order to see if inefficiency adversely affects income, the net income from crop production is regressed on the inefficiency scores. The random effect model result is reported in Table 5. The result generally suggests that both technical and allocative inefficiency significantly reduces net-income. The effect of technical inefficiency however is stronger.

We introduced both types of inefficiency in the net income model and the result is reported in Table 6. Based on the results, the impact of road quality on net-income that occurs through road induced increase in technical and allocative efficiency respectively will be 0.40 (0.17*2.36) and 0.026 (0.62*0.042). This means close to 40% of higher average income in villages with road access is due to road induced higher technical efficiency. The impact of road on raising farm income through improving allocative efficiency however is 2.6%. Such low level of impact is expected in an environment where farmers face imperfection in goods, financial and factor markets.

6. Conclusion

The paper investigates the impact of rural road quality on farm income through raising technical and allocative efficiency. The result shows that technically and allocative inefficiency significantly reduce return to land and labour. The effect of technical inefficiency in reducing income however is stronger.

Among household specific determinants of farm efficiency, land and family size, the level of land fragmentation, the adoption and level of fertilizer use, age and human capital endowment of farm households are important ones. The presence of inefficiency suggests that there is room to increase farm output by application of modern technology and efficient use of improved inputs. As farmers are already operating on their land frontier, any future income growth should come from an improvement in efficiency. Providing farmers with good road access will improve farm efficiency and rural income.

References

Ahmed, R. and Hossain, M. (1990). Developmental Impact of Rural Infrastructure in Bangladesh. Research Report no. 83, IFPRI.

Aigner, D., Lovell, C. and Schmidt P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. Journal of Econometrics, 6, 1.

Ali, M. and Byerlee, D. (1991). Economic Efficiency of Small Farmers in a Changing World: a Survey of Recent Evidence. Journal of International Development, 3,1.

Ali, M. and Flinn, J. (1989). Profit Efficiency among Basmati Rice Producers in Pakistan Punjab. American Journal of Agricultural Economics, 71, 2.

Bizimana, C., Nieuwoudt, W. and Ferrer, S. (2004). Farm size, land fragmentation and economic efficiency in southern Rwanda, Agrekon, 43, 2.

Bravo-Ureta, B. and Pinheiro, A. (1993). Efficiency Analysis of Developing Country Agriculture: A Review of the Frontier Function Literature. Agricultural and Resource Economics Review, 22, 1.

Bravo-Ureta B. and Pinheiro E. (1997). Technical, Economic, and Allocative Efficiency in Peasant Farming: Evidence from the Dominican Republic. The Developing Economies, 35, 1.

Chavas, J-P., Petrie, R. and Roth, M. (2005). Farm Household Production Efficiency: Evidence from the Gambia. American Journal of Agricultural Economics, 87, 1.

Croppenstedt, A. and Demeke, M. (1997). An Empirical Study of Cereal Crop Production and Technical Efficiency of Private Farmers in Ethiopia: A Mixed Fixed-random Coefficients Approach. Applied Economics, 29, 9.

Dercon, S. and Hoddinott, J. (2004). The Ethiopian Rural Household Surveys: Introduction. IFPRI and University of Oxford.

Dercon, S., D.Gilligan, J.Hoddinott and T. Woldehanna. (2006). The impact of roads and Agricultural Extension on Crop Income, Consumption and Poverty in Fifteen Ethiopian villages. ESSP Policy Conference Brief No. 5, June.

Fafchamps, M. (1992). Cash Crop Production, Food Price Volatility, and Rural Market Integration in the Third World. American Journal of Agricultural Economics, 74, 1.

Gebreegziabher, Z., Oskam, A. and Woldehanna, T. (2004). Technical Efficiency of Peasant Farmers in northern Ethiopia: A stochastic frontier approach, Draft.

Haji, J. , (2006). Production Efficiency of Smallholders' Vegetable-dominated Mixed Farming System in Eastern Ethiopia: A Non-Parametric Approach. Journal of African Economies, 16, 1.

Hallam, D. and Machado, F. (1996). Efficiency analysis with panel data: A study of Portuguese dairy farms. European Review of Agricultural Economics 23, 1.

Huffman, W. (1977). Allocative Efficiency: The Role of Human Capital. The Quarterly Journal of Economics, 91, 1.

Jondrow, J., Lovell, C., Materov, I. and Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. Journal of Econometrics 19, 2-3.

Kalirajan, K. (1990). On Measuring Economic Efficiency. Journal of Applied Economics, 5, 1.

Larson, D. and Plessmann, F. (2009). Do farmers choose to be inefficient? Evidence from Bicol. Journal of Development Economics, 90, 1.

Lau, L. and Yotopoulos, P. (1971). A Test for Relative Efficiency and Application to Indian Agriculture. The American Economic Review, 61, 1.

McPherson, M. (1986). Why do researchers continue to ignore risk in tests of farmer efficiency? A comment on Shapiro's rejection of the efficient but poor hypotheses. Journal of Development Studies, 22, 3.

Mulat Demeke (1999). Agricultural Technology, Economic Viability and Poverty Alleviation in Ethiopia. Paper Presented to the Agricultural Transformation Policy Workshop Nairobi, Kenya, 27-30 June.

Omamo, S. (1998). Transport Cost and Smallholder Cropping Choices: An Application to Siaya District Kenya. American Journal of Agricultural Econnomics, 80, 3.

Parikh, A, Ali, F. and Shah, M. (1995). Measurement of economic efficiency in Pakistan agriculture. American Journal of Agricultural Economics, 77, 3.

Rahman, S. (2003). Profit Efficiency among Bangladesh Rice Farmers. Paper presented on the 25th International Conference of Agricultural Economists (IAAE), Durban, South Africa.

Seyouma, E., Batteseb, G. and Fleming, E. (1998). Technical efficiency and productivity of maize producers in eastern Ethiopia: a study of farmers within and outside the Sasakawa-Global 2000 project. Agricultural Economics 19, 3.

Shapiro, K. (1983). Efficiency Differentials in Peasant Agriculture and Their Implications for Development Policies. the Journal of Development Studies, 19, 2.

Sherlund, S., Barrett, C. and Adesina, A. (2002). Smallholder Technical Efficiency Controlling for Environmental Production Conditions. Journal of Development Economics, 69, 2.

Shultz, T. (1964). Transforming Traditional Agriculture. New Haven: Yale University Press.

Stifel, D. and Minten, B. (2004). Isolation, welfare and agricultural productivity. IFPRI, Working Paper.

Table 1: Estimates of the Time Invariant Production Frontier*

Independent Variables**	Coeff.	Z	P>z
Land Size	0.39	11.63	0.00
Number of Oxen	0.34	6.96	0.00
Labor (in man days)	0.07	3.32	0.00
Rain Shock Dummy	-0.04	-2.37	0.02
Fertilizer Applied	0.10	7.48	0.00
Soil Quality Dummy	0.24	3.27	0.00
Constant	1.86	8.25	0.00
mu	0.78	3.43	0.00
γ(gamma)	0.15		
sigma_u2	0.11		
sigma_v2	0.64		
Wald chi2(6)= 563.77			
Log likelihood=-2026.34			

*Unit of analysis is village; Number of groups=14,

**Except the Dummies, all the other variables are in natural log

Table 2: Level of Technical Efficiency by Type of Road Access

Type of Road	Mean	Stdev.	Min.	Max.
Poor Road	0.44	0.14	0.25	0.65
Good Road	0.57	0.16	0.35	0.90
Total	0.52	0.16	0.25	0.90

Table 3: Determinants of Technical Efficiency-Tobit Model

Independent Variables	Model I			Model II		
	Coeff.	Z	P>z	Coeff.	Z	P>z
Road Quality	0.17	17.86	0.00	0.09	6.64	0.00
Schooling	0.05	6.33	0.00	0.05	6.25	0.00
Age	-0.06	-5.47	0.00	-0.05	-4.62	0.00
Family Size	0.01	0.90	0.37	0.01	1.01	0.31
Gender Dummy	-0.03	-3.41	0.00	-0.02	-2.23	0.03
Nos. of Plots Cultivated	-0.01	-4.78	0.00	-0.01	-6.03	0.00
Nos. of Crops Cultivated	-0.01	-2.53	0.01	-0.01	-2.64	0.01
Dummy for Credit Access	0.04	4.79	0.00	0.03	3.56	0.00
RoadQuality*Fert use Dummy				0.08	4.22	0.00
Fertilizer Use Dummy				0.04	2.63	0.01
Constant Term	0.59	16.56	0.00	0.56	15.92	0.00

Table 4: Determinants of Allocative Inefficiency of Fertilizer

Independent Variables	Coeff.	z	P>|z|
Per-capita Land Size	-0.006	-2.36	0.02
Number of Livestock owned	-0.013	-3.94	0.00
Schooling	-0.012	-2.1	0.04
Age	0.001	0.18	0.86
Rain shock dummy	0.005	2.28	0.02
Road Quality Dummy	-0.042	-5.6	0.00
Gender of the Head	0.014	1.63	0.10
Dummy for Credit Access	-0.012	-2.24	0.03
Constant	0.184	6.12	0.00
Wald-ch2(8) =107.4, N=767			

Table 5: The Impact of Inefficiency on Income

Independent Variable	Random Effect Model (the Whole Sample)		
	Coef.	Z	P>z
Technical Inefficiency	-2.36	-12.7	0.01
Allocative Inefficiency	-0.62	-9.2	0.00
Constant Term	8.33	89.3	0.00
	R2 Overall=0.15 Wald chi2(2) = 256.0		

*The income from crops is measured in natural log.

Table 6: Estimates of Net Income Determinants: The Hausman-Taylor RE IV

Independent Variables	Coefficient	Z	P>z
TV Exogenous			
Land Size	0.22	6.55	0.00
Number of Oxen	0.28	5.17	0.00
Number of Adults	0.10	2.06	0.04
Rain Shock Dummy	-0.03	-1.86	0.06
Soil Quality Dummy	0.16	1.75	0.08
Schooling	0.30	5.33	0.00
Age	0.08	1.37	0.17
Gender Dummy(Female Headed=1)	-0.19	-3.27	0.00
Teff Dummy	0.26	4.77	0.00
TV Endogenous			
Road Quality Dummy	0.64	7.61	0.00
Allocative Inefficiency	-0.53	-7.01	0.00
TI Exogenous			
Distance to Town	-0.01	-0.43	0.67
Altitude	-0.31	-2.72	0.01
Temperature	-0.54	-2.11	0.04
TI Endogenous			
Technical Inefficiency	-1.22	-2.07	0.04
Constant	10.52	5.91	0.00

Note: The net Income model is postulated in the framework of a spatial equilibrium framework where village level market prices are assumed to be endogenously adjust to the local infrastructure. To address the possibility of the endogeneity of road, the Hausman-Taylor RE IV method is used to estimate the model. The Allocative and Technical Inefficiency Scores are assumed to be endogenous variables as they are generated measures. TV= Time Varying, TI= Time Invariant.

Endnotes:

1 Since the net income is partially differentiated with respect to its determinants, the dummy of the road quality in the regression of net-income on inefficiency is assumed to measure the contribution of road in increasing income through improving efficiency.

2 Jondrow, et al., (1982) was first who suggested the decomposition of the error term as well as estimating the μi for each observation. According to this approach, the decomposition of the μ is based on the assumption that

$$\sigma^2 = \sigma_\mu^2 + \sigma_v^2, \quad \mu_* = \frac{\sigma_u^2 * \varepsilon}{\sigma^2}$$

3 When the unit of analysis is household level convergence could not be achieved and the log-likelihood remains the same after 13 iterations. However, when the unit of analysis is village, convergence is achieved at the 5th iterations. Although the mu is not significant when household is considered as the unit of analysis, the sign of the coefficient estimates of the frontier are more or less similar, except that the magnitude of fertilizer variable is higher when the unit of analysis is at household level.

4 In some households, labor shortage was reported as one problem. In such cases, higher family size enables to solve such shortages.

5 As commonly claimed, in response to market imperfections, farmers tend to be voluntarily inefficient or employ inputs up to the point where the expected marginal value contribution of the input is greater than its marginal cost, which is considered inefficient in context of the conventional efficiency criteria (Larson and Plessmann, 2009). Such allocation strategy although rational, given the constraints, it is not however without cost. What we are arguing here is that given the constraints, better road access generally reduces the tendency to be risk avert.

6 Huffman (1977) reported that education increases the speed of adjustment in the use of fertilizer in response to the fall of its price.

7 The result generally suggests that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer could realize up to 44% (1-(0.50/0.90) increased output (Bravo-Ureta and Pinheiro, 1997).

8 The elasticity of output to labour while close to zero in villages with poor road access, it is close to 9% in villages with good road access.

9 In other words the result suggests that by improving the road condition that allows accessibility to all types of vehicles, it is possible to improve the technical efficiency of the sample by close to 13%.

10 For the sake of saving space the result is not reported here but can be provided upon request.

11 For example, the optimal input use criteria suggest that the input should be used up to the point where the output elasticity of the input is equal to the share of the cost of the input to revenue. In the case of fertilizer, while the elasticity of crop output to fertilizer for the sample was 0.22, the share of fertilizer to crop revenue was only 0.08 indicating that fertilizer input is underutilized by close to three times. But when evaluated at the shadow price, the inefficiency level is expected to be lower as the shadow price takes into account the risk of fertilizer application and other various market constraints.

12 For risk considerations, farmers are willing to produce a number of crops either because they wanted to avoid higher price of purchase or due to lack of purchasing power. Devoting a large area to some crops that farm households are less efficient in producing costs them in terms of lost efficiency in the crops in which they are more efficient (Wolgin, 1975).

13 Although not reported, it was found that both allocative and technical efficiency reduces land and labor productivity of the sampled households. However, the effect of technical inefficiency is stronger.